EA ELITE IAL MATHEMATICS

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WME01 Mechanics 1 Classified Questions

138 unique questions grouped by primary topic, with cross-topic placements where a question also belongs in another chapter.

342
topic placements

WME01
Mechanics 1

Question bank
standalone IAL route

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Prepared for Dr Eslam Ahmed - eliteigcse.com

M1

TOPIC

Quantities, Units & Modelling

WME01/01 OCTOBER 2019

Question 2

9 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Constant Acceleration in 1D

2. A small ball is released from rest from a point that is 40 m above horizontal ground. The ball bounces on the ground and rebounds vertically. Each time the ball bounces on the ground, the speed of the ball is instantaneously reduced by 50%. The ball is modelled as a particle moving freely under gravity, from the instant when it is released until it first hits the ground, and between each successive bounce.

(a) Find the time from the instant when the ball is released from rest to the instant when it hits the ground for the second time.

(5)

(b) Find the maximum height reached by the ball above the ground after the ball's third bounce.

(4)

WME01/01 OCTOBER 2019

Question 5

8 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

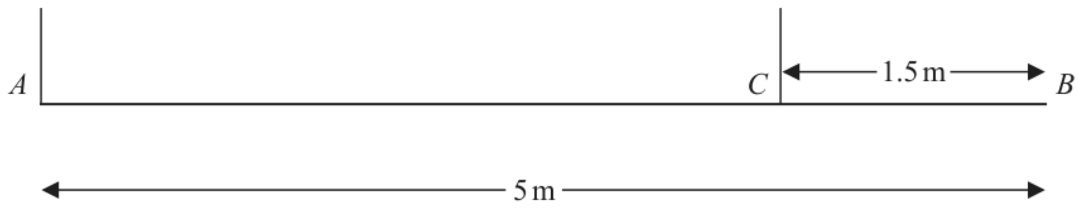


Figure 2

A non-uniform beam, AB, has length 5 m and mass 12 kg. The beam is suspended in a horizontal position by two vertical ropes. One rope is attached to the beam at A. The other rope is attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 2. The distance of the centre of mass of the beam from A is 1.75 m. The beam is modelled as a non-uniform rod and the ropes are modelled as light inextensible strings.

A particle of mass M kg is now placed on the beam at B and the beam remains in equilibrium in a horizontal position.

(a) Find the largest possible value of M.

(3)

The particle at B is now removed and a particle of mass 15 kg is now placed on the beam at the point D, where $AD = x$ metres. The beam remains in equilibrium in a horizontal position.

Given that the tension in the rope attached to the beam at C is now twice the tension in the rope attached to the beam at A,

(b) find the value of x.

(5)

12 marks

WME01/01 OCTOBER 2019

Quantities, Units & Modelling

Question 6

Also in Quantities, Units & Modelling

Primary: Kinematics Graphs

6. An athlete runs a 200 m race along a straight horizontal track.

In a model of the motion of the athlete, air resistance is ignored, the athlete starts from rest at time $t = 0$ seconds and moves with uniform acceleration $0.8\,\text{m s}^{-2}$ for T seconds, reaching a speed of $V\,\text{m s}^{-1}$. She then maintains this speed until she crosses the finishing line.

The total time from when the athlete starts to when she crosses the finishing line is 30 s.

(a) Sketch a speed-time graph for the model of the motion of the athlete from the instant when she starts to the instant when she crosses the finishing line.

(2)

(b) Write down an expression for V in terms of T.

(1)

(c) Show that $T^2 - kT + 500 = 0$, where k is a constant to be found.

(4)

(d) Hence find the value of T, justifying your answer carefully.

(3)

(e) Considering your speed-time graph or otherwise, state two ways, apart from including air resistance, in which the model could be made to be more realistic.

(2)

WME01/01 JANUARY 2020

Question 1

8 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

1. Two particles, P and Q, of mass m_1 and m_2 respectively, are moving on a smooth horizontal plane. The particles are moving towards each other in opposite directions along the same straight line when they collide directly. Immediately before the collision, both particles are moving with speed u.

The direction of motion of each particle is reversed by the collision.

Immediately after the collision, the speed of Q is $\frac{1}{3}u$.

(a) Find, in terms of m_2 and u, the magnitude of the impulse exerted by P on Q in the collision.

(3)

(b) Find, in terms of m_1, m_2 and u, the speed of P immediately after the collision.

(3)

(c) Hence show that $m_2 > \frac{3}{4} m_1$

(2)

WME01/01 JANUARY 2020

Question 2

7 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

2.

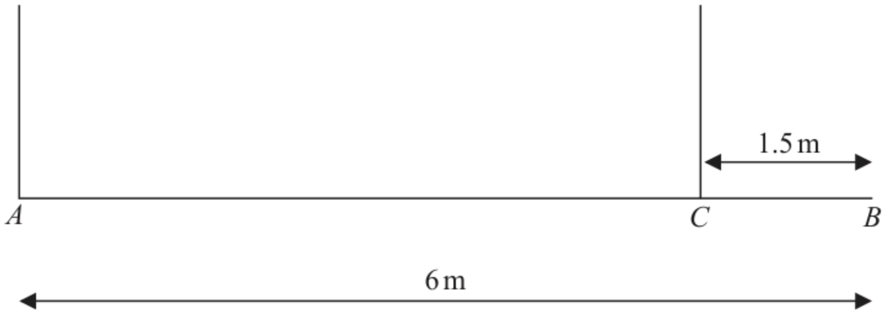


Figure 1

A non-uniform beam AB has length 6 m and weight W newtons. The beam is supported in equilibrium in a horizontal position by two vertical ropes, one attached to the beam at A and the other attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 1.

The centre of mass of the beam is 2.625 m from A.

The ropes are modelled as light strings. The beam is modelled as a non-uniform rod.

Given that the tension in the rope attached at C is 20 N greater than the tension in the rope attached at A,

(a) find the value of W.

(6)

(b) State how you have used the fact that the beam is modelled as a rod.

(1)

WME01/01 JANUARY 2020

Question 4

10 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

4.

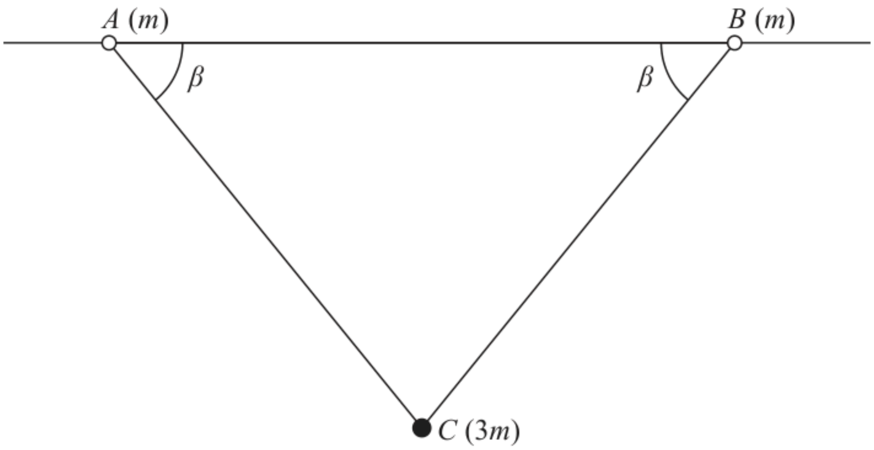


Figure 2

Two identical small rings, A and B, each of mass m, are threaded onto a rough horizontal wire. The rings are connected by a light inextensible string. A particle C of mass $3m$ is attached to the midpoint of the string. The particle C hangs in equilibrium below the wire with angle $BAC = \beta$, as shown in Figure 2.

The tension in each of the parts, AC and BC, of the string is T

(a) By considering particle C, find T in terms of m, g and β

(2)

(b) Find, in terms of m and g, the magnitude of the normal reaction between the wire and A.

(3)

The coefficient of friction between each ring and the wire is $\frac{4}{5}$

The two rings, A and B, are on the point of sliding along the wire towards each other.

(c) Find the value of $\tan\beta$

(5)

WME01/01 JANUARY 2021

Question 1

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Constant Acceleration in 1D

1. A small stone is projected vertically upwards with speed $20\,\text{m}\,\text{s}^{-1}$ from a point O which is 5 m above horizontal ground. The stone is modelled as a particle moving freely under gravity.

Find

(a) the speed of the stone at the instant when it is 2 m above the ground,

(2)

(b) the total time between the instant when the stone is projected from O and the instant when it first strikes the ground.

(4)

WME01/01 JANUARY 2021

Question 2

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

2. Two particles, P and Q, have masses $2m$ and m respectively. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal plane. The particles collide directly.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $2u$.

The magnitude of the impulse exerted on Q by P in the collision is $5mu$.

Find

(a) the speed of P immediately after the collision,

(3)

(b) the speed of Q immediately after the collision.

(3)

WME01/01 JANUARY 2021

Question 3

9 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

3.

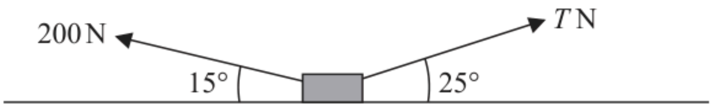


Figure 1

A parcel of mass 20 kg is at rest on a rough horizontal floor. The coefficient of friction between the parcel and the floor is 0.3

Two forces, both acting in the same vertical plane, of magnitudes 200 N and T N are applied to the parcel. The line of action of the 200 N force makes an angle of 15° with the horizontal and the line of action of the T N force makes an angle of 25° with the horizontal, as shown in Figure 1. The parcel is modelled as a particle P.

Find the smallest value of T for which P remains in equilibrium.

(9)

WME01/01 JANUARY 2021

Question 4

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

4.

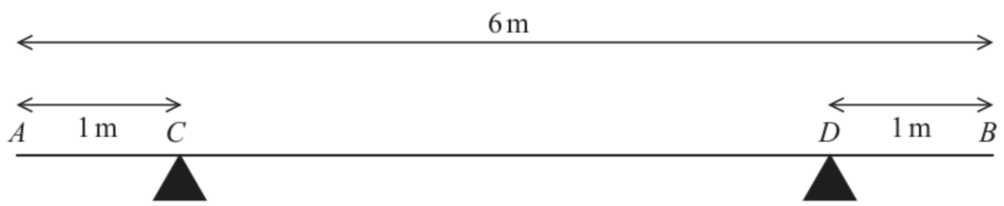


Figure 2

A metal girder AB has weight W newtons and length 6 m. The girder rests in a horizontal position on two supports C and D where $AC = DB = 1$ m, as shown in Figure 2.

When a force of magnitude 900 N is applied vertically upwards to the girder at A, the girder is about to tilt about D.

When a force of magnitude 1500 N is applied vertically upwards to the girder at B, the girder is about to tilt about C.

The girder is modelled as a non-uniform rod whose centre of mass is a distance x metres from A.

Find the value of x.

(6)

WME01/01 MAY/JUNE 2021

Question 1

7 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

1. A particle P has mass $3m$ and a particle Q has mass $5m$. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately before the collision the speed of P is ku, where k is a constant, and the speed of Q is $2u$.

Immediately after the collision the speed of P is u and the speed of Q is $3u$.

The direction of motion of Q is reversed by the collision.

(a) Find, in terms of m and u, the magnitude of the impulse exerted on Q by P in the collision.

(2)

(b) Find the two possible values of k.

(5)

8 marks

WME01/01 MAY/JUNE 2021

Quantities, Units & Modelling

Question 2

Also in Quantities, Units & Modelling

Primary: Constant Acceleration in 1D

2. A car moves along a straight horizontal road with constant acceleration $a\,\mathrm{m\,s^{-2}}$ where $a > 0$

The car is modelled as a particle.

At time $t = 0$, the car passes point A and is moving with speed $u\,\mathrm{m\,s^{-1}}$

In the first three seconds after passing A the car travels 20 m.

In the fourth second after passing A the car travels 10 m.

The speed of the car as it passes point B is $20\,\mathrm{m\,s^{-1}}$

Find the time taken for the car to travel from A to B.

(8)

WME01/01 MAY/JUNE 2021

Question 4

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Newton's Second Law

4.

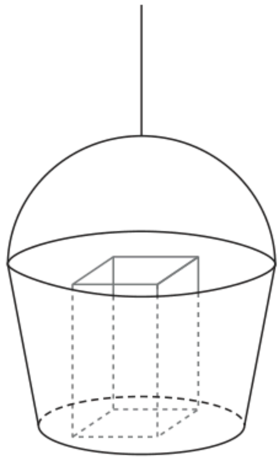


Figure 1

Figure 1 shows a large bucket used by a crane on a building site to move materials between the ground and the top of the building. The mass of the bucket is 15 kg.

The bucket is attached to a vertical cable with the bottom of the bucket horizontal. The cable is modelled as light and inextensible.

When the bucket is on the ground, a bag of cement of mass 25 kg is placed in the bucket.

The bucket with the bag of cement moves vertically upwards with constant acceleration $0.2\,\mathrm{m\,s^{-2}}$. Air resistance is modelled as being negligible.

(a) Find the tension in the cable.

(3)

At the top of the building, the bag of cement is removed. A box of tools of mass 12 kg is now placed in the bucket.

Later on the bucket with the box of tools is moving vertically downwards with constant deceleration $0.1\,\mathrm{m\,s^{-2}}$. Air resistance is again modelled as being negligible.

(b) Find the magnitude of the normal reaction between the bucket and the box of tools.

(3)

WME01/01 MAY/JUNE 2021

Question 7

10 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

7.

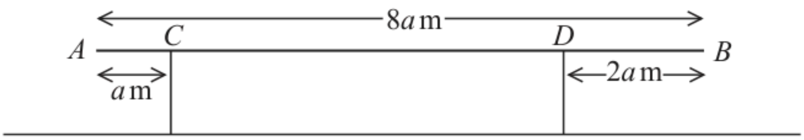


Figure 2

A non-uniform beam AB, of mass 60 kg and length $8a$ metres, rests in equilibrium in a horizontal position on two vertical supports. One support is at C, where $AC = a$ metres and the other support is at D, where $DB = 2a$ metres, as shown in Figure 2.

The magnitude of the normal reaction between the beam and the support at D is three times the magnitude of the normal reaction between the beam and the support at C.

By modelling the beam as a non-uniform rod whose centre of mass is at a distance x metres from A,

(a) find an expression for x in terms of a.

(5)

A box of mass M kg is placed on the beam at E, where $AE = 2a$ metres.

The beam remains in equilibrium in a horizontal position.

The magnitude of the normal reaction between the beam and the support at C is now equal to the magnitude of the normal reaction between the beam and the support at D.

By modelling the box as a particle,

(b) find the value of M.

(5)

WME01/01 OCTOBER 2021

Question 5

10 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

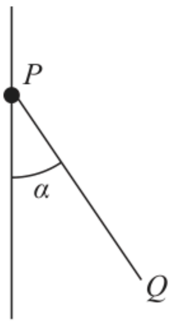


Figure 2

A small bead of mass 0.2 kg is attached to the end P of a light rod PQ. The bead is threaded onto a fixed vertical rough wire.

The bead is held in equilibrium with the rod PQ inclined to the wire at an angle α, where $\tan\alpha = \frac{4}{3}$, as shown in Figure 2.

The thrust in the rod is T newtons.

The bead is modelled as a particle.

(a) Find the magnitude and direction of the friction force acting on the bead when $T = 2.5$

(3)

The coefficient of friction between the bead and the wire is μ.

Given that the greatest possible value of T is 6.125

(b) find the value of μ.

(7)

WME01/01 JANUARY 2022

Question 1

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

1.

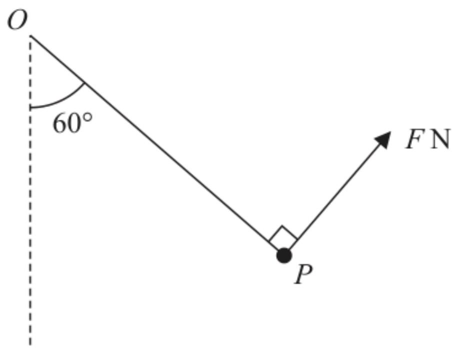


Figure 1

A particle P of weight 5 N is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point O. The particle P is held in equilibrium by a force of magnitude F newtons. The direction of this force is perpendicular to the string and OP makes an angle of 60° with the vertical, as shown in Figure 1.

Find

(a) the value of F

(3)

(b) the tension in the string.

(3)

WME01/01 JANUARY 2022

Question 3

7 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

3.

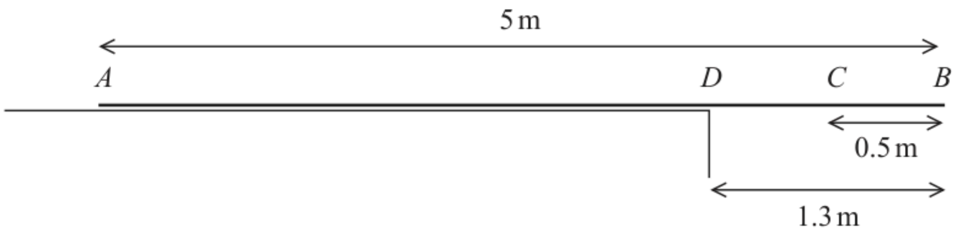


Figure 2

A beam *ADCB* has length 5 m. The beam lies on a horizontal step with the end *A* on the step and the end *B* projecting over the edge of the step. The edge of the step is at the point *D* where *DB* = 1.3 m, as shown in Figure 2.

When a small boy of mass 30 kg stands on the beam at *C*, where *CB* = 0.5 m, the beam is on the point of tilting.

The boy is modelled as a particle and the beam is modelled as a uniform rod.

(a) Find the mass of the beam.

(3)

A block of mass *X* kg is now placed on the beam at *A*.

The block is modelled as a particle.

(b) Find the smallest value of *X* that will enable the boy to stand on the beam at *B* without the beam tilting.

(3)

(c) State how you have used the modelling assumption that the block is a particle in your calculations.

(1)

WME01/01 MAY/JUNE 2022

Question 3

7 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Newton's Second Law

3. A tractor of mass 6 tonnes is dragging a large block of mass 2 tonnes along rough horizontal ground. The cable connecting the tractor to the block is horizontal and parallel to the direction of motion.

The cable is modelled as being light and inextensible.

The driving force of the tractor is 7400 N and the resistance to the motion of the tractor is 200 N. The resistance to the motion of the block is R newtons, where R is a constant.

Given that the tension in the cable is 6000 N and the tractor is accelerating,

(a) find the value of R.

(6)

(b) State how you have used the fact that the cable is modelled as being inextensible.

(1)

WME01/01 MAY/JUNE 2022

Question 4

12 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

4.

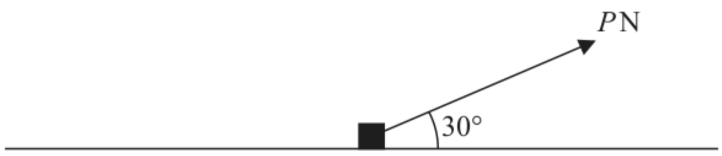


Figure 1

A small block of mass 5 kg lies at rest on a rough horizontal plane.

The coefficient of friction between the block and the plane is $\frac{3}{7}$

A force of magnitude P newtons is applied to the block in a direction which makes an angle of 30° with the plane, as shown in Figure 1.

The block is modelled as a particle.

Given that $P = 14$

(a) find the magnitude of the frictional force exerted on the block by the plane and describe what happens to the block, justifying your answer.

(6)

The value of P is now changed so that the block is on the point of slipping along the plane.

(b) Find the value of P

(6)

WME01/01 MAY/JUNE 2022

Question 5

9 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

5.

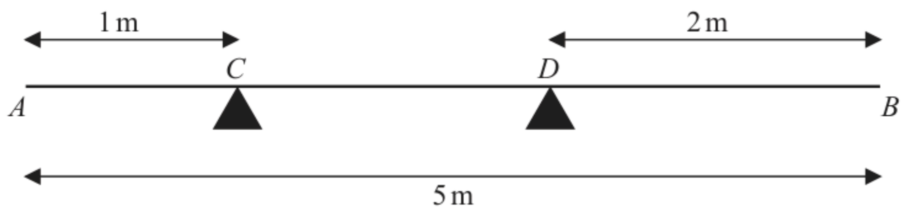


Figure 2

A uniform rod AB has length 5 m and mass 5 kg. The rod rests in equilibrium in a horizontal position on two supports C and D, where $AC = 1\text{ m}$ and $DB = 2\text{ m}$, as shown in Figure 2.

A particle of mass 10 kg is placed on the rod at A and a particle of mass M kg is placed on the rod at B. The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the magnitude of the reaction on the rod at C.

(3)

(b) Find, in terms of M, the magnitude of the reaction on the rod at D.

(3)

(c) Hence, or otherwise, find the range of possible values of M.

(3)

5 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

WME01/01 OCTOBER 2022

Question 1

1. A railway truck S of mass 20 tonnes is moving along a straight horizontal track when it collides with another railway truck T of mass 30 tonnes which is at rest. Immediately before the collision the speed of S is $4\,\text{m}\,\text{s}^{-1}$
As a result of the collision, the two railway trucks join together.

Find

(a) the common speed of the railway trucks immediately after the collision,

(2)

(b) the magnitude of the impulse exerted on S in the collision, stating the units of your answer.

(3)

6 marks

WME01/01 OCTOBER 2022

Quantities, Units & Modelling

Question 4

Also in Quantities, Units & Modelling

Primary: Newton's Second Law

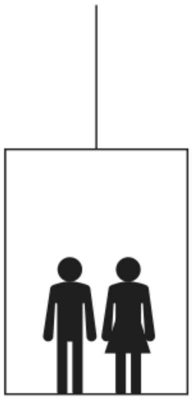


Figure 3

Two children, Alan and Bhavana, are standing on the horizontal floor of a lift, as shown in Figure 3.

The lift has mass 250 kg. The lift is raised vertically upwards with constant acceleration by a vertical cable which is attached to the top of the lift. The cable is modelled as being light and inextensible. While the lift is accelerating upwards, the tension in the cable is 3616 N.

As the lift accelerates upwards, the floor of the lift exerts a force of magnitude 565 N on Alan and a force of magnitude 226 N on Bhavana.

Air resistance is modelled as being negligible and Alan and Bhavana are modelled as particles.

(a) By considering the forces acting on the lift only, find the acceleration of the lift.

(3)

(b) Find the mass of Alan.

(3)

WME01/01 JANUARY 2023

Question 2

8 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

2. Two particles, A and B, are moving in a straight line in opposite directions towards each other on a smooth horizontal surface when they collide directly.

Particle A has mass $3m$ kg and particle B has mass m kg.

Immediately before the collision, both particles have a speed of $1.5\,\mathrm{m\,s^{-1}}$

Immediately after the collision, the direction of motion of A is unchanged and the difference between the speed of A and speed of B is $1\,\mathrm{m\,s^{-1}}$

(a) Find (i) the speed of A immediately after the collision,

(ii) the speed of B immediately after the collision.

(5)

(b) Find, in terms of m, the magnitude of the impulse exerted on B in the collision.

(3)

WME01/01 JANUARY 2023

Question 4

8 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

4.

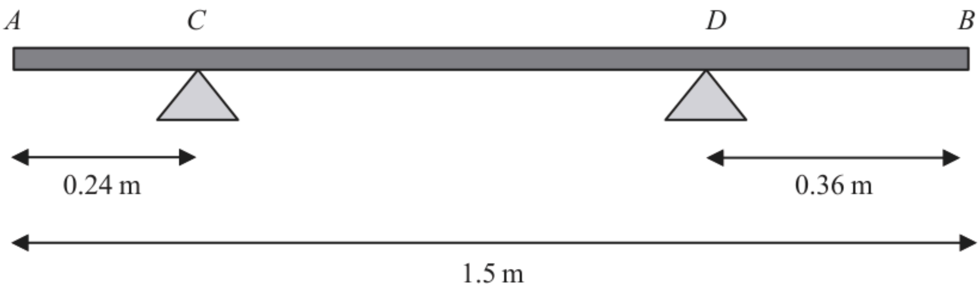


Figure 1

A branch AB, of length 1.5 m, rests horizontally in equilibrium on two supports.

The two supports are at the points C and D, where $AC = 0.24\,\text{m}$ and $DB = 0.36\,\text{m}$, as shown in Figure 1.

When a force of 150 N is applied vertically upwards at B, the branch is on the point of tilting about C.

When a force of 225 N is applied vertically downwards at B, the branch is on the point of tilting about D.

The branch is modelled as a non-uniform rod AB of weight W newtons.

The distance from the point C to the centre of mass of the rod is x metres.

Use the model to find

(i) the value of W

(ii) the value of x

(8)

9 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Constant Acceleration in 1D

WME01/01 JANUARY 2023

Question 5

Figure 2

Three points P, Q and R are on a horizontal road where PQR is a straight line.

The point Q is between P and R, with $PQ = 6x$ metres and $QR = 5x$ metres, as shown in Figure 2.

A vehicle moves along the road from P to Q with constant acceleration.

The vehicle is modelled as a particle.

At time $t = 0$, the vehicle passes P with speed $u\,\text{m s}^{-1}$

At time $t = 12$ s, the vehicle passes Q with speed $2u\,\text{m s}^{-1}$

Using the model,

(a) show that $x = 3u$

(2)

As the vehicle passes Q, the acceleration of the vehicle changes instantaneously to $1.5\,\text{m s}^{-2}$

The vehicle continues to move with a constant acceleration of $1.5\,\text{m s}^{-2}$ and passes R with speed $3u\,\text{m s}^{-1}$

Using the model,

(b) find the value of u,

(3)

(c) find the distance travelled by the vehicle during the first 14 seconds after passing P

(4)

WME01/01 JANUARY 2023

Question 6

8 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

6.

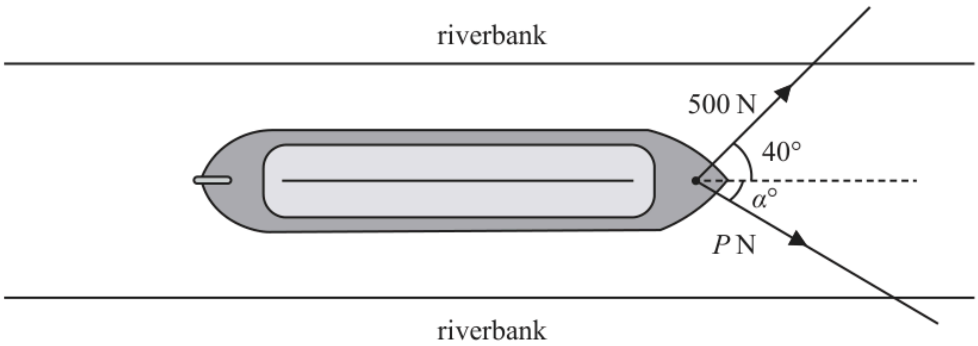


Figure 3

A boat is pulled along a river at a constant speed by two ropes.

The banks of the river are parallel and the boat travels horizontally in a straight line, parallel to the riverbanks.

- The tension in the first rope is 500 N acting at an angle of 40° to the direction of motion, as shown in Figure 3.
- The tension in the second rope is P newtons, acting at an angle of $\alpha°$ to the direction of motion, also shown in Figure 3.
- The resistance to motion of the boat as it moves through the water is a constant force of magnitude 900 N

The boat is modelled as a particle. The ropes are modelled as being light and lying in a horizontal plane.

Use the model to find

(i) the value of α

(ii) the value of P

(8)

WME01/01 JANUARY 2023

Question 7

7 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Newton's Second Law

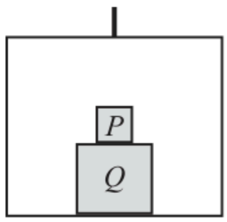


Figure 4

A simple lift operates by means of a vertical cable which is attached to the top of the lift.
The lift has mass m
A box Q is placed on the floor of the lift.
A box P is placed directly on top of box Q, as shown in Figure 4.

The cable is modelled as being light and inextensible and air resistance is modelled as being negligible.

The tension in the cable is $\frac{42mg}{5}$

The lift and its contents move vertically upwards with acceleration $\frac{2g}{5}$

Using the model,

(a) find, in terms of m, the combined mass of boxes P and Q

(4)

During the motion of the lift, the force exerted on box P by box Q is $\frac{14mg}{5}$

Using the model,

(b) find, in terms of m, the mass of box P

(3)

WME01/01 MAY/JUNE 2023

Question 1

7 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

1. A particle A has mass 4 kg and a particle B has mass 2 kg.

The particles move towards each other in opposite directions along the same straight line on a smooth horizontal table and collide directly.

Immediately before the collision, the speed of A is $2u\,\text{m s}^{-1}$ and the speed of B is $3u\,\text{m s}^{-1}$

Immediately after the collision, the speed of B is $2u\,\text{m s}^{-1}$

The direction of motion of B is reversed by the collision.

(a) Find, in terms of u, the speed of A immediately after the collision.

(3)

(b) State the direction of motion of A immediately after the collision.

(1)

(c) Find, in terms of u, the magnitude of the impulse received by B in the collision. State the units of your answer.

(3)

12 marks

WME01/01 MAY/JUNE 2023

Quantities, Units & Modelling

Question 4

Also in Quantities, Units & Modelling

Primary: Moments

4.

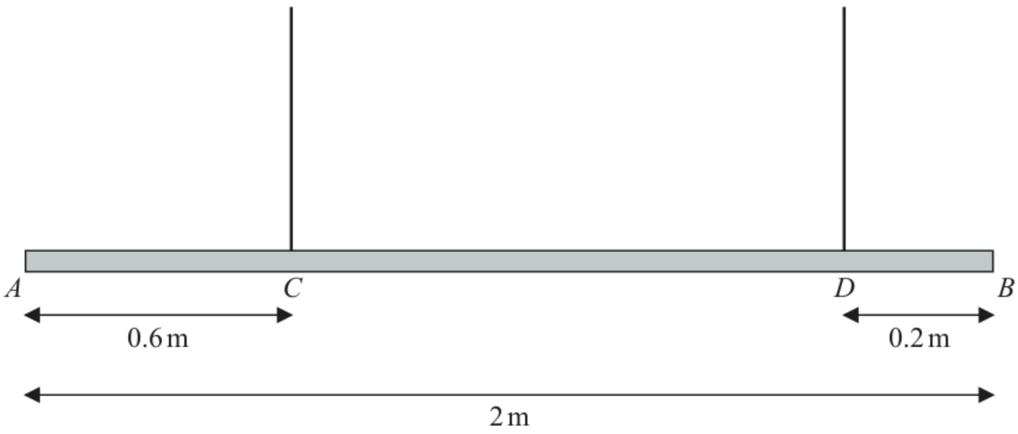


Figure 1

Figure 1 shows a beam AB, of mass m kg and length 2 m, suspended by two light vertical ropes.
The ropes are attached to the points C and D on the beam, where $AC = 0.6$ m and $DB = 0.2$ m
The beam is in equilibrium in a horizontal position.

A particle of mass pm kg is attached to the beam at A and the beam remains in equilibrium in a horizontal position.

The beam is modelled as a uniform rod.

(a) Given that the tension in the rope attached at C is four times the tension in the rope attached at D, use the model to find the exact value of p.

(7)

The particle of mass pm kg at A is removed and replaced by a particle of mass qm kg at A.
The beam remains in equilibrium in a horizontal position but is now on the point of tilting.

(b) Using the model, find the exact value of q

(4)

(c) State how you have used the modelling assumption that the beam is uniform.

(1)

Question 1

5 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

1.

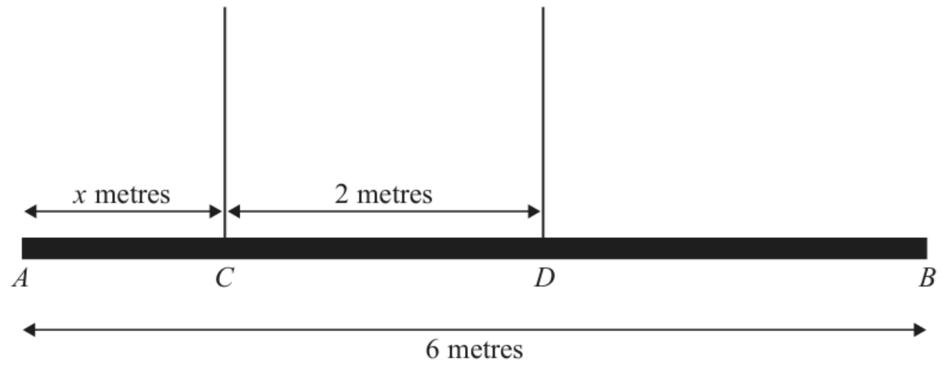


Figure 1

Figure 1 shows a beam AB with weight 24 N and length 6 m.

The beam is suspended by two light vertical ropes. The ropes are attached to the points C and D on the beam where $AC = x$ metres and $CD = 2$ m.

The tension in the rope attached to the beam at C is double the tension in the rope attached to the beam at D.

The beam is modelled as a uniform rod, resting horizontally in equilibrium.

Find

(i) the tension in the rope attached to the beam at D.

(ii) the value of x.

(5)

WME01/01 JANUARY 2024

Question 1

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Forces

1.

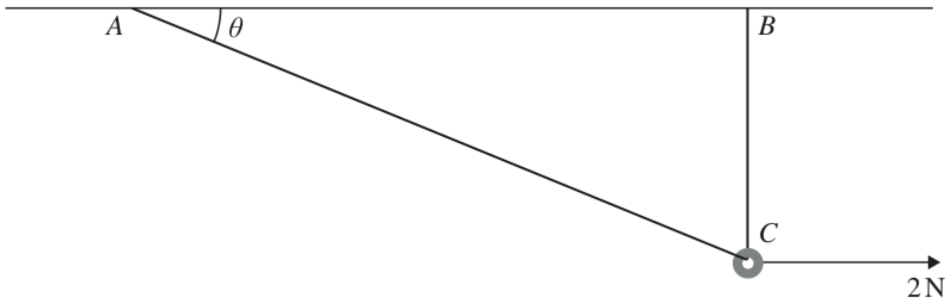


Figure 1

Figure 1 shows a small smooth ring **threaded** onto a light inextensible string.

One end of the string is attached to a fixed point A on a horizontal ceiling and the other end of the string is attached to a fixed point B on the ceiling.

A horizontal force of magnitude 2 N acts on the ring so that the ring rests in equilibrium at a point C, vertically below B, with the string taut.

The line of action of the horizontal force and the string both lie in the same vertical plane.

The angle that the string makes with the ceiling at A is θ, where $\tan\theta = \frac{3}{4}$

The tension in the string is T newtons. The mass of the ring is M kg.

(a) Find the value of T

(3)

(b) Find the value of M

(3)

WME01/01 JANUARY 2024

Question 2

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

2.

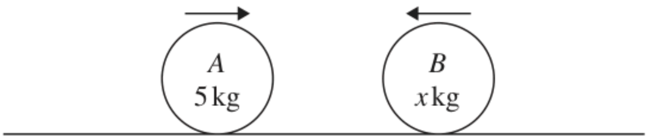


Figure 2

Figure 2 shows two particles, *A* and *B*, moving in opposite directions on a smooth horizontal surface. Particle *A* has mass 5 kg and particle *B* has mass *x* kg.

The particles collide directly.

Immediately before the collision, the speed of *A* is $3\,\text{m s}^{-1}$ and the speed of *B* is $x\,\text{m s}^{-1}$

Immediately after the collision, the speed of *A* is $1\,\text{m s}^{-1}$ and its direction of motion is unchanged.

Immediately after the collision, the speed of *B* is $1.5\,\text{m s}^{-1}$

(a) Find the value of *x*.

(3)

(b) Find the magnitude of the impulse exerted on *A* by *B* in the collision.

(3)

WME01/01 JANUARY 2024

Question 5

10 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

5.

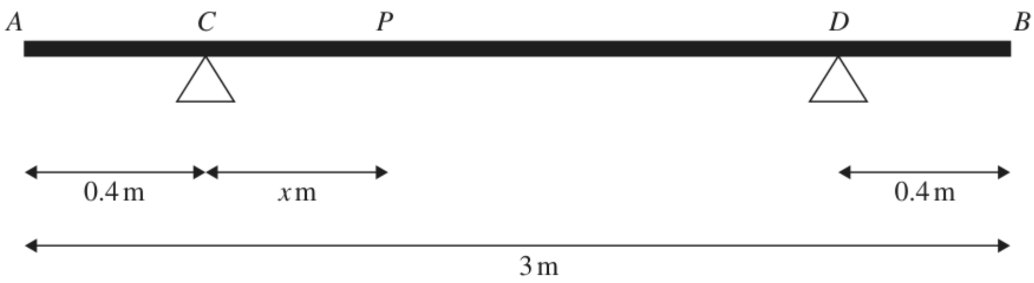


Figure 4

A beam AB has mass 30 kg and length 3 m.

The beam rests on supports at C and D where $AC = 0.4$ m and $DB = 0.4$ m, as shown in Figure 4.

A person of mass 55 kg stands on the beam between C and D.

The person is modelled as a particle at the point P, where $CP = x$ metres and $0 < x < 2.2$

The beam is modelled as a uniform rod resting in equilibrium in a horizontal position.

Using the model,

(a) show that the magnitude of the reaction at C is $(686 - 245x)$ N.

(3)

The magnitude of the reaction at C is **four** times the magnitude of the reaction at D.

Using the model,

(b) find the value of x

(4)

The person steps off the beam and places a package of mass M kg at A.

The package is modelled as a particle at the point A.

The beam is now on the point of tilting about C.

Using the model,

(c) find the value of M

(3)

WME01/01 MAY/JUNE 2024

Question 3

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Newton's Second Law

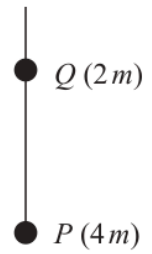


Figure 1

Two particles, P and Q, have masses $4m$ and $2m$ respectively. The particles are connected by a light inextensible string. A second light inextensible string has one end attached to Q. Both strings are taut and vertical, as shown in Figure 1.

The particles are **accelerating** vertically **downwards**.

Given that the tension in the string connecting the two particles is $3mg$, find, in terms of m and g, the tension in the upper string.

(6)

Question 4

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

4.

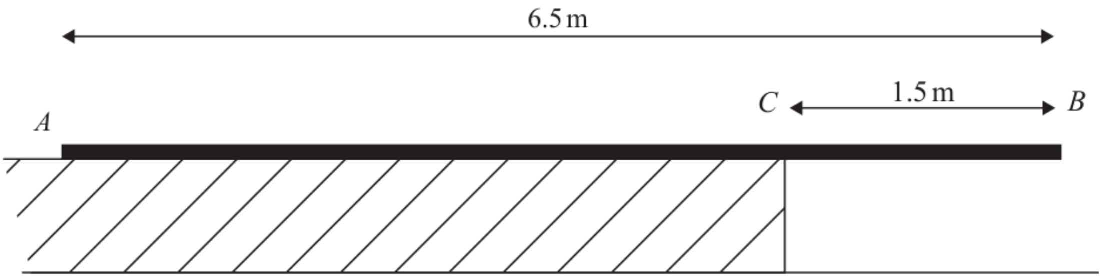


Figure 2

A non-uniform rod AB has length 6.5 m and mass 1.2 kg. The centre of mass of the rod is 3 m from A. The rod rests on a horizontal step and overhangs the end of the step C by 1.5 m, as shown in Figure 2.

The rod is perpendicular to the edge of the step.

A particle of mass 4 kg is placed on the rod at B and another particle, whose mass is M kg, is placed on the rod at D, where $AD = 0.5$ m.

The rod remains in equilibrium in a horizontal position.

(a) Find the smallest possible value of M.

(3)

The particle at B **and** the particle at D are now **removed**.

A new particle is placed on the rod at the point E, where $EB = 0.9$ m.

The rod remains in equilibrium in a horizontal position but is on the point of tilting about C.

(b) Find the magnitude of the force acting on the rod at C.

(3)

WME01/01 OCTOBER 2024

Question 1

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

1. Particle A has mass $4m$ and particle B has mass $3m$.

The particles are moving in opposite directions along the same straight line on a smooth horizontal surface when they collide directly.

Immediately **before** the collision, the speed of A is $2x$ and the speed of B is x.

Immediately **after** the collision, the speed of A is y and the speed of B is $5y$.

The direction of motion of each particle is reversed as a result of the collision.

(a) Show that $y = \frac{5}{11}x$.

(3)

(b) Find, in terms of m and x, the magnitude of the impulse received by A in the collision.

(3)

WME01/01 OCTOBER 2024

Question 2

9 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

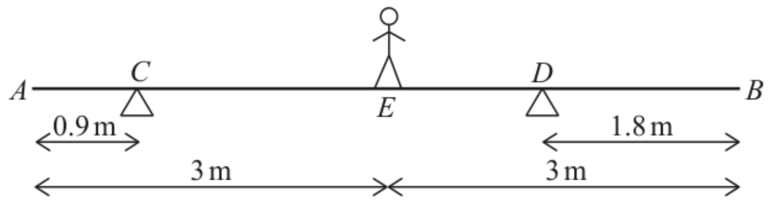


Figure 1

A non-uniform beam AB has length 6 m and mass 50 kg. The beam rests horizontally on two supports at C and D, where $AC = 0.9$ m and $DB = 1.8$ m.

A child of mass 25 kg stands on the beam at E, where $AE = EB = 3$ m, as shown in Figure 1.

The beam is in equilibrium.

The magnitude of the normal reaction between the beam and the support at C is R_C newtons.

The magnitude of the normal reaction between the beam and the support at D is R_D newtons.

The beam is modelled as a rod and the child is modelled as a particle.

The centre of mass of the beam is between C and D and is a distance x metres from D.

Given that $2R_D = 3R_C$

(a) show that $x = 1.38$

(6)

The child remains at E and a block of mass M kg is placed on the beam at B.

The block is modelled as a particle.

Given that the beam is on the point of tilting,

(b) find the value of M.

(3)

WME01/01 JANUARY 2025

Question 4

10 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Moments

4.

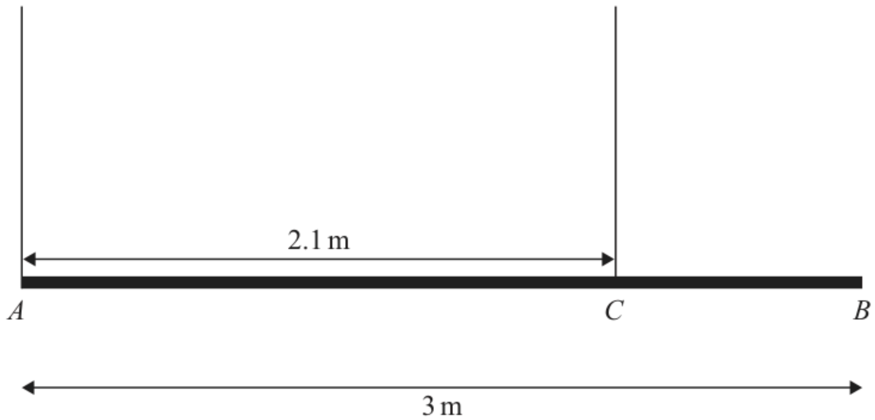


Figure 2

A uniform rod AB has length 3 m and weight W newtons.
The rod is suspended by two light vertical ropes.
One rope is attached to the rod at A and the other rope is attached to the rod at C, where $AC = 2.1$ m.

The rod is in equilibrium in a horizontal position, as shown in Figure 2.

The tension in the rope at C is 350 N.

(a) Show that $W = 490$

(3)

A particle P of weight 210 N is attached to the rod at a distance d metres from A.
The tension in the rope at C is now 600 N.
The rod remains in equilibrium in a horizontal position.

(b) Find the value of d.

(3)

Particle P is removed from the rod.
A particle Q of weight X newtons is now attached at B.
The rod remains in equilibrium in a horizontal position and is now on the point of tilting.

(c) Find the value of X.

(4)

7 marks

WME01/01 JANUARY 2025

Quantities, Units & Modelling

Question 5

Also in Quantities, Units & Modelling

Primary: Working with Vectors

5. [*In this question* $\mathbf{i}$ *and* $\mathbf{j}$ *are horizontal perpendicular unit vectors and position vectors are given relative to a fixed origin.*]

In a game, a ball B is rolled across a horizontal surface towards a fixed target.
The ball is modelled as a particle moving with constant velocity.

At time $t = 1$ s, the position vector of B is $(-2\mathbf{i} + 5\mathbf{j})$ m.
At time $t = 9$ s, the position vector of B is $(10\mathbf{i} - 3\mathbf{j})$ m.

(a) Find the velocity of the ball.

(3)

The position vector of the target is $(13\mathbf{i} - 5\mathbf{j})$ m.

(b) Use the model to find the distance of B from the target at time $t = 7$ s.

(4)

WME01/01 MAY/JUNE 2025

Question 1

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

1.

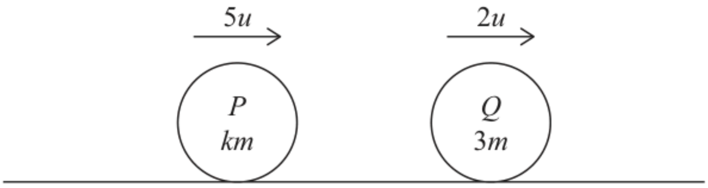


Figure 1

Figure 1 shows two particles, P and Q, moving in the same direction along the same straight line on a smooth horizontal surface.
Particle P has mass km and particle Q has mass $3m$
The particles collide directly.

Immediately before the collision, the speed of P is $5u$ and the speed of Q is $2u$

Immediately after the collision, the speed of P is $2u$ and its direction of motion is unchanged.

Immediately after the collision, the speed of Q is v

The impulse exerted on Q by P in the collision has magnitude $4.5mu$

(a) Find v in terms of u only.

(3)

(b) Find the value of k

(3)

Question 2

2.

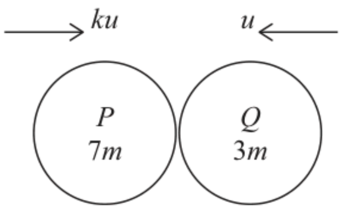


Figure 2

Particle P of mass $7m$ and particle Q of mass $3m$ are moving in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately **before** the collision, the speed of P is ku and the speed of Q is u, as shown in Figure 2.

Immediately **after** the collision, the speed of P is w and the speed of Q is $2w$.

The direction of motion of Q is reversed by the collision.

The impulse received by Q in the collision has magnitude $\frac{7}{2}mu$.

(a) Find w in terms of u.

(3)

(b) Find the two possible values of k.

(5)

WME01/01 JANUARY 2026

Question 1

6 marks

Quantities, Units & Modelling

Also in Quantities, Units & Modelling

Primary: Momentum, Impulse & Collisions

1. A particle P of mass $3m$ and a particle Q of mass $5m$ are on a smooth horizontal surface. The particles move towards each other in opposite directions along the same straight line and collide.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $4u$

The magnitude of the impulse exerted on P by Q in the collision is $\frac{33}{2}mu$

Find

(i) the speed of P immediately after the collision,

(ii) the speed of Q immediately after the collision.

(6)

TOPIC

Working with Vectors

Question 7

7 marks

Working with Vectors

7. Two forces, **F** and **G**, act on a particle. The force **F** has magnitude 4 N and acts in a direction with a bearing of 120° and the force **G** has magnitude 6 N and acts due north.

Given that **P** = 2**F** + **G**, find

(i) the magnitude of **P**

(ii) the direction of **P**, giving your answer as a bearing to the nearest degree.

(7)

Question 8

8. [*In this question, the horizontal unit vectors* **i** *and* **j** *are directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two speedboats, A and B, are each moving with constant velocity. The velocity of A is $20\,\text{km h}^{-1}$ due west and the velocity of B is $40\,\text{km h}^{-1}$ on a bearing of 150°. The boats are modelled as particles.

At noon, the position vector of A is $60\mathbf{i}$ km and B is at the origin O. At time t hours after noon, the position vector of A is $\mathbf{r}$ km and the position vector of B is $\mathbf{s}$ km.

(a) Find the velocity of B in the form $(p\mathbf{i} + q\mathbf{j})\,\text{km h}^{-1}$

(3)

(b) Find expressions for $\mathbf{r}$ and $\mathbf{s}$ in terms of t, $\mathbf{i}$ and $\mathbf{j}$.

(3)

(c) Find the time, to the nearest minute, at which the distance between the boats is the same as it was at noon.

(8)

Question 6

11 marks

Working with Vectors

6. A force $\mathbf{F}$ is given by $\mathbf{F} = (10\mathbf{i} + \mathbf{j})$ N.

(a) Find the exact value of the magnitude of $\mathbf{F}$.

(2)

(b) Find, in degrees, the size of the angle between the direction of $\mathbf{F}$ and the direction of the vector $(\mathbf{i} + \mathbf{j})$.

(4)

The resultant of the force $\mathbf{F}$ and the force $(-15\mathbf{i} + a\mathbf{j})$ N, where a is a constant, is parallel to, but in the opposite direction to, the vector $(2\mathbf{i} - 3\mathbf{j})$.

(c) Find the value of a.

(5)

Question 5

7 marks

Working with Vectors

5. A particle is acted upon by two forces **F** and **G**. The force **F** has magnitude 8 N and acts in a direction with a bearing of 240°. The force **G** has magnitude 10 N and acts due South.

Given that $\mathbf{R} = \mathbf{F} + \mathbf{G}$, find

(i) the magnitude of **R**,

(ii) the direction of **R**, giving your answer as a bearing to the nearest degree.

(7)

Question 6

12 marks

Working with Vectors

6. Two girls, Agatha and Brionie, are roller skating inside a large empty building. The girls are modelled as particles.

At time $t = 0$, Agatha is at the point with position vector $(11\mathbf{i} + 11\mathbf{j})$ m and Brionie is at the point with position vector $(7\mathbf{i} + 16\mathbf{j})$ m. The position vectors are given relative to the door, O, and $\mathbf{i}$ and $\mathbf{j}$ are horizontal perpendicular unit vectors.

Agatha skates with constant velocity $(3\mathbf{i} - \mathbf{j})\,\text{m s}^{-1}$

Brionie skates with constant velocity $(4\mathbf{i} - 2\mathbf{j})\,\text{m s}^{-1}$

(a) Find the position vector of Agatha at time t seconds.
(2)

At time $t = 6$ seconds, Agatha passes through the point P.

(b) Show that Brionie also passes through P and find the value of t when this occurs.
(4)

At time t seconds, Agatha is at the point A and Brionie is at the point B.

(c) Show that $\overrightarrow{AB} = [(t - 4)\mathbf{i} + (5 - t)\mathbf{j}]$ m
(2)

(d) Find the distance between the two girls when they are closest together.
(4)

Question 3

9 marks

Working with Vectors

3. [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors.*]

Three forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, are given by

$$\mathbf{F}_1 = (5\mathbf{i} + 2\mathbf{j})\,\text{N} \qquad \mathbf{F}_2 = (-3\mathbf{i} + \mathbf{j})\,\text{N} \qquad \mathbf{F}_3 = (a\mathbf{i} + b\mathbf{j})\,\text{N}$$

where a and b are constants.

The forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ act on a particle P of mass 4 kg.

Given that P rests in equilibrium on a smooth horizontal surface under the action of these three forces,

(a) find the size of the angle between the direction of $\mathbf{F}_3$ and the direction of $-\mathbf{j}$.

(4)

The force $\mathbf{F}_3$ is now removed and replaced by the force $\mathbf{F}_4$ given by $\mathbf{F}_4 = \lambda(\mathbf{i} + 3\mathbf{j})\,\text{N}$, where λ is a positive constant.

When the three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_4$ act on P, the acceleration of P has magnitude $3.25\ \text{m s}^{-2}$

(b) Find the value of λ.

(5)

9 marks

Question 5

Working with Vectors

5. [*In this question* $\mathbf{i}$ *and* $\mathbf{j}$ *are perpendicular horizontal unit vectors.*]

A particle P is moving with constant acceleration. At 2 pm, the velocity of P is $(3\mathbf{i} + 5\mathbf{j})$ km h^{-1} and at 2.30 pm the velocity of P is $(\mathbf{i} + 7\mathbf{j})$ km h^{-1}

At time T hours after 2 pm, P is moving in the direction of the vector $(-\mathbf{i} + 2\mathbf{j})$

(a) Find the value of T.

(6)

Another particle, Q, has velocity $\mathbf{v}_Q$ km h^{-1} at time t hours after 2 pm, where

$$\mathbf{v}_Q = (-4 - 2t)\mathbf{i} + (\mu + 3t)\mathbf{j}$$

and μ is a constant.

Given that there is an instant when the velocity of P is equal to the velocity of Q,

(b) find the value of μ.

(3)

Question 4

8 marks

Working with Vectors

4. The position vector, $\mathbf{r}$ metres, of a particle P at time t seconds, relative to a fixed origin O, is given by

$$\mathbf{r} = (t - 3)\mathbf{i} + (1 - 2t)\mathbf{j}$$

(a) Find, to the nearest degree, the size of the angle between $\mathbf{r}$ and the vector $\mathbf{j}$, when $t = 2$

(3)

(b) Find the values of t for which the distance of P from O is 2.5 m.

(5)

WME01/01 OCTOBER 2021

Question 8

12 marks

Working with Vectors

8. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin.*]

At 7 am a ship leaves a port and moves with constant velocity. The position vector of the port is $(-2\mathbf{i} + 9\mathbf{j})$ km.

At 7.36 am the ship is at the point with position vector $(4\mathbf{i} + 6\mathbf{j})$ km.

(a) Show that the velocity of the ship is $(10\mathbf{i} - 5\mathbf{j})$ km h^{-1}

(2)

(b) Find the position vector of the ship t hours after leaving port.

(2)

At 8.48 am a passenger on the ship notices that a lighthouse is due east of the ship.

At 9 am the same passenger notices that the lighthouse is now north east of the ship.

(c) Find the position vector of the lighthouse.

(4)

(d) Find the position vector of the ship when it is due south of the lighthouse.

(4)

(Total 12 marks)

Question 6

12 marks

Working with Vectors

6. [*In this question* **i** *and* **j** *are horizontal unit vectors.*]

A particle P of mass 2 kg moves under the action of two forces, $(p\mathbf{i} + q\mathbf{j})$ N and $(2q\mathbf{i} + p\mathbf{j})$ N, where p and q are constants.

Given that the acceleration of P is $(\mathbf{i} - \mathbf{j})\,\mathrm{m\,s^{-2}}$

(a) find the value of p and the value of q.

(5)

(b) Find the size of the angle between the direction of the acceleration and the vector **j**.

(2)

At time $t = 0$, the velocity of P is $(3\mathbf{i} - 4\mathbf{j})\,\mathrm{m\,s^{-1}}$

At $t = T$ seconds, P is moving in the direction of the vector $(11\mathbf{i} - 13\mathbf{j})$.

(c) Find the value of T.

(5)

Question 8

8. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin.*]

A ship A moves with constant velocity $(3\mathbf{i} - 10\mathbf{j})\,\text{km h}^{-1}$

At time t hours, the position vector of A is $\mathbf{r}$ km.

At time $t = 0$, A is at the point with position vector $(13\mathbf{i} + 5\mathbf{j})$ km.

(a) Find $\mathbf{r}$ in terms of t.

(2)

Another ship B moves with constant velocity $(15\mathbf{i} + 14\mathbf{j})\,\text{km h}^{-1}$

At time $t = 0$, B is at the point with position vector $(3\mathbf{i} - 5\mathbf{j})$ km.

(b) Show that, at time t hours,

$$\overrightarrow{AB} = [(12t - 10)\mathbf{i} + (24t - 10)\mathbf{j}]\,\text{km}$$

(4)

Given that the two ships do not change course,

(c) find the shortest distance between the two ships,

(6)

(d) find the bearing of ship B from ship A when the ships are closest.

(2)

(Total 14 marks)

Question 6

6 marks

Working with Vectors

6. A particle P is moving with constant acceleration.

At time $t = 1$ second, P has velocity $(-\mathbf{i} + 4\mathbf{j})\,\mathrm{m\,s^{-1}}$

At time $t = 4$ seconds, P has velocity $(5\mathbf{i} - 8\mathbf{j})\,\mathrm{m\,s^{-1}}$

Find the speed of P at time $t = 3.5$ seconds.

(6)

Question 8

8. [*In this question,* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two boats, P and Q, are moving with constant velocities.

The velocity of P is $15\mathbf{i}\,\mathrm{m\,s^{-1}}$ and the velocity of Q is $(20\mathbf{i} - 20\mathbf{j})\,\mathrm{m\,s^{-1}}$

(a) Find the direction in which Q is travelling, giving your answer as a bearing.

(2)

The boats are modelled as particles.

At time $t = 0$, P is at the origin O and Q is at the point with position vector $200\mathbf{j}$ m.

At time t seconds, the position vector of P is $\mathbf{p}$ m and the position vector of Q is $\mathbf{q}$ m.

(b) Show that

$$\overrightarrow{PQ} = [5t\mathbf{i} + (200 - 20t)\mathbf{j}]\,\mathrm{m}$$

(5)

(c) Find the bearing of P from Q when $t = 10$

(2)

(d) Find the distance between P and Q when Q is north east of P

(5)

(e) Find the times when P and Q are 200 m apart.

(3)

(Total 17 marks)

TOTAL FOR PAPER: 75 MARKS

Question 6

9 marks

Working with Vectors

6. [*In this question,* **i** *and* **j** *are horizontal unit vectors.*]

A particle A of mass 0.5 kg is at rest on a smooth horizontal plane.

At time $t = 0$, two forces, $\mathbf{F}_1 = (-3\mathbf{i} + 2\mathbf{j})$ N and $\mathbf{F}_2 = (p\mathbf{i} + q\mathbf{j})$ N, where p and q are constants, are applied to A.

Given that A moves in the direction of the vector $(\mathbf{i} - 2\mathbf{j})$,

(a) show that $2p + q - 4 = 0$

(4)

Given that $p = 5$

(b) find the speed of A at time $t = 4$ seconds.

(5)

Question 8

16 marks

Working with Vectors

8. [*In this question,* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two ships, A and B, are moving with constant velocities.
The velocity of A is $(3\mathbf{i} + 12\mathbf{j})\,\text{km h}^{-1}$ and the velocity of B is $(p\mathbf{i} + q\mathbf{j})\,\text{km h}^{-1}$

(a) Find the speed of A.

(2)

The ships are modelled as particles.
At 12 noon, A is at the point with position vector $(-9\mathbf{i} + 6\mathbf{j})\,\text{km}$ and B is at the point with position vector $(16\mathbf{i} + 6\mathbf{j})\,\text{km}$.

At time t hours after 12 noon,

$$\overrightarrow{AB} = [(25 - 12t)\mathbf{i} - 9t\mathbf{j}]\,\text{km}$$

(b) Find the value of p and the value of q.

(7)

(c) Find the bearing of A from B when the ships are 15 km apart, giving your answer to the nearest degree.

(7)

(Total 16 marks)

Question 3

10 marks

Working with Vectors

3. A particle P is moving with constant acceleration $(-4\mathbf{i} + \mathbf{j})\,\mathrm{m\,s^{-2}}$

At time $t = 0$, P has velocity $(14\mathbf{i} - 5\mathbf{j})\,\mathrm{m\,s^{-1}}$

(a) Find the speed of P at time $t = 2$ seconds.

(3)

(b) Find the size of the angle between the direction of **i** and the direction of motion of P at time $t = 2$ seconds.

(3)

At time $t = T$ seconds, P is moving in the direction of vector $(2\mathbf{i} - 3\mathbf{j})$

(c) Find the value of T

(4)

Question 2

[*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors*.]

2. A particle P rests in equilibrium on a smooth horizontal plane.

A system of **three** forces, $\mathbf{F}_1$ N, $\mathbf{F}_2$ N and $\mathbf{F}_3$ N where

$$\mathbf{F}_1 = (3c\mathbf{i} + 4c\mathbf{j})$$
$$\mathbf{F}_2 = (-14\mathbf{i} + 7\mathbf{j})$$

is applied to P.

Given that P remains in equilibrium,

(a) find $\mathbf{F}_3$ in terms of c, **i** and **j**.

(2)

The force $\mathbf{F}_3$ is **removed** from the system.

Given that $c = 2$

(b) find the size of the angle between the direction of **i** and the direction of the resultant force acting on P.

(4)

The mass of P is m kg.

Given that the magnitude of the acceleration of P is $8.5\,\text{m}\,\text{s}^{-2}$

(c) find the value of m.

(4)

WME01/01 MAY/JUNE 2023

Question 8

9 marks

Working with Vectors

8.

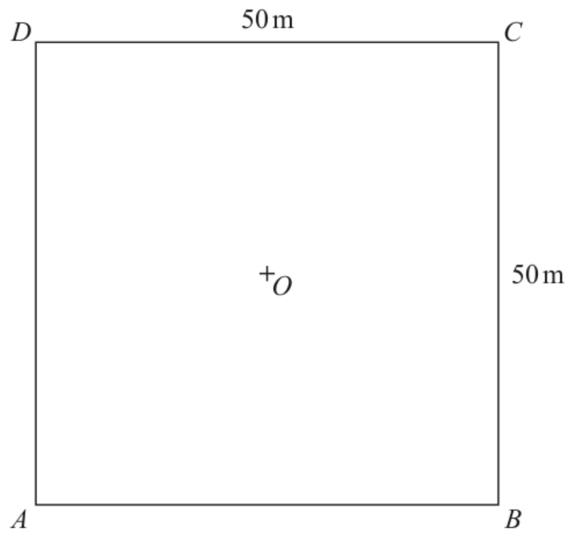


Figure 5

A square floor space $ABCD$, with centre O, is modelled as a flat horizontal surface measuring 50 m by 50 m, as shown in Figure 5.
The horizontal unit vectors $\mathbf{i}$ and $\mathbf{j}$ are in the direction of $\overrightarrow{AB}$ and $\overrightarrow{AD}$ respectively.

All position vectors are given relative to O.

A small robot R is programmed to travel across the floor at a constant velocity.

- At time $t = 0$, R is at the point with position vector $(-2\mathbf{i} + \mathbf{j})$ m
- At time $t = 11$ s, R is at the point with position vector $(9\mathbf{i} + 23\mathbf{j})$ m
- At time t seconds, the position vector of R is $\mathbf{r}$ metres

(a) Find, in terms of t, $\mathbf{i}$ and $\mathbf{j}$, an expression for $\mathbf{r}$

(3)

A second robot S is at the point C.

- At time $t = 0$, S leaves C and moves with constant velocity $(-\mathbf{i} - \mathbf{j})$ m s^{-1}
- At time t seconds, the position vector of S is $\mathbf{s}$ metres

(b) Write down, in terms of t, $\mathbf{i}$ and $\mathbf{j}$, an expression for $\mathbf{s}$

(1)

(c) Show that

$$\overrightarrow{SR} = [(2t - 27)\mathbf{i} + (3t - 24)\mathbf{j}] \text{ m}$$

(2)

(d) Find the time when the distance between R and S is a minimum.

(3)

Question 4

10 marks

Working with Vectors

4. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively.*]

A particle P moves with constant acceleration $(-\lambda\mathbf{i} + 2\lambda\mathbf{j})\,\text{m s}^{-2}$, where λ is a positive constant.

At time $t = 0$, the velocity of P is $(5\mathbf{i} - 8\mathbf{j})\,\text{m s}^{-1}$

(a) Find the velocity of P when $t = 5\,\text{s}$, giving your answer in terms of **i**, **j** and λ.

(2)

The speed of P when $t = 5\,\text{s}$ is $13\,\text{m s}^{-1}$

(b) Show that

$$25\lambda^2 - 42\lambda - 16 = 0$$

(3)

(c) Find the direction of motion of P when $t = 4\,\text{s}$, giving your answer as a bearing to the nearest degree.

(5)

Question 6

15 marks

Working with Vectors

6. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

At 12:00, a ship P sets sail from a harbour with position vector $(15\mathbf{i} + 36\mathbf{j})$ km.
At 12:30, P is at the point with position vector $(20\mathbf{i} + 34\mathbf{j})$ km.

Given that P moves with constant velocity,

(a) show that the velocity of P is $(10\mathbf{i} - 4\mathbf{j})\,\text{km h}^{-1}$

(2)

At time t hours after 12:00, the position vector of P is $\mathbf{p}$ km.

(b) Find an expression for $\mathbf{p}$ in terms of $\mathbf{i}$, $\mathbf{j}$ and t.

(2)

A second ship Q is also travelling at a constant velocity.

At time t hours after 12:00, the position vector of Q is given by $\mathbf{q}$ km, where

$$\mathbf{q} = (42 - 8t)\mathbf{i} + (9 + 14t)\mathbf{j}$$

Ships P and Q are modelled as particles.

If both ships maintained their course,

(c) (i) verify that they would collide at 13:30

(ii) find the position vector of the point at which the collision would occur.

(4)

At 12:30 Q changes speed and direction to avoid the collision.

Ship Q now travels due north with a constant speed of $15\,\text{km h}^{-1}$

Ship P maintains the same constant velocity throughout.

(d) Find the exact distance between P and Q at 14:30

(7)

Question 7

11 marks

Working with Vectors

7. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

At midnight, a ship S is at the point with position vector $(19\mathbf{i} + 22\mathbf{j})$ km

The ship travels with constant velocity $(12\mathbf{i} - 16\mathbf{j})\,\text{km h}^{-1}$

(a) Find the speed of S.

(2)

At time t hours after midnight, the position vector of S is $\mathbf{s}$ km.

(b) Find an expression for $\mathbf{s}$ in terms of $\mathbf{i}$, $\mathbf{j}$ and t.

(2)

A lighthouse stands on a small rocky island. The lighthouse is modelled as being at the point with position vector $(26\mathbf{i} + 15\mathbf{j})$ km.

It is not safe for ships to be within 1.3 km of the lighthouse.

(c) (i) Find the value of t when S is closest to the lighthouse.

(ii) Hence determine whether it is safe for S to continue its course.

(7)

WME01/01 MAY/JUNE 2024

13 marks

Question 7

Working with Vectors

7. [*In this question, the horizontal unit vectors* **i** *and* **j** *are directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two speedboats, A and B, are each moving with constant velocity.

- the velocity of A is $40\,\text{km}\,\text{h}^{-1}$ due east
- the velocity of B is $20\,\text{km}\,\text{h}^{-1}$ on a bearing of angle α ($0° < \alpha < 90°$), where $\tan\alpha = \frac{4}{3}$

The boats are modelled as particles.

(a) Find, in terms of **i** and **j**, the velocity of B in $\text{km}\,\text{h}^{-1}$

(2)

At noon

- the position vector of A is $20\mathbf{j}$ km
- the position vector of B is $(10\mathbf{i} + 5\mathbf{j})$ km

At time t hours after noon

- the position vector of A is $\mathbf{r}$ km, where $\mathbf{r} = 20\mathbf{j} + 40t\mathbf{i}$
- the position vector of B is $\mathbf{s}$ km

(b) Find an expression for $\mathbf{s}$ in terms of t, **i** and **j**.

(2)

(c) Show that at time t hours after noon,

$$\overrightarrow{AB} = [(10 - 24t)\mathbf{i} + (12t - 15)\mathbf{j}]\,\text{km}$$

(2)

(d) Show that the boats will never collide.

(3)

(e) Find the distance between the boats when the bearing of B from A is 225°

(4)

WME01/01 OCTOBER 2024

11 marks

Question 3

Working with Vectors

3. [*In this question* **i** *and* **j** *are horizontal unit vectors and position vectors are given relative to a fixed origin.*]

A ship A is moving with constant velocity.

At 1 pm, the position vector of A is $(25\mathbf{i} + 10\mathbf{j})$ km.

At 3 pm, the position vector of A is $(55\mathbf{i} + 34\mathbf{j})$ km.

At time t hours after 1 pm, the position vector of A is $\mathbf{r}_A$ km.

(a) Show that $\mathbf{r}_A = (25 + 15t)\mathbf{i} + (10 + 12t)\mathbf{j}$

(4)

The speed of A is $V\,\text{m s}^{-1}$

(b) Find the value of V.

(2)

A ship B is moving with constant velocity $(20\mathbf{i} - 6\mathbf{j})\,\text{km h}^{-1}$

At 1 pm, the position vector of B is $(35\mathbf{i} + 51\mathbf{j})$ km.

At 2:30 pm, B passes through the point P.

(c) Show that A also passes through P.

(5)

Question 5

7 marks

Working with Vectors

5. [*In this question* $\mathbf{i}$ *and* $\mathbf{j}$ *are horizontal perpendicular unit vectors and position vectors are given relative to a fixed origin.*]

In a game, a ball B is rolled across a horizontal surface towards a fixed target.
The ball is modelled as a particle moving with constant velocity.

At time $t = 1$ s, the position vector of B is $(-2\mathbf{i} + 5\mathbf{j})$ m.
At time $t = 9$ s, the position vector of B is $(10\mathbf{i} - 3\mathbf{j})$ m.

(a) Find the velocity of the ball.

(3)

The position vector of the target is $(13\mathbf{i} - 5\mathbf{j})$ m.

(b) Use the model to find the distance of B from the target at time $t = 7$ s.

(4)

Question 2

7 marks

Working with Vectors

2. [*In this question* $\mathbf{i}$ *and* $\mathbf{j}$ *are horizontal unit vectors directed due east and due north respectively. Position vectors are given relative to a fixed origin.*]

Two particles, A and B, are moving on a smooth horizontal surface.
Each particle is moving with constant velocity.

At time t seconds, the position vector of A is given by $\mathbf{r}$ metres.

- When $t = 2$, $\mathbf{r} = (-5\mathbf{i} + 16\mathbf{j})$
- When $t = 5$, $\mathbf{r} = (10\mathbf{i} + 4\mathbf{j})$

(a) Find, in terms of $\mathbf{i}$ and $\mathbf{j}$, the velocity of A.

(2)

(b) Find an expression for $\mathbf{r}$ at time t seconds.
Give your answer in the form $p\mathbf{i} + q\mathbf{j}$, where p and q are functions of t

(2)

At time t seconds, the position vector of B is given by $\mathbf{s}$ metres where

$$\mathbf{s} = -5\mathbf{i} + 7\mathbf{j} + t(2\mathbf{i} - 3\mathbf{j})$$

(c) Find, to the nearest degree, the bearing of B from A when $t = 5$

(3)

Question 7

13 marks

Working with Vectors

7. [*In this question* **i** *and* **j** *are horizontal unit vectors.*]

Two boats, A and B, are each moving with constant acceleration.

At time t hours after noon, boat A has velocity $\mathbf{v}_A \text{ km h}^{-1}$, where

$$\mathbf{v}_A = 2\mathbf{i} + 3\mathbf{j} + (\mathbf{i} - 4\mathbf{j})t$$

(a) Find the magnitude of the acceleration of A.

(2)

When $t = 2$, the velocity of B is $(4\mathbf{i} + \mathbf{j}) \text{ km h}^{-1}$

When $t = 5$, the velocity of B is $(\mathbf{i} - 5\mathbf{j}) \text{ km h}^{-1}$

(b) Find the acceleration of B, giving your answer in terms of **i** and **j**.

(2)

(c) Find the velocity of B at time $t = 0$, giving your answer in terms of **i** and **j**.

(2)

At time T_1 hours after noon, both boats are moving with the same speed.

(d) Find the exact value of T_1

(4)

At time T_2 hours after noon, both boats are moving in the same direction.

(e) Show that $3T_2^2 + pT_2 + q = 0$, where p and q are integers to be found.

(3)

Question 6

16 marks

Working with Vectors

6. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

At 9 am, a ship S leaves a harbour and moves with constant velocity $(10\mathbf{i} + 15\mathbf{j})\,\text{km h}^{-1}$

(a) Find the exact speed of S

(2)

The harbour is at the origin O.

At 9 am, a boat B leaves the point with position vector $(50\mathbf{i} + 10\mathbf{j})\,\text{km}$ and moves with constant velocity $(-8\mathbf{i} + 10\mathbf{j})\,\text{km h}^{-1}$

(b) Find the direction in which B is moving, giving your answer as a bearing to the nearest degree.

(3)

(c) Show that at time t hours after 9 am,

$$\overrightarrow{SB} = [(50 - 18t)\mathbf{i} + (10 - 5t)\mathbf{j}]\,\text{km}$$

(4)

(d) Show that B and S do not collide.

(3)

When B is north-east of S, the distance between S and B is d km.

(e) Find the value of d.

(4)

WME01/01 OCTOBER 2019

Question 6

12 marks

Working with Vectors

Also in Working with Vectors

Primary: Kinematics Graphs

6. An athlete runs a 200 m race along a straight horizontal track.

In a model of the motion of the athlete, air resistance is ignored, the athlete starts from rest at time $t = 0$ seconds and moves with uniform acceleration $0.8\,\mathrm{m\,s^{-2}}$ for T seconds, reaching a speed of $V\,\mathrm{m\,s^{-1}}$. She then maintains this speed until she crosses the finishing line.

The total time from when the athlete starts to when she crosses the finishing line is 30 s.

(a) Sketch a speed-time graph for the model of the motion of the athlete from the instant when she starts to the instant when she crosses the finishing line.

(2)

(b) Write down an expression for V in terms of T.

(1)

(c) Show that $T^2 - kT + 500 = 0$, where k is a constant to be found.

(4)

(d) Hence find the value of T, justifying your answer carefully.

(3)

(e) Considering your speed-time graph or otherwise, state two ways, apart from including air resistance, in which the model could be made to be more realistic.

(2)

10 marks

Working with Vectors

Also in Working with Vectors

Primary: Kinematics Graphs

WME01/01 JANUARY 2020

Question 5

5. A car travels at a constant speed of $40\,\text{m}\,\text{s}^{-1}$ in a straight line along a horizontal racetrack. At time $t = 0$, the car passes a motorcyclist who is at rest. The motorcyclist immediately sets off to catch up with the car.

The motorcyclist accelerates at $4\,\text{m}\,\text{s}^{-2}$ for $15\,\text{s}$ and then accelerates at $1\,\text{m}\,\text{s}^{-2}$ for a further T seconds until he catches up with the car.

(a) Sketch, on the same axes, the speed-time graph for the motion of the car and the speed-time graph for the motion of the motorcyclist, from time $t = 0$ to the instant when the motorcyclist catches up with the car.

(2)

At the instant when $t = t_1$ seconds, the car and the motorcyclist are moving at the same speed.

(b) Find the value of t_1

(2)

(c) Show that $T^2 + kT - 300 = 0$, where k is a constant to be found.

(6)

WME01/01 MAY/JUNE 2021

Question 1

7 marks

Working with Vectors

Also in Working with Vectors

Primary: Momentum, Impulse & Collisions

1. A particle P has mass $3m$ and a particle Q has mass $5m$. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately before the collision the speed of P is ku, where k is a constant, and the speed of Q is $2u$.

Immediately after the collision the speed of P is u and the speed of Q is $3u$.

The direction of motion of Q is reversed by the collision.

(a) Find, in terms of m and u, the magnitude of the impulse exerted on Q by P in the collision.

(2)

(b) Find the two possible values of k.

(5)

WME01/01 JANUARY 2022

Question 2

7 marks

Working with Vectors

Also in Working with Vectors

Primary: Momentum, Impulse & Collisions

2. A particle P has mass km and a particle Q has mass m. The particles are moving towards each other in opposite directions along the same straight line when they collide directly.

Immediately before the collision, P has speed $3u$ and Q has speed u.

As a result of the collision, the direction of motion of each particle is reversed and the speed of each particle is halved.

(a) Find the value of k.

(4)

(b) Find, in terms of m and u, the magnitude of the impulse exerted on Q in the collision.

(3)

7 marks

Working with Vectors

Also in Working with Vectors

Primary: Newton's Second Law

WME01/01 MAY/JUNE 2022

Question 3

3. A tractor of mass 6 tonnes is dragging a large block of mass 2 tonnes along rough horizontal ground. The cable connecting the tractor to the block is horizontal and parallel to the direction of motion.

The cable is modelled as being light and inextensible.

The driving force of the tractor is 7400 N and the resistance to the motion of the tractor is 200 N. The resistance to the motion of the block is R newtons, where R is a constant.

Given that the tension in the cable is 6000 N and the tractor is accelerating,

(a) find the value of R.

(6)

(b) State how you have used the fact that the cable is modelled as being inextensible.

(1)

WME01/01 JANUARY 2023

Question 2

8 marks

Working with Vectors

Also in Working with Vectors

Primary: Momentum, Impulse & Collisions

2. Two particles, A and B, are moving in a straight line in opposite directions towards each other on a smooth horizontal surface when they collide directly.

Particle A has mass $3m$ kg and particle B has mass m kg.

Immediately before the collision, both particles have a speed of $1.5\,\text{m s}^{-1}$

Immediately after the collision, the direction of motion of A is unchanged and the difference between the speed of A and speed of B is $1\,\text{m s}^{-1}$

(a) Find (i) the speed of A immediately after the collision,

(ii) the speed of B immediately after the collision.

(5)

(b) Find, in terms of m, the magnitude of the impulse exerted on B in the collision.

(3)

WME01/01 JANUARY 2023

Question 6

8 marks

Working with Vectors

Also in Working with Vectors

Primary: Forces

6.

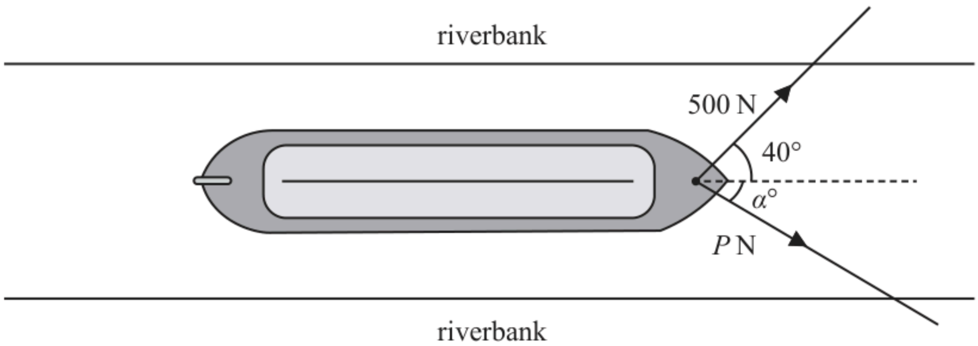


Figure 3

A boat is pulled along a river at a constant speed by two ropes.

The banks of the river are parallel and the boat travels horizontally in a straight line, parallel to the riverbanks.

- The tension in the first rope is 500 N acting at an angle of 40° to the direction of motion, as shown in Figure 3.
- The tension in the second rope is P newtons, acting at an angle of $\alpha°$ to the direction of motion, also shown in Figure 3.
- The resistance to motion of the boat as it moves through the water is a constant force of magnitude 900 N

The boat is modelled as a particle. The ropes are modelled as being light and lying in a horizontal plane.

Use the model to find

(i) the value of α

(ii) the value of P

(8)

WME01/01 JANUARY 2024

Question 4

8 marks

Working with Vectors

Also in Working with Vectors

Primary: Forces

4.

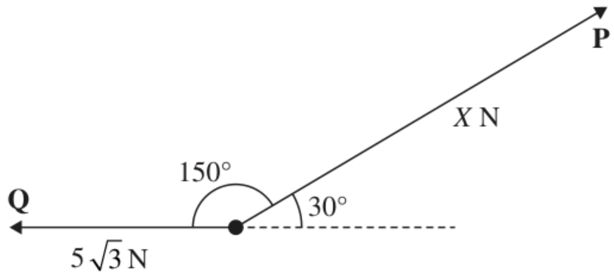


Figure 3

Figure 3 shows two horizontal forces **P** and **Q** acting on a particle.

The angle between the direction of **P** and the direction of **Q** is 150°

Force **P** has magnitude X newtons.

Force **Q** has magnitude $5\sqrt{3}$ N.

The resultant of **P** and **Q** has magnitude $\sqrt{129}$ N.

Find

(i) the value of X.

(ii) the angle between **Q** and the resultant, giving your answer to the nearest degree.

(8)

WME01/01 MAY/JUNE 2024

Question 2

4 marks

Working with Vectors

Also in Working with Vectors

Primary: Forces

2. Two forces, **P** and **Q**, act on a particle.

- **P** has magnitude 10 N and acts due west
- **Q** has magnitude 8 N and acts on a bearing of 330°

Given that **F** = **P** + **Q**, find the magnitude of **F**.

(4)

Question 1

8 marks

Working with Vectors

Also in Working with Vectors

Primary: Forces

1. A particle of mass 2.5 kg moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (6\mathbf{i} + 8\mathbf{j})\,\text{N}$$

$$\mathbf{F}_2 = (-16\mathbf{i} + 2\mathbf{j})\,\text{N}$$

$$\mathbf{F}_3 = (-2\mathbf{i} + 8\mathbf{j})\,\text{N}$$

(a) Find the magnitude of the acceleration of the particle.

(4)

A fourth force, $\mathbf{F}_4 = (p\mathbf{i} + p\mathbf{j})\,\text{N}$, where p is a constant, is added.

The resultant of the four forces acts in the direction of the vector $(7\mathbf{i} + 2\mathbf{j})$.

(b) Find the value of p.

(4)

WME01/01 MAY/JUNE 2025

Question 1

6 marks

Working with Vectors

Also in Working with Vectors

Primary: Momentum, Impulse & Collisions

1.

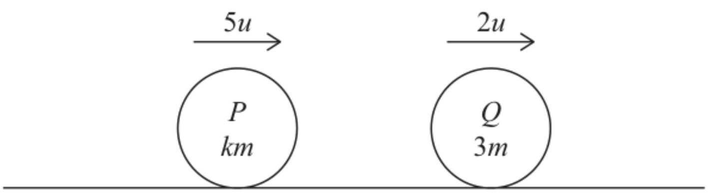


Figure 1

Figure 1 shows two particles, P and Q, moving in the same direction along the same straight line on a smooth horizontal surface.
Particle P has mass km and particle Q has mass $3m$
The particles collide directly.

Immediately before the collision, the speed of P is $5u$ and the speed of Q is $2u$

Immediately after the collision, the speed of P is $2u$ and its direction of motion is unchanged.

Immediately after the collision, the speed of Q is v

The impulse exerted on Q by P in the collision has magnitude $4.5mu$

(a) Find v in terms of u only.

(3)

(b) Find the value of k

(3)

Question 2

8 marks

Working with Vectors

Also in Working with Vectors

Primary: Momentum, Impulse & Collisions

2.

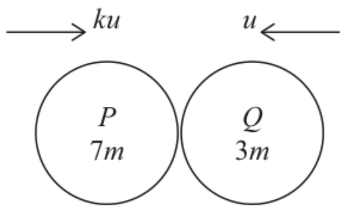


Figure 2

Particle P of mass $7m$ and particle Q of mass $3m$ are moving in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately **before** the collision, the speed of P is ku and the speed of Q is u, as shown in Figure 2.

Immediately **after** the collision, the speed of P is w and the speed of Q is $2w$.

The direction of motion of Q is reversed by the collision.

The impulse received by Q in the collision has magnitude $\frac{7}{2}mu$.

(a) Find w in terms of u.

(3)

(b) Find the two possible values of k.

(5)

WME01/01 OCTOBER 2025

Question 3

14 marks

Working with Vectors

Also in Working with Vectors

Primary: Forces

3. [*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

A particle P of mass 2 kg moves on a smooth horizontal surface under the action of two forces $\mathbf{F}_1$ and $\mathbf{F}_2$, where $\mathbf{F}_1 = (-2\mathbf{i} + 3\mathbf{j})\,\text{N}$ and $\mathbf{F}_2 = (4\mathbf{i} + 2\mathbf{j})\,\text{N}$.

(a) Find the acceleration of P.

(3)

At time $t = 0$, the velocity of P is $(3\mathbf{i} - 4\mathbf{j})\,\text{m s}^{-1}$

(b) Find the speed of P when $t = 3$ seconds.

(4)

An additional force, $\mathbf{F}_3 = (b\mathbf{i} + c\mathbf{j})\,\text{N}$, is applied to P.

The resultant of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ is equal to $\lambda(\mathbf{i} + \mathbf{j})\,\text{N}$, where λ is a constant.

(c) Show that $b - c = 3$

(3)

The resultant of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ has magnitude $10\sqrt{2}\,\text{N}$.

(d) Find the two possible $\mathbf{F}_3$ forces.

(4)

Question 1

6 marks

Working with Vectors

Also in Working with Vectors

Primary: Momentum, Impulse & Collisions

1. A particle P of mass $3m$ and a particle Q of mass $5m$ are on a smooth horizontal surface. The particles move towards each other in opposite directions along the same straight line and collide.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $4u$

The magnitude of the impulse exerted on P by Q in the collision is $\frac{33}{2}mu$

Find

(i) the speed of P immediately after the collision,

(ii) the speed of Q immediately after the collision.

(6)

WME01/01 JANUARY 2026

Question 3

8 marks

Working with Vectors

Also in Working with Vectors

Primary: Forces

3. A particle moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (2p\mathbf{i} - 3p\mathbf{j})\text{N}$$

$$\mathbf{F}_2 = (q\mathbf{i} + \mathbf{j})\text{N}$$

$$\mathbf{F}_3 = (3\mathbf{i} - q\mathbf{j})\text{N}$$

where p and q are constants.

The resultant force acts in the direction of the vector $(4\mathbf{i} - 5\mathbf{j})$

(a) Show that

$$2p - q = 19$$

(4)

The mass of the particle is 0.5 kg.

Given that $p = 7$

(b) find the acceleration of the particle.

(4)

TOPIC

Kinematics Graphs

Question 6

12 marks

Kinematics Graphs

6. An athlete runs a 200 m race along a straight horizontal track.

In a model of the motion of the athlete, air resistance is ignored, the athlete starts from rest at time $t = 0$ seconds and moves with uniform acceleration $0.8\,\text{m s}^{-2}$ for T seconds, reaching a speed of $V\,\text{m s}^{-1}$. She then maintains this speed until she crosses the finishing line.

The total time from when the athlete starts to when she crosses the finishing line is 30 s.

(a) Sketch a speed-time graph for the model of the motion of the athlete from the instant when she starts to the instant when she crosses the finishing line.

(2)

(b) Write down an expression for V in terms of T.

(1)

(c) Show that $T^2 - kT + 500 = 0$, where k is a constant to be found.

(4)

(d) Hence find the value of T, justifying your answer carefully.

(3)

(e) Considering your speed-time graph or otherwise, state two ways, apart from including air resistance, in which the model could be made to be more realistic.

(2)

WME01/01 JANUARY 2020

10 marks

Question 5

Kinematics Graphs

5. A car travels at a constant speed of $40\,\text{m}\,\text{s}^{-1}$ in a straight line along a horizontal racetrack. At time $t = 0$, the car passes a motorcyclist who is at rest. The motorcyclist immediately sets off to catch up with the car.

The motorcyclist accelerates at $4\,\text{m}\,\text{s}^{-2}$ for 15 s and then accelerates at $1\,\text{m}\,\text{s}^{-2}$ for a further T seconds until he catches up with the car.

(a) Sketch, on the same axes, the speed-time graph for the motion of the car and the speed-time graph for the motion of the motorcyclist, from time $t = 0$ to the instant when the motorcyclist catches up with the car.

(2)

At the instant when $t = t_1$ seconds, the car and the motorcyclist are moving at the same speed.

(b) Find the value of t_1

(2)

(c) Show that $T^2 + kT - 300 = 0$, where k is a constant to be found.

(6)

Question 7

12 marks

Kinematics Graphs

7. A helicopter is hovering at rest above horizontal ground at the point H. A parachutist steps out of the helicopter and immediately falls vertically and freely under gravity from rest for 2.5 s. His parachute then opens and causes him to immediately decelerate at a constant rate of $3.9\,\text{m}\,\text{s}^{-2}$ for T seconds ($T < 6$), until his speed is reduced to $V\,\text{m}\,\text{s}^{-1}$. He then moves with this constant speed $V\,\text{m}\,\text{s}^{-1}$ until he hits the ground. While he is decelerating, he falls a distance of 73.75 m. The total time between the instant when he leaves H and the instant when he hits the ground is 20 s.

The parachutist is modelled as a particle.

(a) Find the speed of the parachutist at the instant when his parachute opens.

(1)

(b) Sketch a speed-time graph for the motion of the parachutist from the instant when he leaves H to the instant when he hits the ground.

(2)

(c) Find the value of T.

(5)

(d) Find, to the nearest metre, the height of the point H above the ground.

(4)

Question 8

8. Two trams, tram A and tram B, run on parallel straight horizontal tracks. Initially the two trams are at rest in the depot and level with each other.

At time $t = 0$, tram A starts to move. Tram A moves with constant acceleration $2\,\text{m}\,\text{s}^{-2}$ for 5 seconds and then continues to move along the track at constant speed.

At time $t = 20$ seconds, tram B starts from rest and moves in the same direction as tram A. Tram B moves with constant acceleration $3\,\text{m}\,\text{s}^{-2}$ for 4 seconds and then continues to move along the track at constant speed.

The trams are modelled as particles.

(a) Sketch, on the same axes, a speed-time graph for the motion of tram A and a speed-time graph for the motion of tram B, from $t = 0$ to the instant when tram B overtakes tram A.

(3)

At the instant when the two trams are moving with the same speed, tram A is d metres in front of tram B.

(b) Find the value of d.

(5)

(c) Find the distance of the trams from the depot at the instant when tram B overtakes tram A.

(5)

(Total 13 marks)

Question 7

13 marks

Kinematics Graphs

7. Two small children, Ajaz and Beth, are running a 100 m race along a straight horizontal track.

They both start from rest, leaving the start line at the same time.

Ajaz accelerates at $0.8\,\mathrm{m\,s^{-2}}$ up to a speed of $4\,\mathrm{m\,s^{-1}}$ and then maintains this speed until he crosses the finish line.

Beth accelerates at $1\,\mathrm{m\,s^{-2}}$ for T seconds and then maintains a constant speed until she crosses the finish line.

Ajaz and Beth cross the finish line at the same time.

(a) Sketch, on the same axes, a speed-time graph for each child, from the instant when they leave the start line to the instant when they cross the finish line.

(3)

(b) Find the time taken by Ajaz to complete the race.

(4)

(c) Find the value of T

(4)

(d) Find the difference in the speeds of the two children as they cross the finish line.

(2)

WME01/01 JANUARY 2023

10 marks

Question 1

Kinematics Graphs

1. A train travels along a straight horizontal track between two stations *A* and *B*.

The train starts from rest at station *A* and accelerates uniformly for *T* seconds until it reaches a speed of $20\,\text{m s}^{-1}$

The train then travels at a constant speed of $20\,\text{m s}^{-1}$ for 3 minutes before decelerating uniformly until it comes to rest at station *B*.

The magnitude of the acceleration of the train is twice the magnitude of the deceleration.

(a) On the axes below, sketch a speed–time graph to illustrate the motion of the train as it moves from station *A* to station *B*.

If you need to redraw your graph, use the axes on page 3

(3)

Stations *A* and *B* are 4.8 km apart.

(b) Find the value of *T*

(5)

(c) Find the acceleration of the train during the first *T* seconds of its motion.

(2)

Only use these axes if you need to redraw your graph.

(Total for Question 1 is 10 marks)

WME01/01 MAY/JUNE 2023

Question 5

11 marks

Kinematics Graphs

5.

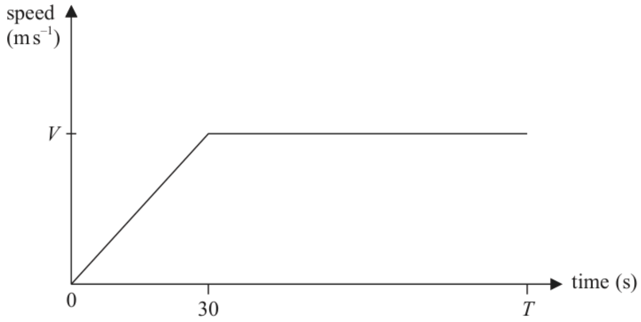


Figure 2

The speed-time graph in Figure 2 illustrates the motion of a car travelling along a straight horizontal road.
At time $t = 0$, the car starts from rest and accelerates uniformly for 30 s until it reaches a speed of V m s^{-1}
The car then travels at a constant speed of V m s^{-1} until time $t = T$ seconds.

(a) Show that the distance travelled by the car between $t = 0$ and $t = T$ seconds is $V(T - 15)$ metres.

(2)

A motorbike also travels along the same road.

- The motorbike starts from rest at time $\boldsymbol{t}$ **= 10 s** and accelerates uniformly for 40 s
- The acceleration of the motorbike is the **same** as the acceleration of the car
- The motorbike then travels at a constant speed for a further 10 s before decelerating uniformly until it reaches a speed of V m s^{-1} at time T seconds

(b) On Figure 2, sketch a speed-time graph for the motion of the motorbike.

[If you need to redraw your sketch, there is a copy of Figure 2 on page 15.]

(2)

(c) Show that the constant speed of the motorbike is $\dfrac{4V}{3}$ m s^{-1}

(2)

At time $t = T$ seconds, the distance travelled by each vehicle is the same.

(d) Find the value of T

(5)

Only use this copy of Figure 2 if you need to redraw your sketch.

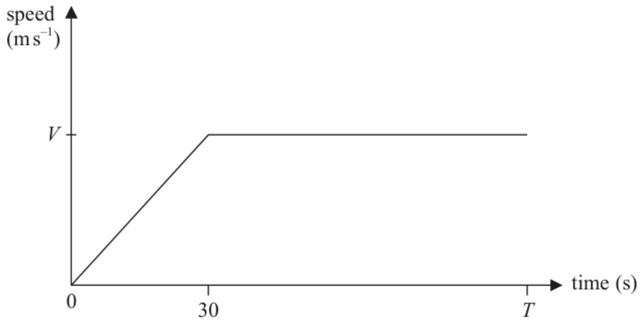


Figure 2

(Total for Question 5 is 11 marks)

WME01/01 OCTOBER 2023

Question 2

10 marks

Kinematics Graphs

2.

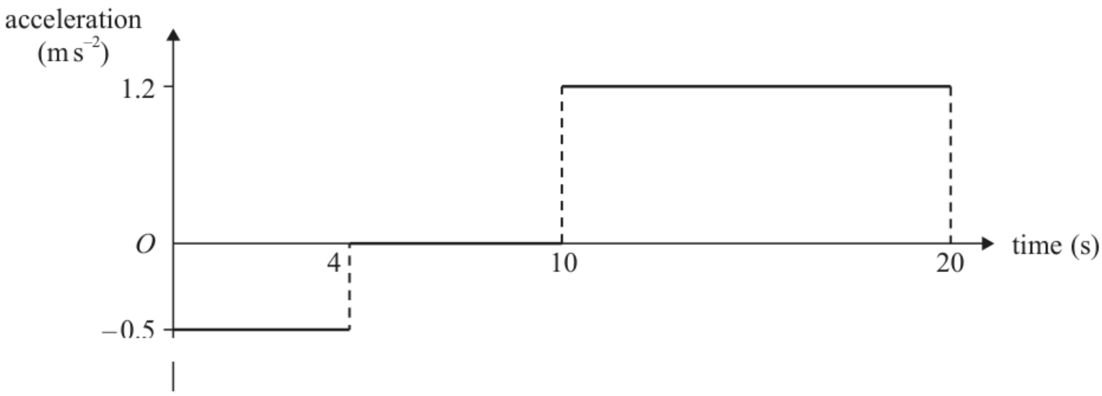


Figure 2

Two fixed points, A and B, are on a straight horizontal road.

The **acceleration-time** graph in Figure 2 represents the motion of a car travelling along the road as it moves from A to B.

At time $t = 0$, the car passes through A with speed $8\,\mathrm{m\,s^{-1}}$

At time $t = 20\,\mathrm{s}$, the car passes through B with speed $v\,\mathrm{m\,s^{-1}}$

(a) Show that $v = 18$

(3)

(b) Sketch a speed-time graph for the motion of the car from A to B.

(3)

(c) Find the distance AB.

(4)

WME01/01 OCTOBER 2024

Question 4

13 marks

Kinematics Graphs

4. The points A and B lie on the same straight horizontal road.

Figure 2, on page 11, shows the speed-time graph of a cyclist P, for his journey from A to B.
At time $t = 0$, P starts from rest at A and accelerates uniformly for 9 seconds until his speed is $V\,\text{m s}^{-1}$

He then travels at constant speed $V\,\text{m s}^{-1}$

When $t = 42$, cyclist P passes B.

Given that the distance AB is 120 m,

(a) show that $V = 3.2$

(3)

(b) Find the acceleration of cyclist P between $t = 0$ and $t = 9$

(2)

Cyclist P continues to cycle along the road in the same direction at the same constant speed, $V\,\text{m s}^{-1}$

When $t = 6$, a second cyclist Q sets off from A and travels in the same direction as P along the same road. She accelerates for T seconds until her speed is $3.6\,\text{m s}^{-1}$

She then travels at constant speed $3.6\,\text{m s}^{-1}$

Cyclist Q catches up with P when $t = 54$

(c) On Figure 2, on page 11, sketch a speed-time graph showing the journeys of **both** cyclists, for the interval $0 \leqslant t \leqslant 54$

(3)

(d) Find the value of T

(5)

Question 4 continued

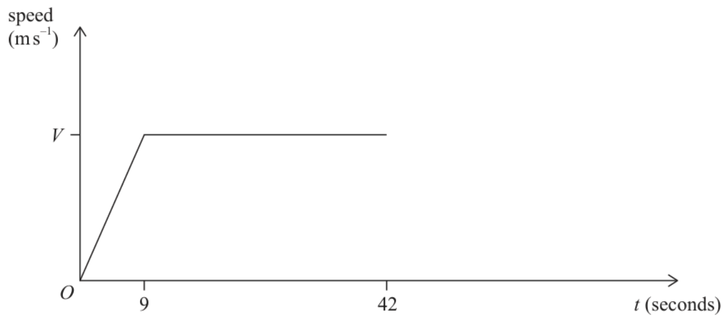
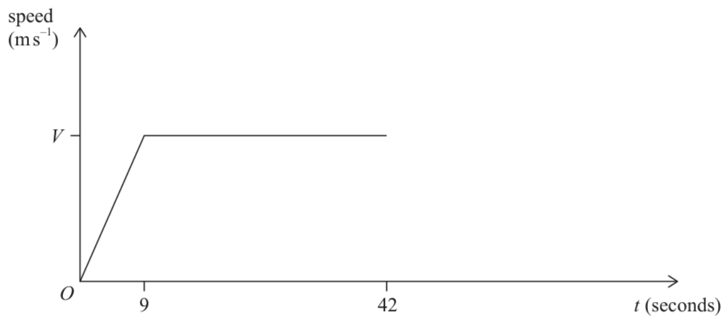


Figure 2

A copy of Figure 2 is on page 13 if you need to redraw your answer to part (c).

Question 4 continued

Only use this copy of Figure 2 if you need to redraw your answer to part (c).



Copy of Figure 2

WME01/01 JANUARY 2025

11 marks

Question 2

Kinematics Graphs

2. The fixed points A, B and C lie in a straight line on a horizontal road.

- At time $t = 0$, a motorbike passes through A with speed $5\,\text{m s}^{-1}$
- From A, the motorbike accelerates uniformly until it reaches B with a speed of $V\,\text{m s}^{-1}$
- The motorbike takes T_1 seconds to travel from A to B
- From B, the motorbike decelerates uniformly until it comes to rest at C
- The motorbike takes T_2 seconds to travel from B to C

(a) Sketch a speed-time graph for the motion of the motorbike as it moves from A to C.
(3)

The distance AB is 132 m and the distance BC is 136 m.

(b) Find, in terms of V, an expression for

(i) T_1

(ii) T_2
(4)

Given that the motorbike takes 28 s to travel from A to C,

(c) find the value of V,
(2)

(d) find the deceleration of the motorbike.
(2)

WME01/01 OCTOBER 2025

Question 6

10 marks

Kinematics Graphs

6.

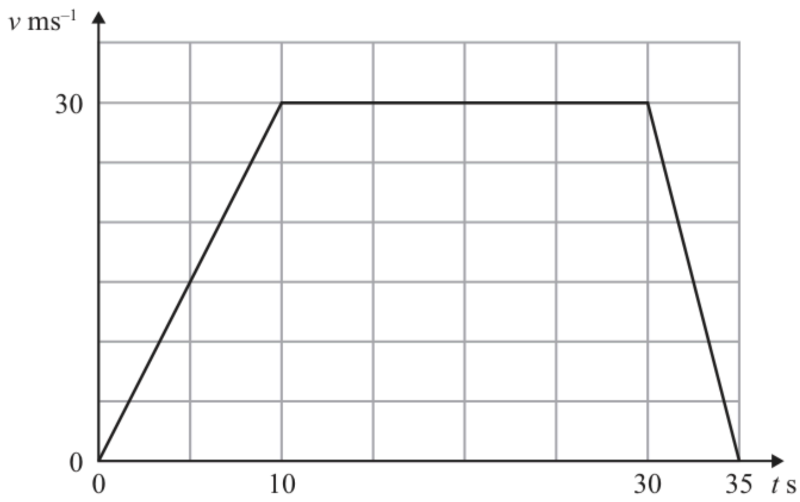


Figure 4

The point O lies on a straight horizontal road.
At time $t = 0$, a car leaves O and travels along the road.

The velocity-time graph in Figure 4 shows the velocity, $v\,\mathrm{m\,s^{-1}}$, of the car at time t seconds for the first 35 seconds of its journey.

(a) Find

(i) the acceleration of the car for the period $0 \leqslant t \leqslant 10$

(ii) the deceleration of the car for the period $30 \leqslant t \leqslant 35$

(2)

(b) Sketch an acceleration-time graph for the car for the period $0 \leqslant t \leqslant 35$

(2)

(c) Find the distance travelled by the car for the period $0 \leqslant t \leqslant 35$

(2)

When $t = 5$, a motorcycle starts from rest at O.
The motorcycle travels along the same road as the car and in the same direction.

For the period $5 \leqslant t \leqslant 20$, the acceleration of the motorcycle is $A\,\mathrm{m\,s^{-2}}$, where A is a positive constant.

The motorcycle catches up with the car when $t = 20$

(d) Find the value of A.

(4)

Question 2

10 marks

Kinematics Graphs

2.

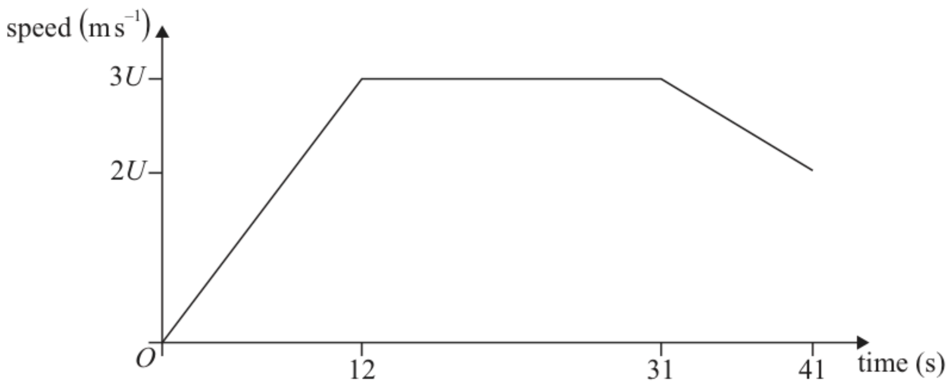


Figure 1

A particle P starts from rest at time $t = 0$ and moves in a straight line

- from $t = 0$ to $t = 12\text{ s}$, P accelerates uniformly until it reaches a speed of $3U\text{ m s}^{-1}$
- from $t = 12\text{ s}$ to $t = 31\text{ s}$, P moves with constant speed $3U\text{ m s}^{-1}$
- from $t = 31\text{ s}$ to $t = 41\text{ s}$, P decelerates uniformly until it has speed $2U\text{ m s}^{-1}$

as shown on the speed-time graph in Figure 1.

The distance travelled by P between $t = 0$ and $t = 41\text{ s}$ is 600 m.

(a) Show that $U = 6$

(3)

(b) Find the distance travelled by P whilst moving from rest to a speed of 6 m s^{-1}

(2)

(c) Find the acceleration of P between $t = 0$ and $t = 12\text{ s}$.

(1)

(d) Find the deceleration of P between $t = 31\text{ s}$ and $t = 41\text{ s}$.

(2)

(e) Sketch an acceleration-time graph to represent the motion of P from $t = 0$ to $t = 41\text{ s}$.

(2)

14 marks

Kinematics Graphs

Also in Kinematics Graphs

Primary: Working with Vectors

WME01/01 OCTOBER 2019

Question 8

8. [*In this question, the horizontal unit vectors* **i** *and* **j** *are directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two speedboats, A and B, are each moving with constant velocity. The velocity of A is $20\,\text{km}\,\text{h}^{-1}$ due west and the velocity of B is $40\,\text{km}\,\text{h}^{-1}$ on a bearing of 150°. The boats are modelled as particles.

At noon, the position vector of A is $60\mathbf{i}$ km and B is at the origin O. At time t hours after noon, the position vector of A is $\mathbf{r}$ km and the position vector of B is $\mathbf{s}$ km.

(a) Find the velocity of B in the form $(p\mathbf{i} + q\mathbf{j})\,\text{km}\,\text{h}^{-1}$

(3)

(b) Find expressions for $\mathbf{r}$ and $\mathbf{s}$ in terms of t, $\mathbf{i}$ and $\mathbf{j}$.

(3)

(c) Find the time, to the nearest minute, at which the distance between the boats is the same as it was at noon.

(8)

WME01/01 OCTOBER 2021

Question 6

5 marks

Kinematics Graphs

Also in Kinematics Graphs

Primary: Constant Acceleration in 1D

6.

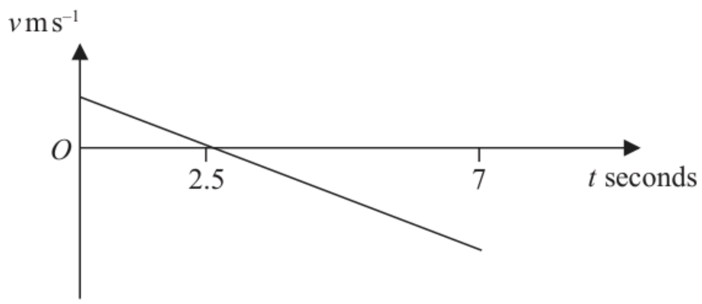


Figure 3

A small ball is thrown vertically upwards at time $t = 0$ from a point A which is above horizontal ground. The ball hits the ground 7 s later.

The ball is modelled as a particle moving freely under gravity.

The velocity-time graph shown in Figure 3 represents the motion of the ball for $0 \leqslant t \leqslant 7$

(a) Find the speed with which the ball is thrown.

(2)

(b) Find the height of A above the ground.

(3)

WME01/01 JANUARY 2022

Question 4

8 marks

Kinematics Graphs

Also in Kinematics Graphs

Primary: Constant Acceleration in 1D

4. At time $t = 0$, a small ball is projected vertically upwards from a point A which is 24.5 m above the ground. The ball first comes to instantaneous rest at the point B, where $AB = 19.6$ m and first hits the ground at time $t = T$ seconds.

The ball is modelled as a particle moving freely under gravity.

(a) Find the value of T.

(6)

(b) Sketch a speed-time graph for the motion of the ball from $t = 0$ to $t = T$ seconds.

(No further calculations are needed in order to draw this sketch.)

(2)

Question 5

5. A small ball is projected vertically upwards with speed $29.4\,\text{m}\,\text{s}^{-1}$ from a point A which is 19.6 m above horizontal ground.

The ball is modelled as a particle moving freely under gravity until it hits the ground. It is assumed that the ball does not rebound.

(a) Find the distance travelled by the ball while its speed is less than $14.7\,\text{m}\,\text{s}^{-1}$

(3)

(b) Find the time for which the ball is moving with a speed of more than $29.4\,\text{m}\,\text{s}^{-1}$

(3)

(c) Sketch a speed-time graph for the motion of the ball from the instant when it is projected from A to the instant when it hits the ground. Show clearly where your graph meets the axes.

(3)

WME01/01 JANUARY 2024

Question 6

12 marks

Kinematics Graphs

Also in Kinematics Graphs

Primary: Constant Acceleration in 1D

6. A particle is projected vertically upwards from a point A with speed 24 m s^{-1}

The point A is 2.5 m vertically above the point B.

Point B lies on horizontal ground.

The particle moves freely under gravity until it hits the ground at B with speed $V \text{ m s}^{-1}$

After hitting the ground the particle does not rebound.

(a) Find the value of V.

(3)

(b) Find the time taken for the particle to reach B.

(3)

The point C is 10 m vertically above A.

(c) Find the length of time for which the particle is above C.

(4)

(d) Sketch a speed-time graph for the motion of the particle from projection to the instant that it reaches B. (No further calculations are required.)

(2)

TOPIC

Constant Acceleration in 1D

Question 2

9 marks

Constant Acceleration in 1D

2. A small ball is released from rest from a point that is 40 m above horizontal ground. The ball bounces on the ground and rebounds vertically. Each time the ball bounces on the ground, the speed of the ball is instantaneously reduced by 50%. The ball is modelled as a particle moving freely under gravity, from the instant when it is released until it first hits the ground, and between each successive bounce.

(a) Find the time from the instant when the ball is released from rest to the instant when it hits the ground for the second time.

(5)

(b) Find the maximum height reached by the ball above the ground after the ball's third bounce.

(4)

Question 3

3. A particle, P, is projected vertically upwards with speed U from a fixed point O. At the instant when P reaches its greatest height H above O, a second particle, Q, is projected with speed $\frac{1}{2}U$ vertically upwards from O.

(a) Find H in terms of U and g.

(2)

(b) Find, in terms of U and g, the time between the instant when Q is projected and the instant when the two particles collide.

(6)

(c) Find where the two particles collide.

(3)

Question 1

6 marks

Constant Acceleration in 1D

1. A small stone is projected vertically upwards with speed $20\,\text{m s}^{-1}$ from a point O which is $5\,\text{m}$ above horizontal ground. The stone is modelled as a particle moving freely under gravity.

Find

(a) the speed of the stone at the instant when it is $2\,\text{m}$ above the ground,

(2)

(b) the total time between the instant when the stone is projected from O and the instant when it first strikes the ground.

(4)

8 marks

Question 2

Constant Acceleration in 1D

2. A car moves along a straight horizontal road with constant acceleration $a\,\text{m s}^{-2}$ where $a > 0$

The car is modelled as a particle.

At time $t = 0$, the car passes point A and is moving with speed $u\,\text{m s}^{-1}$

In the first three seconds after passing A the car travels $20\,\text{m}$.

In the fourth second after passing A the car travels $10\,\text{m}$.

The speed of the car as it passes point B is $20\,\text{m s}^{-1}$

Find the time taken for the car to travel from A to B.

(8)

Question 3

3. A car is moving at a constant speed of $25\,\mathrm{m\,s^{-1}}$ along a straight horizontal road.

The car is modelled as a particle.

At time $t = 0$, the car is at the point A and the driver sees a road sign 48 m ahead.

Let t seconds be the time that elapses after the car passes A.

In a **first** model, the car is assumed to decelerate uniformly at $6\,\mathrm{m\,s^{-2}}$ from A until the car reaches the road sign.

(a) Use this first model to find the speed of the car as it reaches the sign.

(2)

The road sign indicates that the speed limit immediately after the sign is $13\,\mathrm{m\,s^{-1}}$.

In a **second** model, the car is assumed to decelerate uniformly at $6\,\mathrm{m\,s^{-2}}$ from A until it reaches a speed of $13\,\mathrm{m\,s^{-1}}$. The car then maintains this speed until it reaches the road sign.

(b) Use this second model to find the value of t at which the car reaches the sign.

(4)

In a **third** model, the car is assumed to move with constant speed $25\,\mathrm{m\,s^{-1}}$ from A until time $t = 0.2$, the car then decelerates uniformly at $6\,\mathrm{m\,s^{-2}}$ until it reaches a speed of $13\,\mathrm{m\,s^{-1}}$. The car then maintains this speed until it reaches the road sign.

(c) Use this third model to find the value of t at which the car reaches the sign.

(4)

Question 6

5 marks

Constant Acceleration in 1D

6.

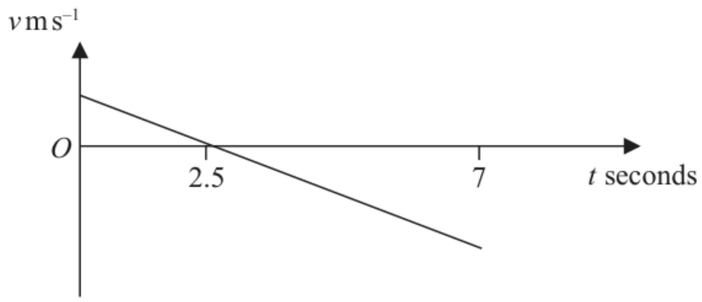


Figure 3

A small ball is thrown vertically upwards at time $t = 0$ from a point A which is above horizontal ground. The ball hits the ground 7 s later.

The ball is modelled as a particle moving freely under gravity.

The velocity-time graph shown in Figure 3 represents the motion of the ball for $0 \leqslant t \leqslant 7$

(a) Find the speed with which the ball is thrown.

(2)

(b) Find the height of A above the ground.

(3)

WME01/01 JANUARY 2022

8 marks

Question 4

Constant Acceleration in 1D

4. At time $t = 0$, a small ball is projected vertically upwards from a point A which is 24.5 m above the ground. The ball first comes to instantaneous rest at the point B, where $AB = 19.6$ m and first hits the ground at time $t = T$ seconds.

The ball is modelled as a particle moving freely under gravity.

(a) Find the value of T.

(6)

(b) Sketch a speed-time graph for the motion of the ball from $t = 0$ to $t = T$ seconds.

(No further calculations are needed in order to draw this sketch.)

(2)

Question 2

7 marks

Constant Acceleration in 1D

2. A motorbike is moving with constant acceleration along a straight horizontal road.

The motorbike passes a point P and 10 seconds later passes a point Q.

The speed of the motorbike as it passes Q is $28\,\text{m}\,\text{s}^{-1}$

Given that $PQ = 220\,\text{m}$,

(a) find the acceleration of the motorbike,

(3)

(b) find the distance travelled by the motorbike during the fifth second after passing P

(4)

WME01/01 OCTOBER 2022

Question 5

9 marks

Constant Acceleration in 1D

5. A small ball is projected vertically upwards with speed $29.4\,\text{m}\,\text{s}^{-1}$ from a point A which is 19.6 m above horizontal ground.

The ball is modelled as a particle moving freely under gravity until it hits the ground. It is assumed that the ball does not rebound.

(a) Find the distance travelled by the ball while its speed is less than $14.7\,\text{m}\,\text{s}^{-1}$

(3)

(b) Find the time for which the ball is moving with a speed of more than $29.4\,\text{m}\,\text{s}^{-1}$

(3)

(c) Sketch a speed-time graph for the motion of the ball from the instant when it is projected from A to the instant when it hits the ground. Show clearly where your graph meets the axes.

(3)

WME01/01 JANUARY 2023

9 marks

Question 5

Constant Acceleration in 1D

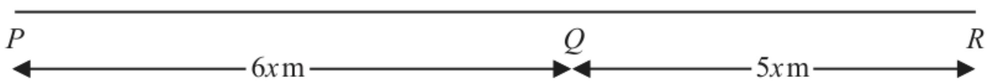


Figure 2

Three points P, Q and R are on a horizontal road where PQR is a straight line.

The point Q is between P and R, with $PQ = 6x$ metres and $QR = 5x$ metres, as shown in Figure 2.

A vehicle moves along the road from P to Q with constant acceleration.

The vehicle is modelled as a particle.

At time $t = 0$, the vehicle passes P with speed $u\,\text{m s}^{-1}$

At time $t = 12$ s, the vehicle passes Q with speed $2u\,\text{m s}^{-1}$

Using the model,

(a) show that $x = 3u$

(2)

As the vehicle passes Q, the acceleration of the vehicle changes instantaneously to $1.5\,\text{m s}^{-2}$

The vehicle continues to move with a constant acceleration of $1.5\,\text{m s}^{-2}$ and passes R with speed $3u\,\text{m s}^{-1}$

Using the model,

(b) find the value of u,

(3)

(c) find the distance travelled by the vehicle during the first 14 seconds after passing P

(4)

Question 3

8 marks

Constant Acceleration in 1D

3. Two students observe a book of mass 0.2 kg fall vertically from rest from a shelf that is 1.5 m above the floor.

Student A suggests that the book is modelled as a particle falling freely under gravity.

(a) Use student A's model to find the time taken for the book to reach the floor.

(3)

Student B suggests an improved model where the book is modelled as a particle experiencing a constant resistance to motion of magnitude R newtons.

Given that the time taken for the book to reach the floor is 0.6 seconds,

(b) use student B's model to find the value of R

(5)

Question 3

10 marks

Constant Acceleration in 1D

3. A van travels with constant acceleration along a straight horizontal road.

The van passes a point A with speed $u\,\text{m}\,\text{s}^{-1}$ and 20 seconds later passes a point B with speed $28\,\text{m}\,\text{s}^{-1}$

The distance AB is 400 m.

(a) Show that $u = 12$

(2)

(b) Find the time taken for the van to travel from A to the midpoint of AB.

(5)

The van has mass 1200 kg.

During its motion the van experiences a constant resistive force of magnitude 260 N

(c) Find the magnitude of the driving force exerted by the engine of the van as it travels from A to B.

(3)

Question 6

12 marks

Constant Acceleration in 1D

6. A particle is projected vertically upwards from a point A with speed $24\,\text{m s}^{-1}$

The point A is 2.5 m vertically above the point B.

Point B lies on horizontal ground.

The particle moves freely under gravity until it hits the ground at B with speed $V\,\text{m s}^{-1}$

After hitting the ground the particle does not rebound.

(a) Find the value of V.

(3)

(b) Find the time taken for the particle to reach B.

(3)

The point C is 10 m vertically above A.

(c) Find the length of time for which the particle is above C.

(4)

(d) Sketch a speed-time graph for the motion of the particle from projection to the instant that it reaches B. (No further calculations are required.)

(2)

Question 5

14 marks

Constant Acceleration in 1D

5. A parachute is used to deliver a box of supplies. The parachute is attached to the box.

- the parachute and box are dropped from rest from a helicopter that is hovering at a height of 520 m above the ground
- the parachute and box fall vertically and freely under gravity for 5 seconds, then the parachute opens
- from the instant the parachute opens, it provides a resistance to motion of magnitude 3200 N
- the parachute and box continue to fall vertically downwards after the parachute opens
- the parachute and box are modelled throughout the motion as a particle P of mass 250 kg

(a) Find the distance fallen by P in the first 5 seconds.

(2)

(b) Find the speed with which P lands on the ground.

(7)

(c) Find the total time from the instant when P is dropped from the helicopter to the instant when P lands on the ground.

(3)

(d) Sketch a speed-time graph for the motion of P from the instant when P is dropped from the helicopter to the instant when P lands on the ground.

(2)

Question 7

11 marks

Constant Acceleration in 1D

7 At time $t = 0$, a small ball A is projected vertically upwards with speed $8\,\text{m}\,\text{s}^{-1}$ from a fixed point on horizontal ground.
The ball hits the ground again for the first time at time $t = T_1$ seconds.

Ball A is modelled as a particle moving freely under gravity.

(a) Show that $T_1 = 1.63$ to 3 significant figures.

(2)

After the first impact with the ground, A rebounds to a height of 2 m above the ground.

Given that the mass of A is 0.1 kg,

(b) find the magnitude of the impulse received by A as a result of its first impact with the ground.

(5)

At time $t = 1$ second, another small ball B is projected vertically upwards from another point on the ground with speed $5\,\text{m}\,\text{s}^{-1}$

Ball B is modelled as a particle moving freely under gravity.

At time $t = T_2$ seconds ($T_2 > 1$), A and B are at the same height above the ground for the first time.

(c) Find the value of T_2

(4)

Question 3

8 marks

Constant Acceleration in 1D

3. A particle is projected vertically upwards with speed $U \text{ m s}^{-1}$ from a point A.

The point A is 12 m vertically above the point B.

Point B is on horizontal ground.

The particle moves freely under gravity until it hits the ground at B.

The time taken for the particle to travel from A to B is 4 seconds.

(a) Find the value of U.

(3)

(b) Find the speed of the particle as it hits the ground at B.

(3)

(c) Sketch a speed-time graph for the motion of the particle from the instant it leaves A to the instant it reaches B. (No further calculations are required.)

(2)

WME01/01 OCTOBER 2019

Question 5

8 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

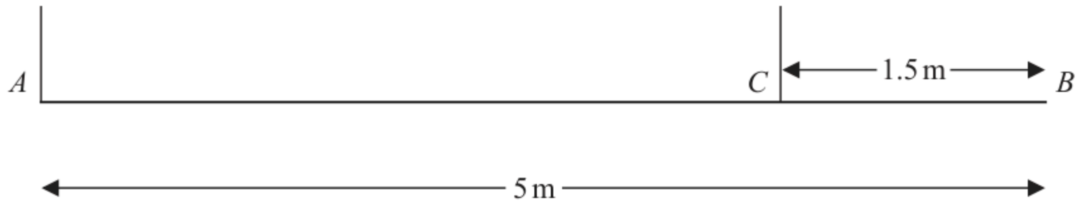


Figure 2

A non-uniform beam, AB, has length 5 m and mass 12 kg. The beam is suspended in a horizontal position by two vertical ropes. One rope is attached to the beam at A. The other rope is attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 2. The distance of the centre of mass of the beam from A is 1.75 m. The beam is modelled as a non-uniform rod and the ropes are modelled as light inextensible strings.

A particle of mass M kg is now placed on the beam at B and the beam remains in equilibrium in a horizontal position.

(a) Find the largest possible value of M.

(3)

The particle at B is now removed and a particle of mass 15 kg is now placed on the beam at the point D, where $AD = x$ metres. The beam remains in equilibrium in a horizontal position.

Given that the tension in the rope attached to the beam at C is now twice the tension in the rope attached to the beam at A,

(b) find the value of x.

(5)

WME01/01 JANUARY 2020

Question 2

7 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

2.

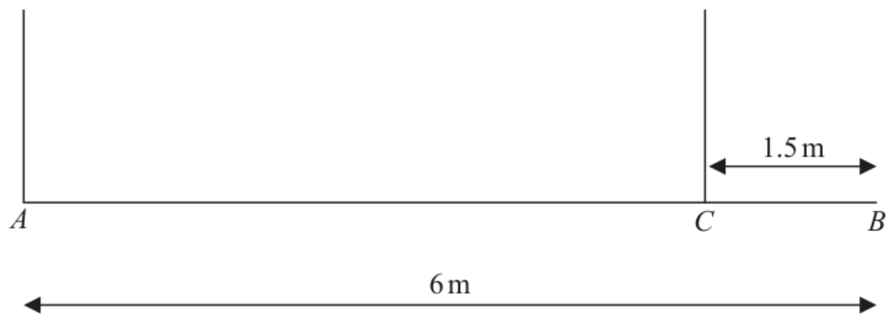


Figure 1

A non-uniform beam AB has length 6 m and weight W newtons. The beam is supported in equilibrium in a horizontal position by two vertical ropes, one attached to the beam at A and the other attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 1.

The centre of mass of the beam is 2.625 m from A.

The ropes are modelled as light strings. The beam is modelled as a non-uniform rod.

Given that the tension in the rope attached at C is 20 N greater than the tension in the rope attached at A,

(a) find the value of W.

(6)

(b) State how you have used the fact that the beam is modelled as a rod.

(1)

10 marks

WME01/01 JANUARY 2020

Constant Acceleration in 1D

Question 5

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

5. A car travels at a constant speed of $40\,\text{m s}^{-1}$ in a straight line along a horizontal racetrack. At time $t = 0$, the car passes a motorcyclist who is at rest. The motorcyclist immediately sets off to catch up with the car.

The motorcyclist accelerates at $4\,\text{m s}^{-2}$ for $15\,\text{s}$ and then accelerates at $1\,\text{m s}^{-2}$ for a further T seconds until he catches up with the car.

(a) Sketch, on the same axes, the speed-time graph for the motion of the car and the speed-time graph for the motion of the motorcyclist, from time $t = 0$ to the instant when the motorcyclist catches up with the car.

(2)

At the instant when $t = t_1$ seconds, the car and the motorcyclist are moving at the same speed.

(b) Find the value of t_1

(2)

(c) Show that $T^2 + kT - 300 = 0$, where k is a constant to be found.

(6)

WME01/01 JANUARY 2020

Question 7

18 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

7.

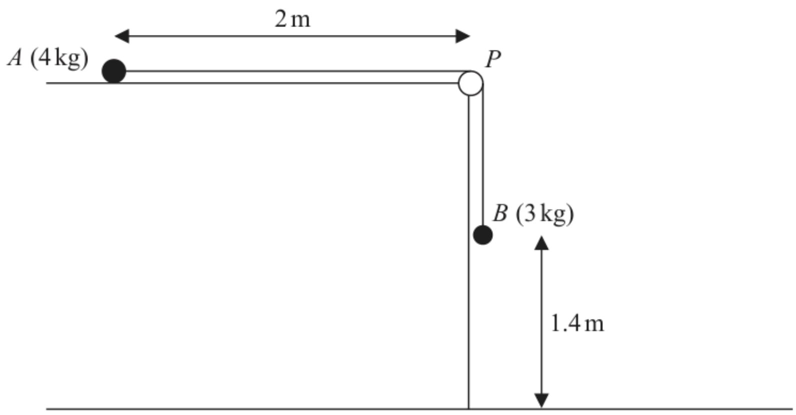


Figure 3

A particle A of mass 4 kg is held at rest on a rough horizontal table. Particle A is attached to one end of a string that passes over a pulley P. The pulley is fixed at the edge of the table. The other end of the string is attached to a particle B, of mass 3 kg, which hangs freely below P.

The part of the string from A to P is perpendicular to the edge of the table and A, P and B all lie in the same vertical plane.

The string is modelled as being light and inextensible and the pulley is modelled as being small, smooth and light.

The system is released from rest with the string taut. At the instant of release, A is 2 m from the edge of the table and B is 1.4 m above a horizontal floor, as shown in Figure 3.

After descending with constant acceleration for 2 seconds, B hits the floor and does not rebound.

(a) Show that the acceleration of A before B hits the floor is $0.7\,\text{m}\,\text{s}^{-2}$

(2)

(b) State which of the modelling assumptions you have used in order to answer part (a).

(1)

(c) Find the magnitude of the resultant force exerted on the pulley by the string.

(4)

The coefficient of friction between A and the table is μ.

(d) Find the value of μ.

(6)

(e) Determine, by calculation, whether or not A reaches the pulley.

(5)

(Total 18 marks)

WME01/01 JANUARY 2021

Question 3

9 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Forces

3.

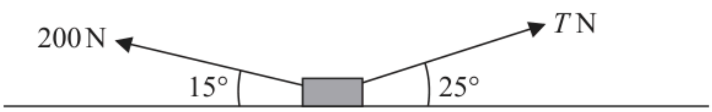


Figure 1

A parcel of mass 20 kg is at rest on a rough horizontal floor. The coefficient of friction between the parcel and the floor is 0.3

Two forces, both acting in the same vertical plane, of magnitudes 200 N and T N are applied to the parcel. The line of action of the 200 N force makes an angle of 15° with the horizontal and the line of action of the T N force makes an angle of 25° with the horizontal, as shown in Figure 1. The parcel is modelled as a particle P.

Find the smallest value of T for which P remains in equilibrium.

(9)

WME01/01 JANUARY 2021

Question 4

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

4.

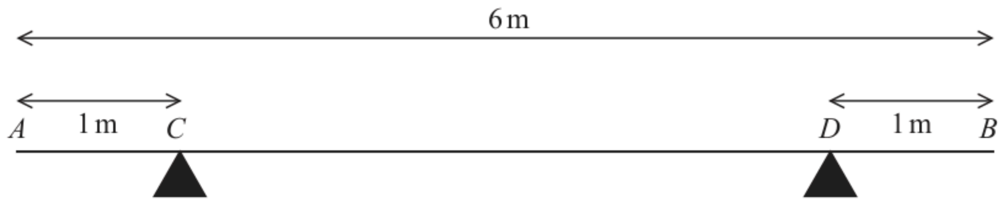


Figure 2

A metal girder AB has weight W newtons and length 6 m. The girder rests in a horizontal position on two supports C and D where $AC = DB = 1$ m, as shown in Figure 2.

When a force of magnitude 900 N is applied vertically upwards to the girder at A, the girder is about to tilt about D.

When a force of magnitude 1500 N is applied vertically upwards to the girder at B, the girder is about to tilt about C.

The girder is modelled as a non-uniform rod whose centre of mass is a distance x metres from A.

Find the value of x.

(6)

WME01/01 JANUARY 2021

Question 7

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

7. A helicopter is hovering at rest above horizontal ground at the point H. A parachutist steps out of the helicopter and immediately falls vertically and freely under gravity from rest for 2.5 s. His parachute then opens and causes him to immediately decelerate at a constant rate of $3.9\,\text{m}\,\text{s}^{-2}$ for T seconds ($T < 6$), until his speed is reduced to $V\,\text{m}\,\text{s}^{-1}$. He then moves with this constant speed $V\,\text{m}\,\text{s}^{-1}$ until he hits the ground. While he is decelerating, he falls a distance of 73.75 m. The total time between the instant when he leaves H and the instant when he hits the ground is 20 s.

The parachutist is modelled as a particle.

(a) Find the speed of the parachutist at the instant when his parachute opens.

(1)

(b) Sketch a speed-time graph for the motion of the parachutist from the instant when he leaves H to the instant when he hits the ground.

(2)

(c) Find the value of T.

(5)

(d) Find, to the nearest metre, the height of the point H above the ground.

(4)

17 marks

WME01/01 JANUARY 2021

Constant Acceleration in 1D

Question 8

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

8.

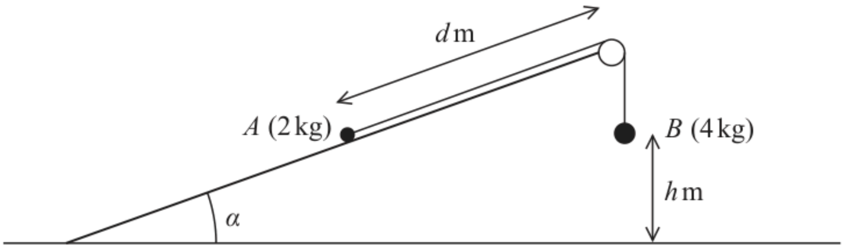


Figure 3

Two particles, A and B, have masses 2 kg and 4 kg respectively. The particles are connected by a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a rough plane. The plane is inclined to the horizontal ground at an angle α where $\tan\alpha = \frac{3}{4}$. The particle A is held at rest on the plane at a distance d metres from the pulley. The particle B hangs freely at rest, vertically below the pulley, at a distance h metres above the ground, as shown in Figure 3. The part of the string between A and the pulley is parallel to a line of greatest slope of the plane. The coefficient of friction between A and the plane is $\frac{1}{4}$

The system is released from rest with the string taut and B descends.

(a) Find the tension in the string as B descends.

(9)

On hitting the ground, B immediately comes to rest.

Given that A comes to rest before reaching the pulley,

(b) find, in terms of h, the range of possible values of d.

(7)

(c) State one physical factor, other than air resistance, that could be taken into account to make the model described above more realistic.

(1)

(Total 17 marks)

WME01/01 MAY/JUNE 2021

Question 4

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

4.

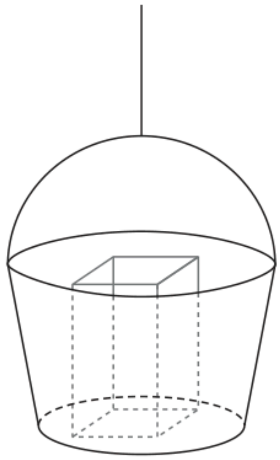


Figure 1

Figure 1 shows a large bucket used by a crane on a building site to move materials between the ground and the top of the building. The mass of the bucket is 15 kg.

The bucket is attached to a vertical cable with the bottom of the bucket horizontal. The cable is modelled as light and inextensible.

When the bucket is on the ground, a bag of cement of mass 25 kg is placed in the bucket.

The bucket with the bag of cement moves vertically upwards with constant acceleration $0.2\,\mathrm{m\,s^{-2}}$. Air resistance is modelled as being negligible.

(a) Find the tension in the cable.

(3)

At the top of the building, the bag of cement is removed. A box of tools of mass 12 kg is now placed in the bucket.

Later on the bucket with the box of tools is moving vertically downwards with constant deceleration $0.1\,\mathrm{m\,s^{-2}}$. Air resistance is again modelled as being negligible.

(b) Find the magnitude of the normal reaction between the bucket and the box of tools.

(3)

WME01/01 MAY/JUNE 2021

Question 6

13 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

6. A fixed rough plane is inclined at an angle θ to the horizontal, where $\tan\theta = \frac{5}{12}$

A particle of mass 6 kg is projected with speed $5\ \mathrm{m\,s^{-1}}$ from a point A on the plane, up a line of greatest slope of the plane.

The coefficient of friction between the particle and the plane is $\frac{1}{4}$

(a) Find the magnitude of the frictional force acting on the particle as it moves up the plane.

(3)

The particle comes to instantaneous rest at the point B.

(b) Find the distance AB.

(5)

The particle now slides down the plane from B. At the instant when the particle passes through the point C on the plane, the speed of the particle is again $5\ \mathrm{m\,s^{-1}}$

(c) Find the distance BC.

(5)

WME01/01 MAY/JUNE 2021

Question 7

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

7.

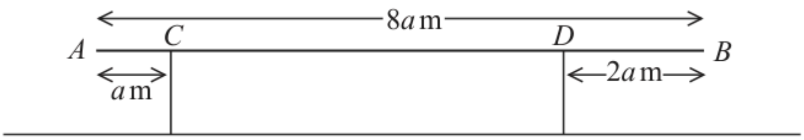


Figure 2

A non-uniform beam AB, of mass 60 kg and length $8a$ metres, rests in equilibrium in a horizontal position on two vertical supports. One support is at C, where $AC = a$ metres and the other support is at D, where $DB = 2a$ metres, as shown in Figure 2.

The magnitude of the normal reaction between the beam and the support at D is three times the magnitude of the normal reaction between the beam and the support at C.

By modelling the beam as a non-uniform rod whose centre of mass is at a distance x metres from A,

(a) find an expression for x in terms of a.

(5)

A box of mass M kg is placed on the beam at E, where $AE = 2a$ metres.

The beam remains in equilibrium in a horizontal position.

The magnitude of the normal reaction between the beam and the support at C is now equal to the magnitude of the normal reaction between the beam and the support at D.

By modelling the box as a particle,

(b) find the value of M.

(5)

Question 8

13 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

8. Two trams, tram A and tram B, run on parallel straight horizontal tracks. Initially the two trams are at rest in the depot and level with each other.

At time $t = 0$, tram A starts to move. Tram A moves with constant acceleration $2\,\text{m s}^{-2}$ for 5 seconds and then continues to move along the track at constant speed.

At time $t = 20$ seconds, tram B starts from rest and moves in the same direction as tram A. Tram B moves with constant acceleration $3\,\text{m s}^{-2}$ for 4 seconds and then continues to move along the track at constant speed.

The trams are modelled as particles.

(a) Sketch, on the same axes, a speed-time graph for the motion of tram A and a speed-time graph for the motion of tram B, from $t = 0$ to the instant when tram B overtakes tram A.

(3)

At the instant when the two trams are moving with the same speed, tram A is d metres in front of tram B.

(b) Find the value of d.

(5)

(c) Find the distance of the trams from the depot at the instant when tram B overtakes tram A.

(5)

(Total 13 marks)

10 marks

WME01/01 OCTOBER 2021

Constant Acceleration in 1D

Question 2

Also in Constant Acceleration in 1D

Primary: Momentum, Impulse & Collisions

2. A particle P of mass $2m$ is moving on a rough horizontal plane when it collides directly with a particle Q of mass $4m$ which is at rest on the plane. The speed of P immediately before the collision is $3u$. The speed of Q immediately after the collision is $2u$.

(a) Find, in terms of u, the speed of P immediately after the collision.

(3)

(b) State clearly the direction of motion of P immediately after the collision.

(1)

Following the collision, Q comes to rest after travelling a distance $\frac{6u^2}{g}$ along the plane.

The coefficient of friction between Q and the plane is μ.

(c) Find the value of μ.

(6)

WME01/01 OCTOBER 2021

Question 4

8 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Working with Vectors

4. The position vector, $\mathbf{r}$ metres, of a particle P at time t seconds, relative to a fixed origin O, is given by

$$\mathbf{r} = (t - 3)\mathbf{i} + (1 - 2t)\mathbf{j}$$

(a) Find, to the nearest degree, the size of the angle between $\mathbf{r}$ and the vector $\mathbf{j}$, when $t = 2$ **(3)**

(b) Find the values of t for which the distance of P from O is 2.5 m. **(5)**

WME01/01 OCTOBER 2021

Question 5

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Forces

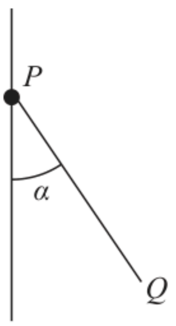


Figure 2

A small bead of mass 0.2 kg is attached to the end P of a light rod PQ. The bead is threaded onto a fixed vertical rough wire.

The bead is held in equilibrium with the rod PQ inclined to the wire at an angle α, where $\tan\alpha = \frac{4}{3}$, as shown in Figure 2.

The thrust in the rod is T newtons.

The bead is modelled as a particle.

(a) Find the magnitude and direction of the friction force acting on the bead when $T = 2.5$

(3)

The coefficient of friction between the bead and the wire is μ.

Given that the greatest possible value of T is 6.125

(b) find the value of μ.

(7)

WME01/01 JANUARY 2022

Question 1

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Forces

1.

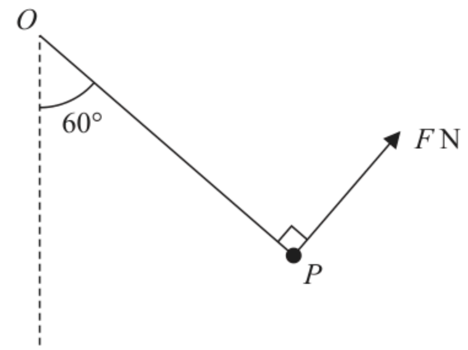


Figure 1

A particle P of weight 5 N is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point O. The particle P is held in equilibrium by a force of magnitude F newtons. The direction of this force is perpendicular to the string and OP makes an angle of 60° with the vertical, as shown in Figure 1.

Find

(a) the value of F

(3)

(b) the tension in the string.

(3)

WME01/01 MAY/JUNE 2022

Question 7

13 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

7. Two small children, Ajaz and Beth, are running a 100 m race along a straight horizontal track.

They both start from rest, leaving the start line at the same time.

Ajaz accelerates at $0.8\,\text{m}\,\text{s}^{-2}$ up to a speed of $4\,\text{m}\,\text{s}^{-1}$ and then maintains this speed until he crosses the finish line.

Beth accelerates at $1\,\text{m}\,\text{s}^{-2}$ for T seconds and then maintains a constant speed until she crosses the finish line.

Ajaz and Beth cross the finish line at the same time.

(a) Sketch, on the same axes, a speed-time graph for each child, from the instant when they leave the start line to the instant when they cross the finish line.

(3)

(b) Find the time taken by Ajaz to complete the race.

(4)

(c) Find the value of T

(4)

(d) Find the difference in the speeds of the two children as they cross the finish line.

(2)

WME01/01 OCTOBER 2022

Question 2

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

Figure 1

A uniform rod AB has length $2a$ and mass M. The rod is held in equilibrium in a horizontal position by two vertical light strings which are attached to the rod at C and D, where $AC = \frac{2}{5}a$ and $DB = \frac{3}{5}a$, as shown in Figure 1.

A particle P is placed on the rod at B.

The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the largest possible mass of the particle P

(3)

Given that the mass of P is $\frac{1}{2}M$

(b) find, in terms of M and g, the tension in the string that is attached to the rod at C.

(3)

WME01/01 OCTOBER 2022

Question 4

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

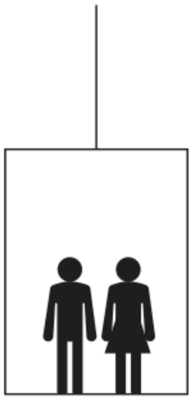


Figure 3

Two children, Alan and Bhavana, are standing on the horizontal floor of a lift, as shown in Figure 3.

The lift has mass 250 kg. The lift is raised vertically upwards with constant acceleration by a vertical cable which is attached to the top of the lift. The cable is modelled as being light and inextensible. While the lift is accelerating upwards, the tension in the cable is 3616 N.

As the lift accelerates upwards, the floor of the lift exerts a force of magnitude 565 N on Alan and a force of magnitude 226 N on Bhavana.

Air resistance is modelled as being negligible and Alan and Bhavana are modelled as particles.

(a) By considering the forces acting on the lift only, find the acceleration of the lift.

(3)

(b) Find the mass of Alan.

(3)

WME01/01 JANUARY 2023

Question 1

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

1. A train travels along a straight horizontal track between two stations A and B.

The train starts from rest at station A and accelerates uniformly for T seconds until it reaches a speed of $20\,\text{m s}^{-1}$

The train then travels at a constant speed of $20\,\text{m s}^{-1}$ for 3 minutes before decelerating uniformly until it comes to rest at station B.

The magnitude of the acceleration of the train is twice the magnitude of the deceleration.

(a) On the axes below, sketch a speed–time graph to illustrate the motion of the train as it moves from station A to station B.

If you need to redraw your graph, use the axes on page 3

(3)

Stations A and B are 4.8 km apart.

(b) Find the value of T

(5)

(c) Find the acceleration of the train during the first T seconds of its motion.

(2)

Only use these axes if you need to redraw your graph.

(Total for Question 1 is 10 marks)

WME01/01 JANUARY 2023

Question 4

8 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

4.

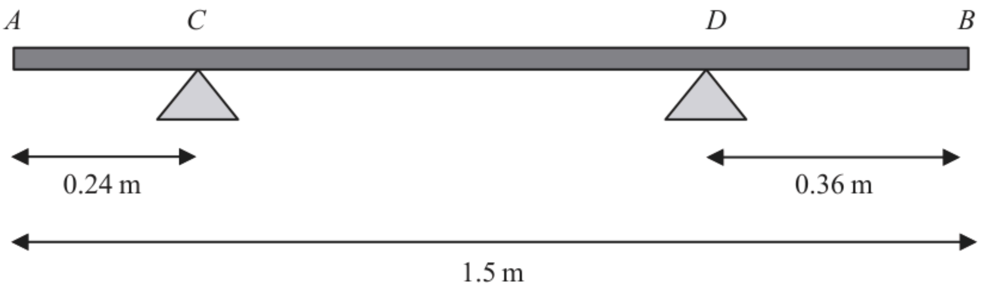


Figure 1

A branch AB, of length 1.5 m, rests horizontally in equilibrium on two supports.

The two supports are at the points C and D, where $AC = 0.24\,\text{m}$ and $DB = 0.36\,\text{m}$, as shown in Figure 1.

When a force of 150 N is applied vertically upwards at B, the branch is on the point of tilting about C.

When a force of 225 N is applied vertically downwards at B, the branch is on the point of tilting about D.

The branch is modelled as a non-uniform rod AB of weight W newtons.

The distance from the point C to the centre of mass of the rod is x metres.

Use the model to find

(i) the value of W

(ii) the value of x

(8)

WME01/01 JANUARY 2023

Question 7

7 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

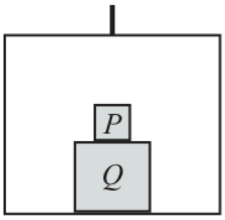


Figure 4

A simple lift operates by means of a vertical cable which is attached to the top of the lift.
The lift has mass m
A box Q is placed on the floor of the lift.
A box P is placed directly on top of box Q, as shown in Figure 4.

The cable is modelled as being light and inextensible and air resistance is modelled as being negligible.

The tension in the cable is $\frac{42mg}{5}$

The lift and its contents move vertically upwards with acceleration $\frac{2g}{5}$

Using the model,

(a) find, in terms of m, the combined mass of boxes P and Q

(4)

During the motion of the lift, the force exerted on box P by box Q is $\frac{14mg}{5}$

Using the model,

(b) find, in terms of m, the mass of box P

(3)

WME01/01 JANUARY 2023

Question 8

15 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

8.

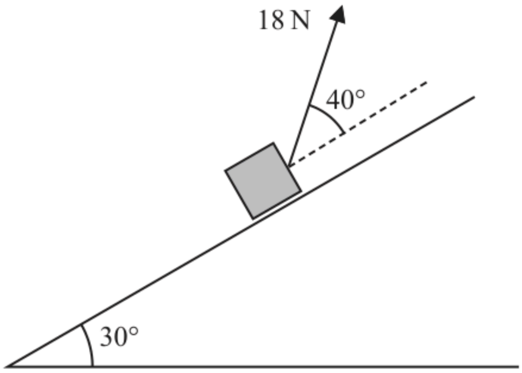


Figure 5

A parcel of mass 2 kg is pulled up a rough inclined plane by the action of a constant force.

The force has magnitude 18 N and acts at an angle of 40° to the plane.

The line of action of the force lies in a vertical plane containing a line of greatest slope of the inclined plane.

The plane is inclined at an angle of 30° to the horizontal, as shown in Figure 5.

The coefficient of friction between the plane and the parcel is 0.3

The parcel is modelled as a particle P

(a) Find the acceleration of P

(8)

The points A and B lie on a line of greatest slope of the plane, where $AB = 5\,\text{m}$ and B is above A. Particle P passes through A with speed $2\,\text{m}\,\text{s}^{-1}$ in the direction AB.

(b) Find the speed of P as it passes through B.

(3)

The force of 18 N is removed at the instant P passes through B. As a result, P comes to rest at the point C.

(c) Determine whether P will remain at rest at C. You must show all stages of your working clearly.

(4)

WME01/01 MAY/JUNE 2023

Question 4

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

4.

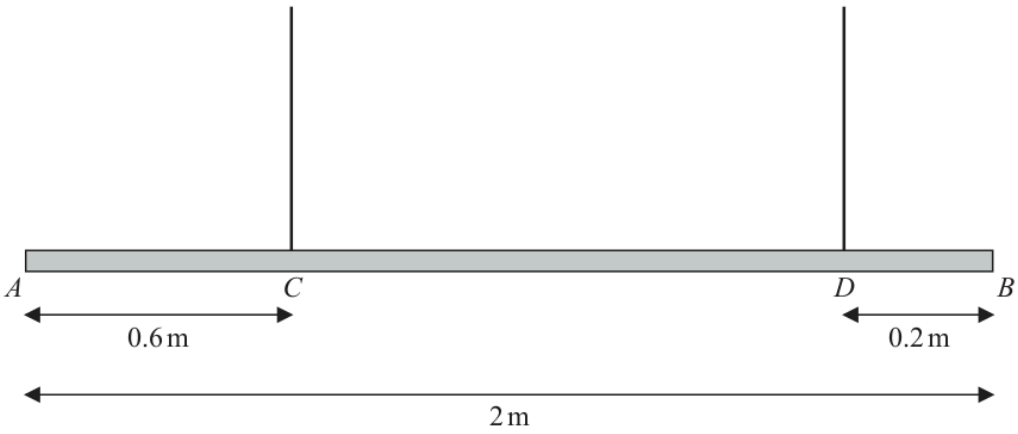


Figure 1

Figure 1 shows a beam AB, of mass m kg and length 2 m, suspended by two light vertical ropes.
The ropes are attached to the points C and D on the beam, where $AC = 0.6$ m and $DB = 0.2$ m
The beam is in equilibrium in a horizontal position.

A particle of mass pm kg is attached to the beam at A and the beam remains in equilibrium in a horizontal position.

The beam is modelled as a uniform rod.

(a) Given that the tension in the rope attached at C is four times the tension in the rope attached at D, use the model to find the exact value of p.

(7)

The particle of mass pm kg at A is removed and replaced by a particle of mass qm kg at A.
The beam remains in equilibrium in a horizontal position but is now on the point of tilting.

(b) Using the model, find the exact value of q

(4)

(c) State how you have used the modelling assumption that the beam is uniform.

(1)

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Question 5

11 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

5.

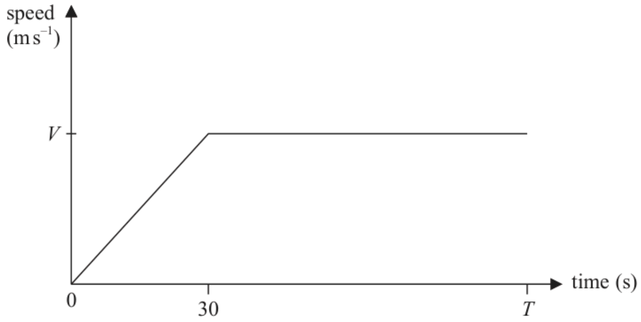


Figure 2

The speed-time graph in Figure 2 illustrates the motion of a car travelling along a straight horizontal road.
At time $t = 0$, the car starts from rest and accelerates uniformly for 30 s until it reaches a speed of $V \text{ m s}^{-1}$
The car then travels at a constant speed of $V \text{ m s}^{-1}$ until time $t = T$ seconds.

(a) Show that the distance travelled by the car between $t = 0$ and $t = T$ seconds is $V(T - 15)$ metres.

(2)

A motorbike also travels along the same road.

- The motorbike starts from rest at time $\boldsymbol{t} = \mathbf{10}$ **s** and accelerates uniformly for 40 s
- The acceleration of the motorbike is the **same** as the acceleration of the car
- The motorbike then travels at a constant speed for a further 10 s before decelerating uniformly until it reaches a speed of $V \text{ m s}^{-1}$ at time T seconds

(b) On Figure 2, sketch a speed-time graph for the motion of the motorbike.

[*If you need to redraw your sketch, there is a copy of Figure 2 on page 15.*]

(2)

(c) Show that the constant speed of the motorbike is $\frac{4V}{3} \text{ m s}^{-1}$

(2)

At time $t = T$ seconds, the distance travelled by each vehicle is the same.

(d) Find the value of T

(5)

Only use this copy of Figure 2 if you need to redraw your sketch.

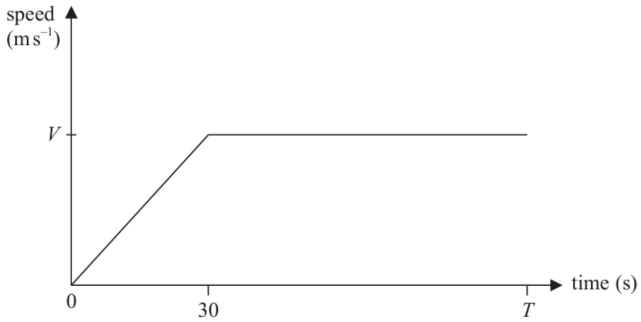


Figure 2

(Total for Question 5 is 11 marks)

WME01/01 MAY/JUNE 2023

Question 7

11 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

7.

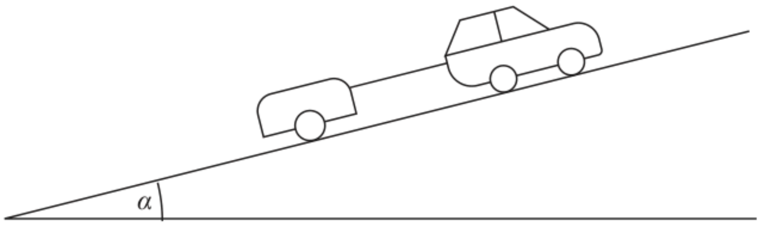


Figure 4

A car of mass 1200 kg is towing a trailer of mass 600 kg up a straight road, as shown in Figure 4.

The road is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{12}$

The driving force produced by the engine of the car is 3000 N.

The car moves with acceleration $0.75\,\text{m}\,\text{s}^{-2}$

The non-gravitational resistance to motion of

- the **car** is modelled as a constant force of magnitude $2R$ newtons
- the **trailer** is modelled as a constant force of magnitude R newtons

The car and the trailer are modelled as particles.
The tow bar between the car and trailer is modelled as a light rod that is parallel to the direction of motion.

Using the model,

(a) show that the value of R is 60

(4)

(b) find the tension in the tow bar.

(3)

When the car and trailer are moving at a speed of $12\,\text{m}\,\text{s}^{-1}$, the tow bar breaks.

Given that the non-gravitational resistance to motion of the trailer remains unchanged,

(c) use the model to find the further distance moved by the trailer before it first comes to rest.

(4)

WME01/01 OCTOBER 2023

Question 1

5 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

1.

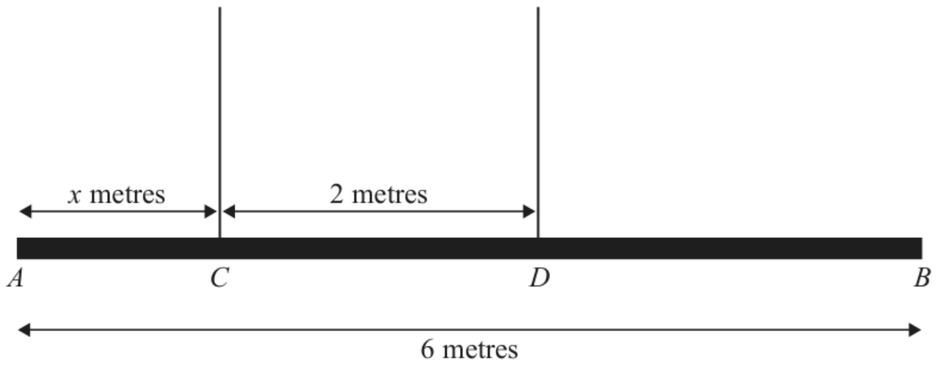


Figure 1

Figure 1 shows a beam AB with weight 24 N and length 6 m.

The beam is suspended by two light vertical ropes. The ropes are attached to the points C and D on the beam where $AC = x$ metres and $CD = 2$ m.

The tension in the rope attached to the beam at C is double the tension in the rope attached to the beam at D.

The beam is modelled as a uniform rod, resting horizontally in equilibrium.

Find

(i) the tension in the rope attached to the beam at D.

(ii) the value of x.

(5)

WME01/01 OCTOBER 2023

Question 2

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

2.

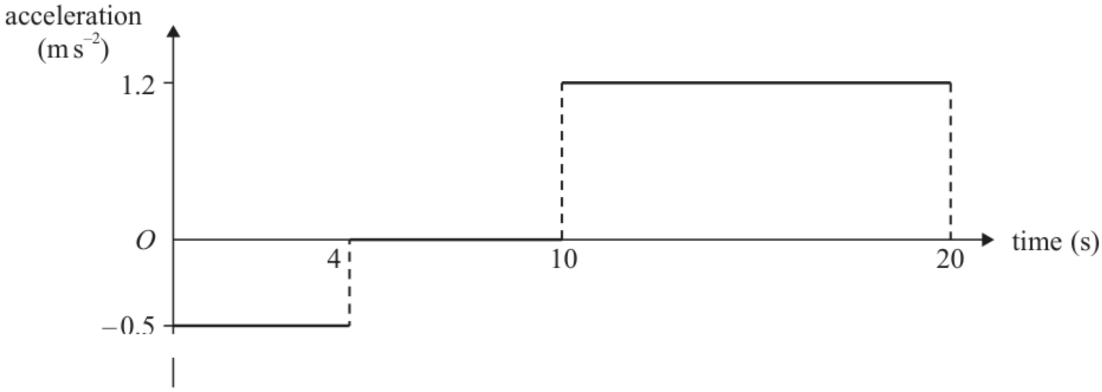


Figure 2

Two fixed points, A and B, are on a straight horizontal road.

The **acceleration-time** graph in Figure 2 represents the motion of a car travelling along the road as it moves from A to B.

At time $t = 0$, the car passes through A with speed $8\,\text{m}\,\text{s}^{-1}$

At time $t = 20\,\text{s}$, the car passes through B with speed $v\,\text{m}\,\text{s}^{-1}$

(a) Show that $v = 18$

(3)

(b) Sketch a speed-time graph for the motion of the car from A to B.

(3)

(c) Find the distance AB.

(4)

10 marks

WME01/01 OCTOBER 2023

Constant Acceleration in 1D

Question 3

Also in Constant Acceleration in 1D

Primary: Momentum, Impulse & Collisions

3. A hammer is used to hit a tent peg into soft ground.

The hammer has mass 1.8 kg and the tent peg has mass 0.2 kg.

The hammer and tent peg are both modelled as particles and the impact is modelled as a direct collision.

Immediately before the impact, the tent peg is stationary and the hammer is moving vertically downwards with speed $10\,\text{m s}^{-1}$

Immediately after the impact, the hammer and tent peg move together, vertically downwards, with the **same** speed $v\,\text{m s}^{-1}$

(a) Find the value of v

(2)

(b) Find the magnitude of the impulse exerted on the tent peg by the hammer, stating the units of your answer.

(3)

The ground exerts a constant vertical resistive force of magnitude R newtons, bringing the hammer and tent peg to rest after they travel a distance of 12 cm.

(c) Find the value of R.

(5)

WME01/01 JANUARY 2024

Question 1

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Forces

1.

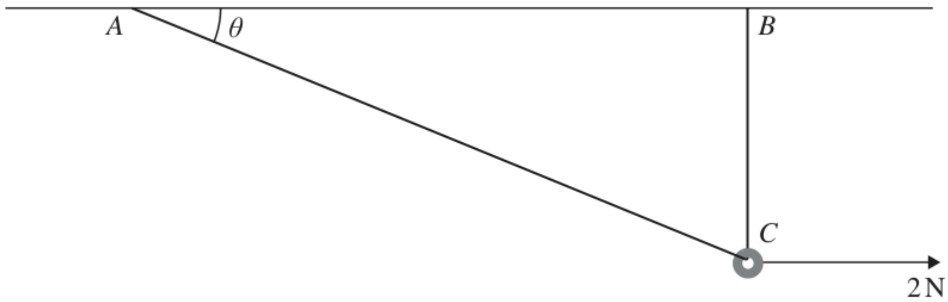


Figure 1

Figure 1 shows a small smooth ring **threaded** onto a light inextensible string.

One end of the string is attached to a fixed point A on a horizontal ceiling and the other end of the string is attached to a fixed point B on the ceiling.

A horizontal force of magnitude 2 N acts on the ring so that the ring rests in equilibrium at a point C, vertically below B, with the string taut.

The line of action of the horizontal force and the string both lie in the same vertical plane.

The angle that the string makes with the ceiling at A is θ, where $\tan\theta = \frac{3}{4}$

The tension in the string is T newtons. The mass of the ring is M kg.

(a) Find the value of T

(3)

(b) Find the value of M

(3)

WME01/01 JANUARY 2024

Question 8

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

8.

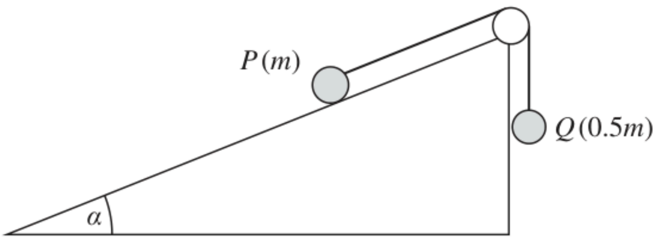


Figure 5

A fixed rough plane is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{5}{12}$

A small smooth pulley is fixed at the top of the plane.

One end of a light inextensible string is attached to a particle P which is at rest on the plane. The string passes over the pulley and the other end of the string is attached to a particle Q which hangs vertically below the pulley, as shown in Figure 5.

Particle P has mass m and particle Q has mass $0.5m$

The string from P to the pulley lies along a line of greatest slope of the plane.

The coefficient of friction between P and the plane is μ.

The system is in **limiting equilibrium** with the string taut and P is on the point of slipping **up** the plane.

(a) Find the value of μ.

(8)

The string breaks and P begins to move down the plane.

When particle P has travelled a distance of 0.8 m down the plane, the speed of P is $V\,\text{m s}^{-1}$

(b) Find the value of V.

(4)

WME01/01 MAY/JUNE 2024

Question 3

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

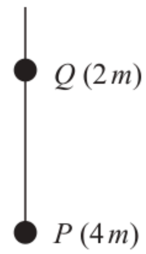


Figure 1

Two particles, P and Q, have masses $4m$ and $2m$ respectively. The particles are connected by a light inextensible string. A second light inextensible string has one end attached to Q. Both strings are taut and vertical, as shown in Figure 1.

The particles are **accelerating** vertically **downwards**.

Given that the tension in the string connecting the two particles is $3mg$, find, in terms of m and g, the tension in the upper string.

(6)

WME01/01 MAY/JUNE 2024

Question 6

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

6.

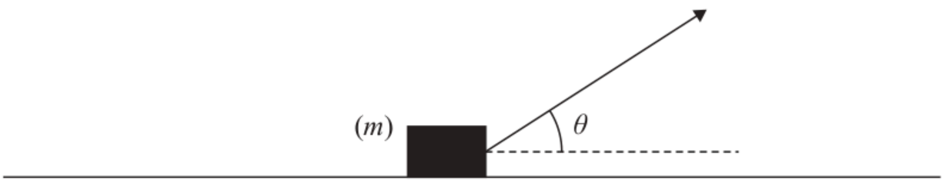


Figure 3

A box of mass m lies on a rough horizontal plane. The box is pulled along the plane in a straight line at **constant speed** by a light rope. The rope is inclined at an angle θ to the plane, as shown in Figure 3.

The coefficient of friction between the box and the plane is $\frac{1}{3}$

The box is modelled as a particle.

Given that $\tan\theta = \frac{3}{4}$

(a) find, in terms of m and g, the tension in the rope.

(7)

The rope is now removed and the box is placed at rest on the plane.
The box is then projected horizontally along the plane with speed u.

The box is again modelled as a particle.

When the box has moved a distance d along the plane, the speed of the box is $\frac{1}{2}u$.

(b) Find d in terms of u and g.

(5)

WME01/01 OCTOBER 2024

Question 4

13 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

4. The points A and B lie on the same straight horizontal road.

Figure 2, on page 11, shows the speed-time graph of a cyclist P, for his journey from A to B.
At time $t = 0$, P starts from rest at A and accelerates uniformly for 9 seconds until his speed is $V\,\mathrm{m\,s^{-1}}$

He then travels at constant speed $V\,\mathrm{m\,s^{-1}}$

When $t = 42$, cyclist P passes B.

Given that the distance AB is 120 m,

(a) show that $V = 3.2$

(3)

(b) Find the acceleration of cyclist P between $t = 0$ and $t = 9$

(2)

Cyclist P continues to cycle along the road in the same direction at the same constant speed, $V\,\mathrm{m\,s^{-1}}$

When $t = 6$, a second cyclist Q sets off from A and travels in the same direction as P along the same road. She accelerates for T seconds until her speed is $3.6\,\mathrm{m\,s^{-1}}$

She then travels at constant speed $3.6\,\mathrm{m\,s^{-1}}$

Cyclist Q catches up with P when $t = 54$

(c) On Figure 2, on page 11, sketch a speed-time graph showing the journeys of **both** cyclists, for the interval $0 \leqslant t \leqslant 54$

(3)

(d) Find the value of T

(5)

Question 4 continued

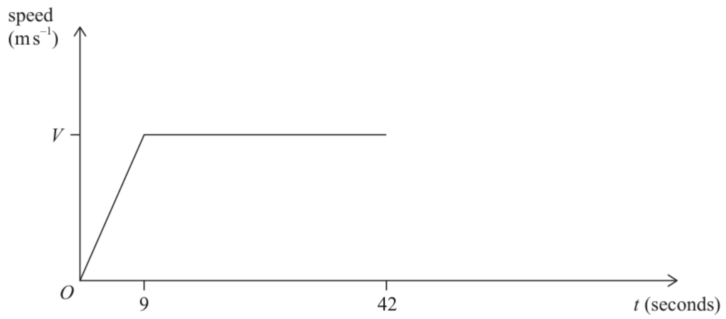
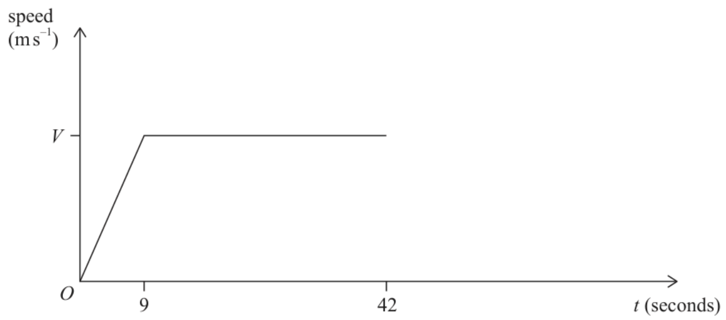


Figure 2

A copy of Figure 2 is on page 13 if you need to redraw your answer to part (c).

Question 4 continued

Only use this copy of Figure 2 if you need to redraw your answer to part (c).



Copy of Figure 2

WME01/01 OCTOBER 2024

Question 5

13 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

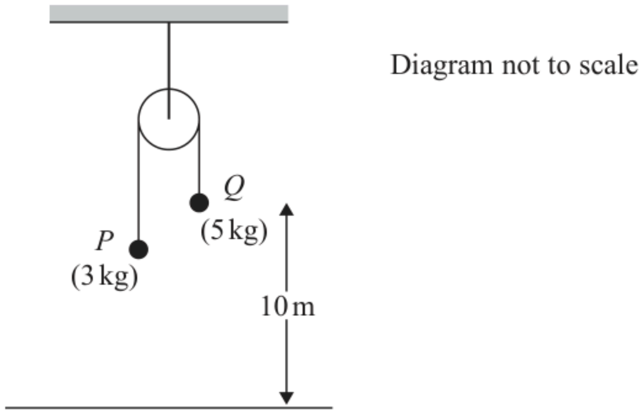


Figure 3

Two particles, P and Q, have masses 3 kg and 5 kg respectively. The particles are connected by a light inextensible string which passes over a small smooth fixed pulley.

The particles are released from rest with the string taut and the hanging parts of the string vertical, as shown in Figure 3.

Immediately after the particles are released from rest, P moves upwards with acceleration $a\,\text{m s}^{-2}$ and the tension in the string is T newtons.

(a) Write down an equation of motion for P.

(2)

(b) Find the value of T.

(4)

The total force acting on the pulley due to the string has magnitude F newtons.

(c) Find the value of F.

(2)

Initially, Q is 10 m above horizontal ground and P is more than 2 m below the pulley.

At the instant when Q has descended a distance of 2 m, the string breaks and Q falls to the ground.

(d) Find the speed of Q at the instant it hits the ground.

(5)

WME01/01 OCTOBER 2024

Question 6

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

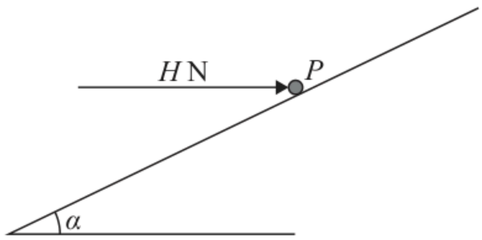


Figure 4

A particle P of mass 5 kg lies on the surface of a rough plane.

The plane is inclined at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$

The particle is held in equilibrium by a horizontal force of magnitude H newtons, as shown in Figure 4.

The horizontal force acts in a vertical plane containing a line of greatest slope of the inclined plane.

The coefficient of friction between the particle and the plane is $\frac{1}{4}$

(a) Find the smallest possible value of H.

(6)

The horizontal force is now removed, and P starts to slide down the slope.

In the first T seconds after P is released from rest, P slides 1.5 m down the slope.

(b) Find the value of T.

(6)

WME01/01 JANUARY 2025

Question 2

11 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

2. The fixed points A, B and C lie in a straight line on a horizontal road.

- At time $t = 0$, a motorbike passes through A with speed $5\,\text{m s}^{-1}$
- From A, the motorbike accelerates uniformly until it reaches B with a speed of $V\,\text{m s}^{-1}$
- The motorbike takes T_1 seconds to travel from A to B
- From B, the motorbike decelerates uniformly until it comes to rest at C
- The motorbike takes T_2 seconds to travel from B to C

(a) Sketch a speed-time graph for the motion of the motorbike as it moves from A to C.

(3)

The distance AB is 132 m and the distance BC is 136 m.

(b) Find, in terms of V, an expression for

(i) T_1

(ii) T_2

(4)

Given that the motorbike takes 28 s to travel from A to C,

(c) find the value of V,

(2)

(d) find the deceleration of the motorbike.

(2)

WME01/01 JANUARY 2025

Question 3

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Momentum, Impulse & Collisions

3.

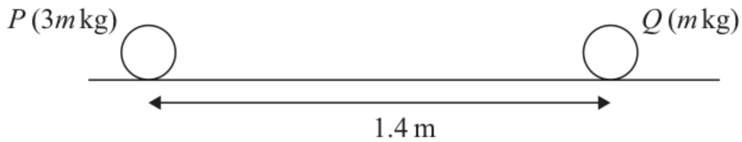


Figure 1

A particle P of mass $3m$ kg and a particle Q of mass m kg are at rest on a rough horizontal surface. The distance between P and Q is 1.4 m, as shown in Figure 1.

An impulse of magnitude λ N s is now applied to P in the direction PQ. Immediately after the impulse is applied, the speed of P is $5\,\text{m s}^{-1}$

(a) Find λ in terms of m.

(2)

Immediately before P collides with Q, the speed of P is $2.5\,\text{m s}^{-1}$
The coefficient of friction between P and the surface is μ

(b) Find the value of μ

(7)

Immediately after P collides with Q, the speed of Q is $2.1\,\text{m s}^{-1}$

(c) Find the speed of P immediately after the collision.

(3)

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Question 4

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

4.

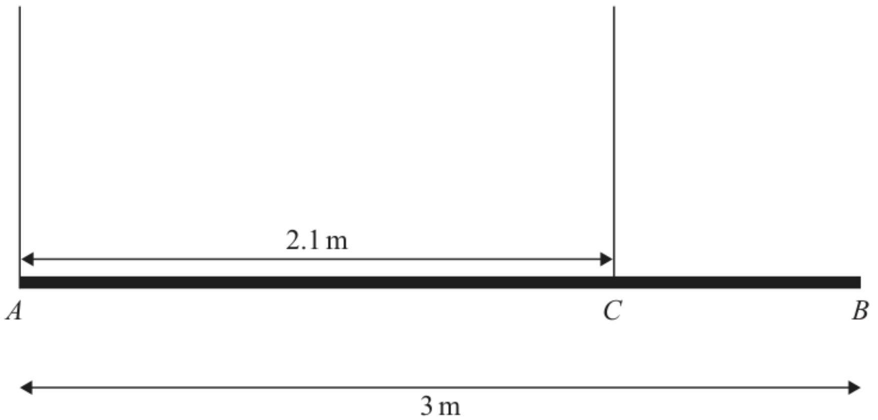

Figure 2

A uniform rod AB has length 3 m and weight W newtons.
The rod is suspended by two light vertical ropes.
One rope is attached to the rod at A and the other rope is attached to the rod at C, where $AC = 2.1$ m.

The rod is in equilibrium in a horizontal position, as shown in Figure 2.

The tension in the rope at C is 350 N.

(a) Show that $W = 490$

(3)

A particle P of weight 210 N is attached to the rod at a distance d metres from A.
The tension in the rope at C is now 600 N.
The rod remains in equilibrium in a horizontal position.

(b) Find the value of d.

(3)

Particle P is removed from the rod.
A particle Q of weight X newtons is now attached at B.
The rod remains in equilibrium in a horizontal position and is now on the point of tilting.

(c) Find the value of X.

(4)

WME01/01 JANUARY 2025

Question 5

7 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Working with Vectors

5. [*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors and position vectors are given relative to a fixed origin.*]

In a game, a ball B is rolled across a horizontal surface towards a fixed target.
The ball is modelled as a particle moving with constant velocity.

At time $t = 1$ s, the position vector of B is $(-2\mathbf{i} + 5\mathbf{j})$ m.
At time $t = 9$ s, the position vector of B is $(10\mathbf{i} - 3\mathbf{j})$ m.

(a) Find the velocity of the ball.

(3)

The position vector of the target is $(13\mathbf{i} - 5\mathbf{j})$ m.

(b) Use the model to find the distance of B from the target at time $t = 7$ s.

(4)

WME01/01 JANUARY 2025

Question 7

15 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Newton's Second Law

7.

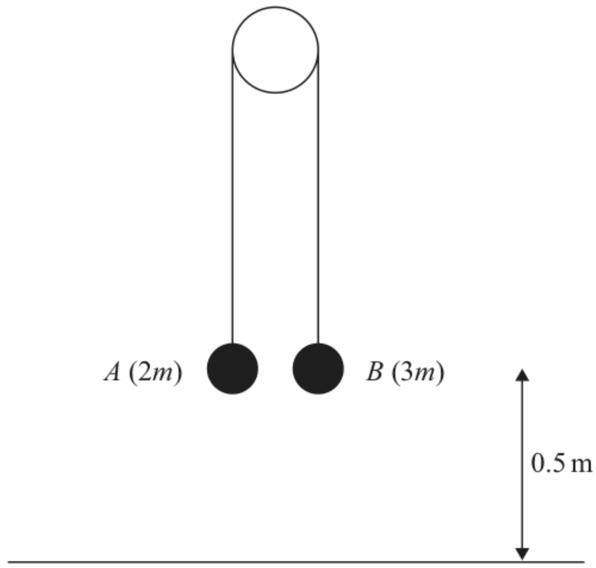

Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$.
The other end is attached to a particle B of mass $3m$.
The string passes over a small smooth fixed pulley.
The string is taut and both straight parts of the string are vertical.
Both particles are held at a distance 0.5 m above a horizontal surface, as shown in Figure 4.

The system is released from rest and B moves downwards.

(a) Find the tension in the string in terms of m and g.

(5)

(b) Find the speed of B at the instant it strikes the surface.

(4)

In the subsequent motion, A does not reach the pulley and B does not rebound after it strikes the surface.

(c) Find the time from the instant when the system is released from rest to the instant when A first reaches a height of 1.06 m above the surface.

(6)

WME01/01 MAY/JUNE 2025

Question 5

6 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

5.

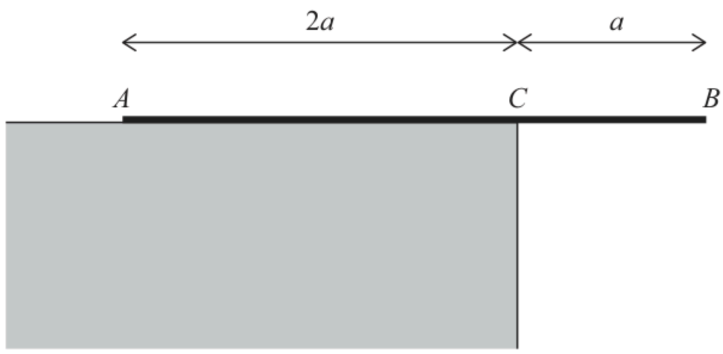

Figure 3

A non-uniform rod AB of length $3a$ rests in equilibrium on a horizontal ledge and overhangs the edge of the ledge at C.
The point C is such that $AC = 2a$ and $CB = a$, as shown in Figure 3.

The rod has weight W.

The distance of the centre of mass of the rod from A is d.

The rod is perpendicular to the edge of the ledge.

When a force of magnitude P, **acting vertically upwards**, is applied to the rod at B, the rod is on the point of tilting about A.

When the force applied at B is replaced by a force of magnitude $1.25P$, **acting vertically downwards** at B, the rod is on the point of tilting about C.

Find d in terms of a.

(6)

WME01/01 MAY/JUNE 2025

Question 6

11 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

6.

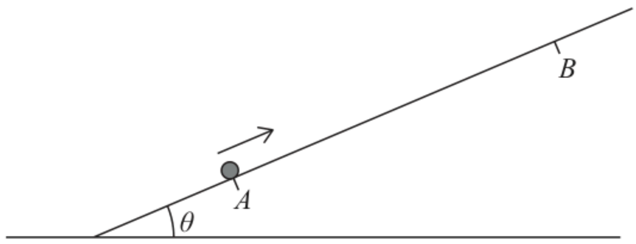

Figure 4

Figure 4 shows a rough plane inclined at an angle θ to the horizontal, where $\tan\theta = \frac{3}{4}$

The points A and B lie on a line of greatest slope of the plane, with B above A.

A package P of mass m is projected up the plane from A towards B.

The coefficient of friction between the plane and the package is $\frac{1}{4}$

The package P is modelled as a particle.

(a) Show that the **deceleration** of P, as it moves from A to B, is $\frac{4}{5}g$ **(6)**

The package P comes to rest at B.

Given that P is projected from A with speed $U\,\text{m s}^{-1}$ and that $AB = 1.5\,\text{m}$,

(b) find the value of U. **(2)**

On reaching B, P is held at rest there by a force of magnitude X newtons acting up the plane in the direction AB.

Given that the mass of P is 2 kg,

(c) find the smallest possible value of X. **(3)**

WME01/01 OCTOBER 2025

Question 1

7 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

1.

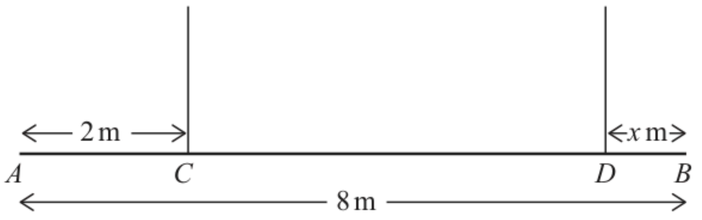

Figure 1

Figure 1 shows a sketch of a beam AB, with weight 240 N and length 8 m.

The beam is held in equilibrium in a horizontal position by two vertical ropes. The ropes are attached to the beam at the points C and D, where $AC = 2$ m and $DB = x$ metres.

The beam is modelled as a uniform rod and the ropes are modelled as light inextensible strings.

The tension in the rope at D is 90 N.

(a) Show that $x = \frac{2}{3}$

(3)

The rope at C will break if its tension exceeds 183 N. The rope at D cannot break. A package of weight W newtons is now attached to the beam at A. The beam remains horizontal and in equilibrium.

The package is modelled as a particle.

It is given that the rope at C does not break.

(b) Find the greatest possible value of W.

(4)

Question 4

9 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Constant Acceleration in 2D

4. The point A is 10 m above horizontal ground.
At time $t = 0$, a particle P is projected vertically upwards with speed $5\,\text{m s}^{-1}$ from A.
Particle P moves freely under gravity.

(a) Find the greatest height above A reached by P.

(3)

The point B is on the ground, vertically below A.
At time $t = 1$ second, a particle Q is projected vertically upwards with speed $7\,\text{m s}^{-1}$ from B.
Particle Q moves freely under gravity.

Particles P and Q collide at time $t = T$ seconds.

(b) Find the value of T.

(4)

(c) Find the speed of P at the instant immediately before the particles collide.

(2)

WME01/01 OCTOBER 2025

Question 5

13 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

5.

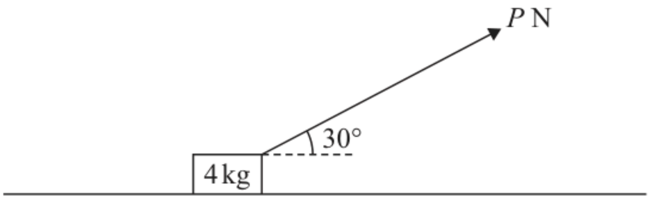

Figure 3

A box of mass 4 kg is placed on a rough horizontal surface.

A force of magnitude P newtons, acting at 30° to the horizontal, is applied to the box, as shown in Figure 3.

The coefficient of friction between the box and the surface is $\frac{2}{3}$

The box is modelled as a particle.

(a) Find the value of P when the box is on the point of sliding along the surface.

(6)

The value of P is now increased to 25 and the box moves along the surface.

Find

(b) the acceleration of the box,

(5)

(c) the speed of the box when it has moved 1.5 m.

(2)

WME01/01 OCTOBER 2025

Question 6

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

6.

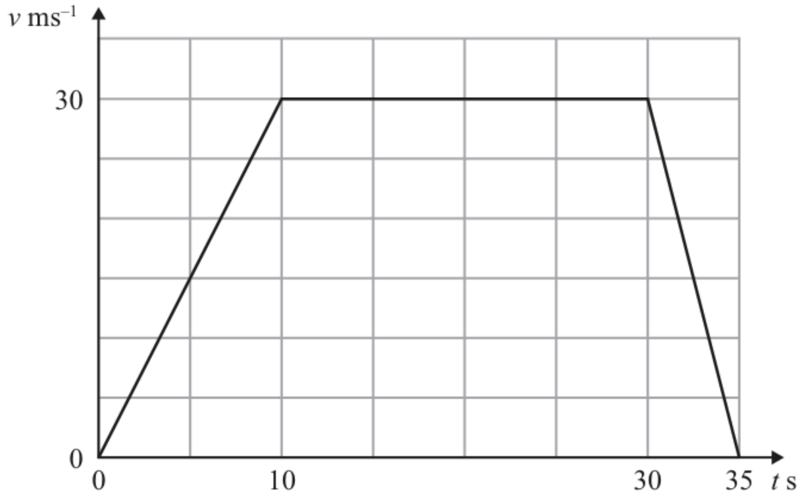

Figure 4

The point O lies on a straight horizontal road.
At time $t = 0$, a car leaves O and travels along the road.

The velocity-time graph in Figure 4 shows the velocity, $v\,\text{m s}^{-1}$, of the car at time t seconds for the first 35 seconds of its journey.

(a) Find

(i) the acceleration of the car for the period $0 \leqslant t \leqslant 10$

(ii) the deceleration of the car for the period $30 \leqslant t \leqslant 35$

(2)

(b) Sketch an acceleration-time graph for the car for the period $0 \leqslant t \leqslant 35$

(2)

(c) Find the distance travelled by the car for the period $0 \leqslant t \leqslant 35$

(2)

When $t = 5$, a motorcycle starts from rest at O.
The motorcycle travels along the same road as the car and in the same direction.

For the period $5 \leqslant t \leqslant 20$, the acceleration of the motorcycle is $A\,\text{m s}^{-2}$, where A is a positive constant.

The motorcycle catches up with the car when $t = 20$

(d) Find the value of A.

(4)

WME01/01 JANUARY 2026

Question 2

10 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Kinematics Graphs

2.

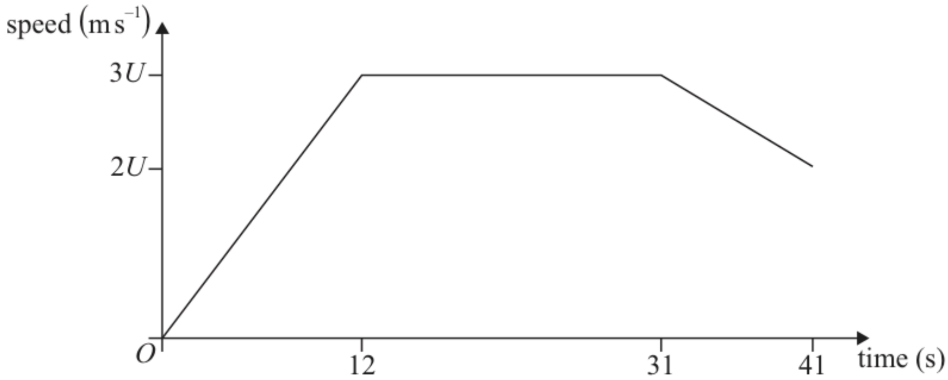

Figure 1

A particle P starts from rest at time $t = 0$ and moves in a straight line

- from $t = 0$ to $t = 12$ s, P accelerates uniformly until it reaches a speed of $3U \text{ m s}^{-1}$
- from $t = 12$ s to $t = 31$ s, P moves with constant speed $3U \text{ m s}^{-1}$
- from $t = 31$ s to $t = 41$ s, P decelerates uniformly until it has speed $2U \text{ m s}^{-1}$

as shown on the speed-time graph in Figure 1.

The distance travelled by P between $t = 0$ and $t = 41$ s is 600 m.

(a) Show that $U = 6$

(3)

(b) Find the distance travelled by P whilst moving from rest to a speed of 6 m s^{-1}

(2)

(c) Find the acceleration of P between $t = 0$ and $t = 12$ s.

(1)

(d) Find the deceleration of P between $t = 31$ s and $t = 41$ s.

(2)

(e) Sketch an acceleration-time graph to represent the motion of P from $t = 0$ to $t = 41$ s.

(2)

WME01/01 JANUARY 2026

Question 4

9 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Moments

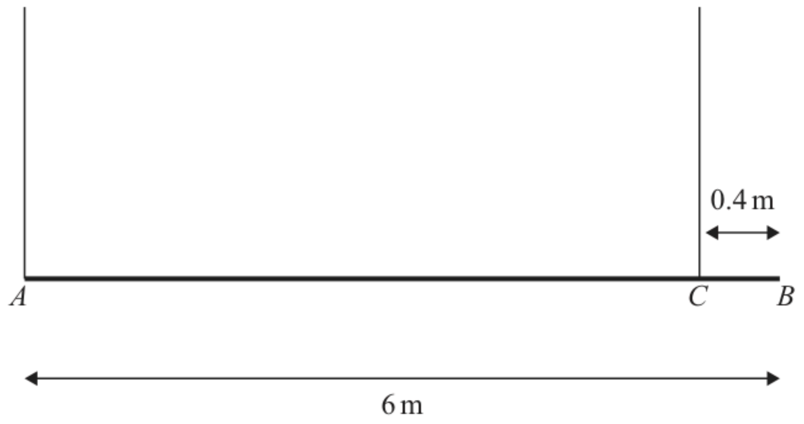

Figure 2

Figure 2 shows a uniform rod AB of length 6 m suspended by two light vertical ropes.

The first rope is attached to the rod at A.
The second rope is attached to the rod at the point C, where $CB = 0.4$ m.

The rod has mass 30 kg.

A particle of mass 20 kg is now attached to the rod at B.

The rod is in equilibrium in a horizontal position.

(a) Find

(i) the tension in the rope attached to the rod at C,
(ii) the tension in the rope attached to the rod at A.

(6)

The particle of mass 20 kg at B is removed and replaced by a particle of mass M kg.

The rod remains in equilibrium in a horizontal position.

(b) Find the exact maximum value of M.

(3)

12 marks

Constant Acceleration in 1D

Also in Constant Acceleration in 1D

Primary: Resolving Forces, Inclined Planes

WME01/01 JANUARY 2026

Question 5

5. The points O, A, B and C are on a rough horizontal surface where $OABC$ is a straight line.

A particle is projected horizontally from O and slides across the surface, passing through A, B and C in that order.

The particle passes through

- A with speed $U \text{ m s}^{-1}$
- B with speed $\frac{U}{2} \text{ m s}^{-1}$

The coefficient of friction between the particle and the surface is $\frac{1}{7}$

It takes 0.75 s for the particle to move from A to B.

(a) Show that $U = 2.1$ to 2 significant figures.

(6)

The particle passes through C with speed $\frac{U}{3} \text{ m s}^{-1}$

(b) Find the time taken to move from B to C.

(3)

(c) Find the distance AC.

(3)

TOPIC

Constant Acceleration in 2D

Question 4

4. The point A is 10 m above horizontal ground.
At time $t = 0$, a particle P is projected vertically upwards with speed $5\,\text{m}\,\text{s}^{-1}$ from A.
Particle P moves freely under gravity.

(a) Find the greatest height above A reached by P.

(3)

The point B is on the ground, vertically below A.
At time $t = 1$ second, a particle Q is projected vertically upwards with speed $7\,\text{m}\,\text{s}^{-1}$ from B.
Particle Q moves freely under gravity.

Particles P and Q collide at time $t = T$ seconds.

(b) Find the value of T.

(4)

(c) Find the speed of P at the instant immediately before the particles collide.

(2)

WME01/01 JANUARY 2021

Question 6

12 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

6. Two girls, Agatha and Brionie, are roller skating inside a large empty building. The girls are modelled as particles.

At time $t = 0$, Agatha is at the point with position vector $(11\mathbf{i} + 11\mathbf{j})$ m and Brionie is at the point with position vector $(7\mathbf{i} + 16\mathbf{j})$ m. The position vectors are given relative to the door, O, and $\mathbf{i}$ and $\mathbf{j}$ are horizontal perpendicular unit vectors.

Agatha skates with constant velocity $(3\mathbf{i} - \mathbf{j})\,\text{m s}^{-1}$

Brionie skates with constant velocity $(4\mathbf{i} - 2\mathbf{j})\,\text{m s}^{-1}$

(a) Find the position vector of Agatha at time t seconds.

(2)

At time $t = 6$ seconds, Agatha passes through the point P.

(b) Show that Brionie also passes through P and find the value of t when this occurs.

(4)

At time t seconds, Agatha is at the point A and Brionie is at the point B.

(c) Show that $\overrightarrow{AB} = [(t - 4)\mathbf{i} + (5 - t)\mathbf{j}]$ m

(2)

(d) Find the distance between the two girls when they are closest together.

(4)

WME01/01 MAY/JUNE 2021

Question 5

5. [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors.*]

A particle P is moving with constant acceleration. At 2 pm, the velocity of P is $(3\mathbf{i} + 5\mathbf{j})$ km h^{-1} and at 2.30 pm the velocity of P is $(\mathbf{i} + 7\mathbf{j})$ km h^{-1}

At time T hours after 2 pm, P is moving in the direction of the vector $(-\mathbf{i} + 2\mathbf{j})$

(a) Find the value of T.

(6)

Another particle, Q, has velocity $\mathbf{v}_Q$ km h^{-1} at time t hours after 2 pm, where

$$\mathbf{v}_Q = (-4 - 2t)\,\mathbf{i} + (\mu + 3t)\,\mathbf{j}$$

and μ is a constant.

Given that there is an instant when the velocity of P is equal to the velocity of Q,

(b) find the value of μ.

(3)

WME01/01 OCTOBER 2021

Question 4

4. The position vector, $\mathbf{r}$ metres, of a particle P at time t seconds, relative to a fixed origin O, is given by

$$\mathbf{r} = (t - 3)\mathbf{i} + (1 - 2t)\mathbf{j}$$

(a) Find, to the nearest degree, the size of the angle between $\mathbf{r}$ and the vector $\mathbf{j}$, when $t = 2$
(3)

(b) Find the values of t for which the distance of P from O is 2.5 m.
(5)

12 marks

WME01/01 OCTOBER 2021

Constant Acceleration in 2D

Question 8

Also in Constant Acceleration in 2D

Primary: Working with Vectors

8. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin.*]

At 7 am a ship leaves a port and moves with constant velocity. The position vector of the port is $(-2\mathbf{i} + 9\mathbf{j})$ km.

At 7.36 am the ship is at the point with position vector $(4\mathbf{i} + 6\mathbf{j})$ km.

(a) Show that the velocity of the ship is $(10\mathbf{i} - 5\mathbf{j})\,\text{km h}^{-1}$

(2)

(b) Find the position vector of the ship t hours after leaving port.

(2)

At 8.48 am a passenger on the ship notices that a lighthouse is due east of the ship.

At 9 am the same passenger notices that the lighthouse is now north east of the ship.

(c) Find the position vector of the lighthouse.

(4)

(d) Find the position vector of the ship when it is due south of the lighthouse.

(4)

(Total 12 marks)

WME01/01 JANUARY 2022

Question 6

12 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

6. [*In this question* **i** *and* **j** *are horizontal unit vectors*.]

A particle P of mass 2 kg moves under the action of two forces, $(p\mathbf{i} + q\mathbf{j})$ N and $(2q\mathbf{i} + p\mathbf{j})$ N, where p and q are constants.

Given that the acceleration of P is $(\mathbf{i} - \mathbf{j})\,\mathrm{m\,s^{-2}}$

(a) find the value of p and the value of q.

(5)

(b) Find the size of the angle between the direction of the acceleration and the vector **j**.

(2)

At time $t = 0$, the velocity of P is $(3\mathbf{i} - 4\mathbf{j})\,\mathrm{m\,s^{-1}}$

At $t = T$ seconds, P is moving in the direction of the vector $(11\mathbf{i} - 13\mathbf{j})$.

(c) Find the value of T.

(5)

WME01/01 JANUARY 2022

Question 8

14 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

8. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin.*]

A ship A moves with constant velocity $(3\mathbf{i} - 10\mathbf{j})\,\text{km h}^{-1}$

At time t hours, the position vector of A is $\mathbf{r}$ km.

At time $t = 0$, A is at the point with position vector $(13\mathbf{i} + 5\mathbf{j})$ km.

(a) Find $\mathbf{r}$ in terms of t.

(2)

Another ship B moves with constant velocity $(15\mathbf{i} + 14\mathbf{j})\,\text{km h}^{-1}$

At time $t = 0$, B is at the point with position vector $(3\mathbf{i} - 5\mathbf{j})$ km.

(b) Show that, at time t hours,

$$\overrightarrow{AB} = \left[(12t - 10)\mathbf{i} + (24t - 10)\mathbf{j}\right]\text{km}$$

(4)

Given that the two ships do not change course,

(c) find the shortest distance between the two ships,

(6)

(d) find the bearing of ship B from ship A when the ships are closest.

(2)

(Total 14 marks)

WME01/01 MAY/JUNE 2022

Question 5

9 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Moments

5.

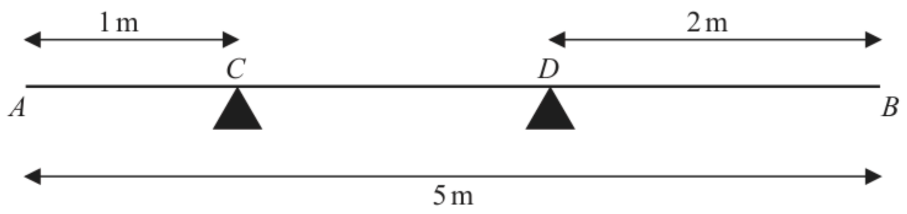

Figure 2

A uniform rod AB has length 5 m and mass 5 kg. The rod rests in equilibrium in a horizontal position on two supports C and D, where $AC = 1$ m and $DB = 2$ m, as shown in Figure 2.

A particle of mass 10 kg is placed on the rod at A and a particle of mass M kg is placed on the rod at B. The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the magnitude of the reaction on the rod at C.

(3)

(b) Find, in terms of M, the magnitude of the reaction on the rod at D.

(3)

(c) Hence, or otherwise, find the range of possible values of M.

(3)

WME01/01 MAY/JUNE 2022

Question 6

6 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

6. A particle P is moving with constant acceleration.

At time $t = 1$ second, P has velocity $(-\mathbf{i} + 4\mathbf{j})\,\mathrm{m\,s^{-1}}$

At time $t = 4$ seconds, P has velocity $(5\mathbf{i} - 8\mathbf{j})\,\mathrm{m\,s^{-1}}$

Find the speed of P at time $t = 3.5$ seconds.

(6)

WME01/01 MAY/JUNE 2022

Question 8

17 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

8. [*In this question,* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two boats, P and Q, are moving with constant velocities.

The velocity of P is $15\mathbf{i}\,\mathrm{m\,s^{-1}}$ and the velocity of Q is $(20\mathbf{i} - 20\mathbf{j})\,\mathrm{m\,s^{-1}}$

(a) Find the direction in which Q is travelling, giving your answer as a bearing.

(2)

The boats are modelled as particles.

At time $t = 0$, P is at the origin O and Q is at the point with position vector $200\mathbf{j}\,\mathrm{m}$.

At time t seconds, the position vector of P is $\mathbf{p}\,\mathrm{m}$ and the position vector of Q is $\mathbf{q}\,\mathrm{m}$.

(b) Show that

$$\overrightarrow{PQ} = [5t\mathbf{i} + (200 - 20t)\mathbf{j}]\,\mathrm{m}$$

(5)

(c) Find the bearing of P from Q when $t = 10$

(2)

(d) Find the distance between P and Q when Q is north east of P

(5)

(e) Find the times when P and Q are 200 m apart.

(3)

(Total 17 marks)

TOTAL FOR PAPER: 75 MARKS

16 marks

WME01/01 OCTOBER 2022

Constant Acceleration in 2D

Question 8

Also in Constant Acceleration in 2D

Primary: Working with Vectors

8. [*In this question,* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two ships, A and B, are moving with constant velocities.
The velocity of A is $(3\mathbf{i} + 12\mathbf{j})\,\text{km h}^{-1}$ and the velocity of B is $(p\mathbf{i} + q\mathbf{j})\,\text{km h}^{-1}$

(a) Find the speed of A.

(2)

The ships are modelled as particles.
At 12 noon, A is at the point with position vector $(-9\mathbf{i} + 6\mathbf{j})\,\text{km}$ and B is at the point with position vector $(16\mathbf{i} + 6\mathbf{j})\,\text{km}$.

At time t hours after 12 noon,

$$\overrightarrow{AB} = [(25 - 12t)\mathbf{i} - 9t\mathbf{j}]\,\text{km}$$

(b) Find the value of p and the value of q.

(7)

(c) Find the bearing of A from B when the ships are 15 km apart, giving your answer to the nearest degree.

(7)

(Total 16 marks)

WME01/01 JANUARY 2023

Question 3

10 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

3. A particle P is moving with constant acceleration $(-4\mathbf{i} + \mathbf{j})\,\mathrm{m\,s^{-2}}$

At time $t = 0$, P has velocity $(14\mathbf{i} - 5\mathbf{j})\,\mathrm{m\,s^{-1}}$

(a) Find the speed of P at time $t = 2$ seconds.

(3)

(b) Find the size of the angle between the direction of $\mathbf{i}$ and the direction of motion of P at time $t = 2$ seconds.

(3)

At time $t = T$ seconds, P is moving in the direction of vector $(2\mathbf{i} - 3\mathbf{j})$

(c) Find the value of T

(4)

WME01/01 MAY/JUNE 2023

Question 8

9 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

8.

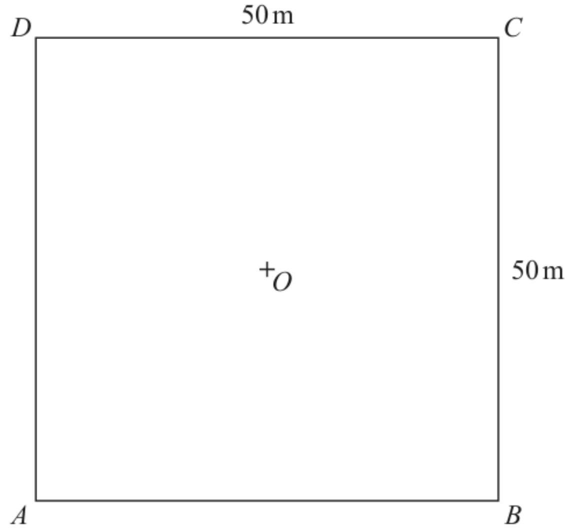

Figure 5

A square floor space *ABCD*, with centre *O*, is modelled as a flat horizontal surface measuring 50 m by 50 m, as shown in Figure 5.
The horizontal unit vectors **i** and **j** are in the direction of $\overrightarrow{AB}$ and $\overrightarrow{AD}$ respectively.

All position vectors are given relative to *O*.

A small robot *R* is programmed to travel across the floor at a constant velocity.

- At time $t = 0$, *R* is at the point with position vector $(-2\mathbf{i} + \mathbf{j})$ m
- At time $t = 11$ s, *R* is at the point with position vector $(9\mathbf{i} + 23\mathbf{j})$ m
- At time *t* seconds, the position vector of *R* is **r** metres

(a) Find, in terms of *t*, **i** and **j**, an expression for **r**

(3)

A second robot *S* is at the point *C*.

- At time $t = 0$, *S* leaves *C* and moves with constant velocity $(-\mathbf{i} - \mathbf{j})$ m s^{-1}
- At time *t* seconds, the position vector of *S* is **s** metres

(b) Write down, in terms of *t*, **i** and **j**, an expression for **s**

(1)

(c) Show that

$$\overrightarrow{SR} = [(2t - 27)\mathbf{i} + (3t - 24)\mathbf{j}]\ \text{m}$$

(2)

(d) Find the time when the distance between *R* and *S* is a minimum.

(3)

Question 4

4. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively.*]

A particle P moves with constant acceleration $(-\lambda\mathbf{i} + 2\lambda\mathbf{j})\,\text{m s}^{-2}$, where λ is a positive constant.

At time $t = 0$, the velocity of P is $(5\mathbf{i} - 8\mathbf{j})\,\text{m s}^{-1}$

(a) Find the velocity of P when $t = 5\,\text{s}$, giving your answer in terms of **i**, **j** and λ.

(2)

The speed of P when $t = 5\,\text{s}$ is $13\,\text{m s}^{-1}$

(b) Show that

$$25\lambda^2 - 42\lambda - 16 = 0$$

(3)

(c) Find the direction of motion of P when $t = 4\,\text{s}$, giving your answer as a bearing to the nearest degree.

(5)

WME01/01 OCTOBER 2023

Question 6

15 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

6. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

At 12:00, a ship P sets sail from a harbour with position vector $(15\mathbf{i} + 36\mathbf{j})$ km.
At 12:30, P is at the point with position vector $(20\mathbf{i} + 34\mathbf{j})$ km.

Given that P moves with constant velocity,

(a) show that the velocity of P is $(10\mathbf{i} - 4\mathbf{j})\,\text{km h}^{-1}$

(2)

At time t hours after 12:00, the position vector of P is $\mathbf{p}$ km.

(b) Find an expression for $\mathbf{p}$ in terms of $\mathbf{i}$, $\mathbf{j}$ and t.

(2)

A second ship Q is also travelling at a constant velocity.

At time t hours after 12:00, the position vector of Q is given by $\mathbf{q}$ km, where

$$\mathbf{q} = (42 - 8t)\mathbf{i} + (9 + 14t)\mathbf{j}$$

Ships P and Q are modelled as particles.

If both ships maintained their course,

(c) (i) verify that they would collide at 13:30

(ii) find the position vector of the point at which the collision would occur.

(4)

At 12:30 Q changes speed and direction to avoid the collision.

Ship Q now travels due north with a constant speed of $15\,\text{km h}^{-1}$

Ship P maintains the same constant velocity throughout.

(d) Find the exact distance between P and Q at 14:30

(7)

Question 7

11 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

7. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

At midnight, a ship S is at the point with position vector $(19\mathbf{i} + 22\mathbf{j})$ km

The ship travels with constant velocity $(12\mathbf{i} - 16\mathbf{j})$ km h^{-1}

(a) Find the speed of S.

(2)

At time t hours after midnight, the position vector of S is $\mathbf{s}$ km.

(b) Find an expression for $\mathbf{s}$ in terms of $\mathbf{i}$, $\mathbf{j}$ and t.

(2)

A lighthouse stands on a small rocky island. The lighthouse is modelled as being at the point with position vector $(26\mathbf{i} + 15\mathbf{j})$ km.

It is not safe for ships to be within 1.3 km of the lighthouse.

(c) (i) Find the value of t when S is closest to the lighthouse.

(ii) Hence determine whether it is safe for S to continue its course.

(7)

13 marks

WME01/01 MAY/JUNE 2024

Constant Acceleration in 2D

Question 7

Also in Constant Acceleration in 2D

Primary: Working with Vectors

7. [*In this question, the horizontal unit vectors* **i** *and* **j** *are directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

Two speedboats, A and B, are each moving with constant velocity.

- the velocity of A is $40\,\text{km}\,\text{h}^{-1}$ due east
- the velocity of B is $20\,\text{km}\,\text{h}^{-1}$ on a bearing of angle α (0° < α < 90°), where $\tan\alpha = \frac{4}{3}$

The boats are modelled as particles.

(a) Find, in terms of **i** and **j**, the velocity of B in $\text{km}\,\text{h}^{-1}$

(2)

At noon

- the position vector of A is $20\mathbf{j}$ km
- the position vector of B is $(10\mathbf{i} + 5\mathbf{j})$ km

At time t hours after noon

- the position vector of A is $\mathbf{r}$ km, where $\mathbf{r} = 20\mathbf{j} + 40t\mathbf{i}$
- the position vector of B is $\mathbf{s}$ km

(b) Find an expression for $\mathbf{s}$ in terms of t, **i** and **j**.

(2)

(c) Show that at time t hours after noon,

$$\overrightarrow{AB} = [(10 - 24t)\mathbf{i} + (12t - 15)\mathbf{j}]\,\text{km}$$

(2)

(d) Show that the boats will never collide.

(3)

(e) Find the distance between the boats when the bearing of B from A is 225°

(4)

11 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

WME01/01 OCTOBER 2024

Question 3

3. [*In this question* **i** *and* **j** *are horizontal unit vectors and position vectors are given relative to a fixed origin.*]

A ship A is moving with constant velocity.

At 1 pm, the position vector of A is $(25\mathbf{i} + 10\mathbf{j})$ km.

At 3 pm, the position vector of A is $(55\mathbf{i} + 34\mathbf{j})$ km.

At time t hours after 1 pm, the position vector of A is $\mathbf{r}_A$ km.

(a) Show that $\mathbf{r}_A = (25 + 15t)\mathbf{i} + (10 + 12t)\mathbf{j}$

(4)

The speed of A is $V\,\text{m}\,\text{s}^{-1}$

(b) Find the value of V.

(2)

A ship B is moving with constant velocity $(20\mathbf{i} - 6\mathbf{j})\,\text{km}\,\text{h}^{-1}$

At 1 pm, the position vector of B is $(35\mathbf{i} + 51\mathbf{j})$ km.

At 2:30 pm, B passes through the point P.

(c) Show that A also passes through P.

(5)

Question 5

5. [*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors and position vectors are given relative to a fixed origin.*]

In a game, a ball B is rolled across a horizontal surface towards a fixed target. The ball is modelled as a particle moving with constant velocity.

At time $t = 1$ s, the position vector of B is $(-2\mathbf{i} + 5\mathbf{j})$ m.
At time $t = 9$ s, the position vector of B is $(10\mathbf{i} - 3\mathbf{j})$ m.

(a) Find the velocity of the ball.

(3)

The position vector of the target is $(13\mathbf{i} - 5\mathbf{j})$ m.

(b) Use the model to find the distance of B from the target at time $t = 7$ s.

(4)

7 marks

Constant Acceleration in 2D

WME01/01 MAY/JUNE 2025

Question 2

Also in Constant Acceleration in 2D

Primary: Working with Vectors

2. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively. Position vectors are given relative to a fixed origin.*]

Two particles, A and B, are moving on a smooth horizontal surface.
Each particle is moving with constant velocity.

At time t seconds, the position vector of A is given by $\mathbf{r}$ metres.

- When $t = 2$, $\mathbf{r} = (-5\mathbf{i} + 16\mathbf{j})$
- When $t = 5$, $\mathbf{r} = (10\mathbf{i} + 4\mathbf{j})$

(a) Find, in terms of **i** and **j**, the velocity of A.

(2)

(b) Find an expression for $\mathbf{r}$ at time t seconds.
Give your answer in the form $p\mathbf{i} + q\mathbf{j}$, where p and q are functions of t

(2)

At time t seconds, the position vector of B is given by $\mathbf{s}$ metres where

$$\mathbf{s} = -5\mathbf{i} + 7\mathbf{j} + t(2\mathbf{i} - 3\mathbf{j})$$

(c) Find, to the nearest degree, the bearing of B from A when $t = 5$

(3)

13 marks

WME01/01 MAY/JUNE 2025

Constant Acceleration in 2D

Question 7

Also in Constant Acceleration in 2D

Primary: Working with Vectors

7. [*In this question* **i** *and* **j** *are horizontal unit vectors.*]

Two boats, A and B, are each moving with constant acceleration.

At time t hours after noon, boat A has velocity $\mathbf{v}_A$ km h^{-1}, where

$$\mathbf{v}_A = 2\mathbf{i} + 3\mathbf{j} + (\mathbf{i} - 4\mathbf{j})t$$

(a) Find the magnitude of the acceleration of A.

(2)

When $t = 2$, the velocity of B is $(4\mathbf{i} + \mathbf{j})$ km h^{-1}

When $t = 5$, the velocity of B is $(\mathbf{i} - 5\mathbf{j})$ km h^{-1}

(b) Find the acceleration of B, giving your answer in terms of **i** and **j**.

(2)

(c) Find the velocity of B at time $t = 0$, giving your answer in terms of **i** and **j**.

(2)

At time T_1 hours after noon, both boats are moving with the same speed.

(d) Find the exact value of T_1

(4)

At time T_2 hours after noon, both boats are moving in the same direction.

(e) Show that $3T_2^2 + pT_2 + q = 0$, where p and q are integers to be found.

(3)

16 marks

Constant Acceleration in 2D

Also in Constant Acceleration in 2D

Primary: Working with Vectors

WME01/01 JANUARY 2026

Question 6

6. [*In this question* **i** *and* **j** *are horizontal unit vectors directed due east and due north respectively and position vectors are given relative to a fixed origin O.*]

At 9 am, a ship S leaves a harbour and moves with constant velocity $(10\mathbf{i} + 15\mathbf{j})\,\text{km}\,\text{h}^{-1}$

(a) Find the exact speed of S

(2)

The harbour is at the origin O.

At 9 am, a boat B leaves the point with position vector $(50\mathbf{i} + 10\mathbf{j})$ km and moves with constant velocity $(-8\mathbf{i} + 10\mathbf{j})\,\text{km}\,\text{h}^{-1}$

(b) Find the direction in which B is moving, giving your answer as a bearing to the nearest degree.

(3)

(c) Show that at time t hours after 9 am,

$$\overrightarrow{SB} = [(50 - 18t)\mathbf{i} + (10 - 5t)\mathbf{j}]\,\text{km}$$

(4)

(d) Show that B and S do not collide.

(3)

When B is north-east of S, the distance between S and B is d km.

(e) Find the value of d.

(4)

TOPIC

Forces

Question 4

10 marks

Forces

4.

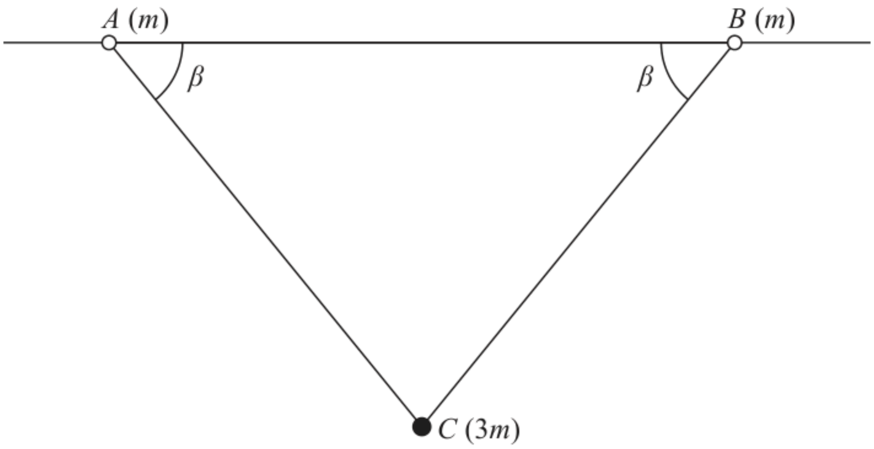

Figure 2

Two identical small rings, A and B, each of mass m, are threaded onto a rough horizontal wire. The rings are connected by a light inextensible string. A particle C of mass $3m$ is attached to the midpoint of the string. The particle C hangs in equilibrium below the wire with angle $BAC = \beta$, as shown in Figure 2.

The tension in each of the parts, AC and BC, of the string is T

(a) By considering particle C, find T in terms of m, g and β

(2)

(b) Find, in terms of m and g, the magnitude of the normal reaction between the wire and A.

(3)

The coefficient of friction between each ring and the wire is $\frac{4}{5}$

The two rings, A and B, are on the point of sliding along the wire towards each other.

(c) Find the value of $\tan\beta$

(5)

Question 3

9 marks

Forces

3.

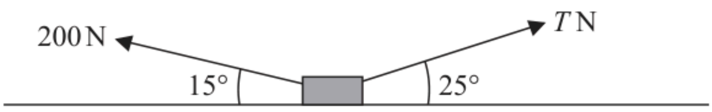

Figure 1

A parcel of mass 20 kg is at rest on a rough horizontal floor. The coefficient of friction between the parcel and the floor is 0.3

Two forces, both acting in the same vertical plane, of magnitudes 200 N and T N are applied to the parcel. The line of action of the 200 N force makes an angle of 15° with the horizontal and the line of action of the T N force makes an angle of 25° with the horizontal, as shown in Figure 1. The parcel is modelled as a particle P.

Find the smallest value of T for which P remains in equilibrium.

(9)

WME01/01 OCTOBER 2021

Question 5

10 marks

Forces

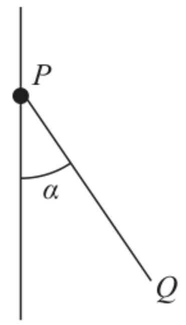

Figure 2

A small bead of mass 0.2 kg is attached to the end P of a light rod PQ. The bead is threaded onto a fixed vertical rough wire.

The bead is held in equilibrium with the rod PQ inclined to the wire at an angle α, where $\tan\alpha = \frac{4}{3}$, as shown in Figure 2.

The thrust in the rod is T newtons.

The bead is modelled as a particle.

(a) Find the magnitude and direction of the friction force acting on the bead when $T = 2.5$

(3)

The coefficient of friction between the bead and the wire is μ.

Given that the greatest possible value of T is 6.125

(b) find the value of μ.

(7)

WME01/01 JANUARY 2022

6 marks

Question 1

Forces

1.

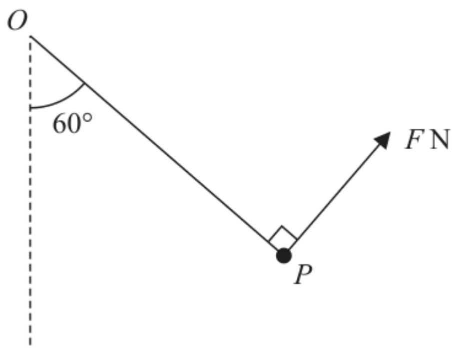

Figure 1

A particle P of weight 5 N is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point O. The particle P is held in equilibrium by a force of magnitude F newtons. The direction of this force is perpendicular to the string and OP makes an angle of 60° with the vertical, as shown in Figure 1.

Find

(a) the value of F

(3)

(b) the tension in the string.

(3)

WME01/01 MAY/JUNE 2022

Question 4

12 marks

Forces

4.

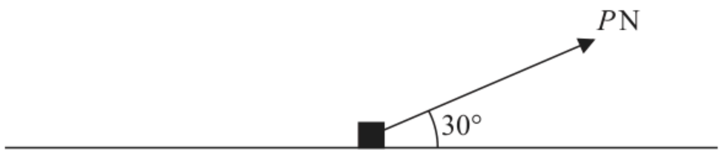

Figure 1

A small block of mass 5 kg lies at rest on a rough horizontal plane.

The coefficient of friction between the block and the plane is $\frac{3}{7}$

A force of magnitude *P* newtons is applied to the block in a direction which makes an angle of 30° with the plane, as shown in Figure 1.

The block is modelled as a particle.

Given that $P = 14$

(a) find the magnitude of the frictional force exerted on the block by the plane and describe what happens to the block, justifying your answer.

(6)

The value of *P* is now changed so that the block is on the point of slipping along the plane.

(b) Find the value of *P*

(6)

WME01/01 JANUARY 2023

8 marks

Question 6

Forces

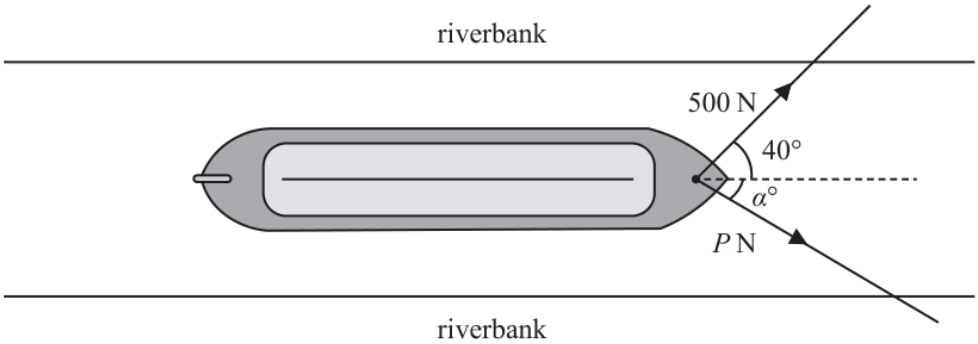

Figure 3

A boat is pulled along a river at a constant speed by two ropes.

The banks of the river are parallel and the boat travels horizontally in a straight line, parallel to the riverbanks.

- The tension in the first rope is 500 N acting at an angle of 40° to the direction of motion, as shown in Figure 3.
- The tension in the second rope is P newtons, acting at an angle of $\alpha°$ to the direction of motion, also shown in Figure 3.
- The resistance to motion of the boat as it moves through the water is a constant force of magnitude 900 N

The boat is modelled as a particle. The ropes are modelled as being light and lying in a horizontal plane.

Use the model to find

(i) the value of α

(ii) the value of P

(8)

Question 6

7 marks

Forces

6.

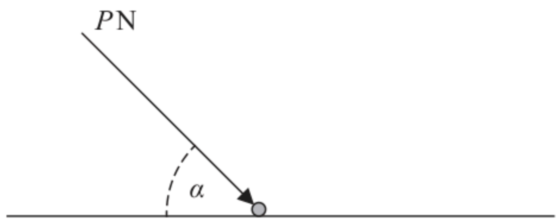

Figure 3

A particle of weight W newtons lies at rest on a rough horizontal surface, as shown in Figure 3.
A force of magnitude P newtons is applied to the particle.

The force acts at an angle α to the horizontal, where $\tan\alpha = \frac{4}{3}$

The coefficient of friction between the particle and the surface is $\frac{1}{4}$

Given that the particle does not move, show that

$$P \leqslant \frac{5W}{8}$$

(7)

WME01/01 OCTOBER 2023

Question 5

12 marks

Forces

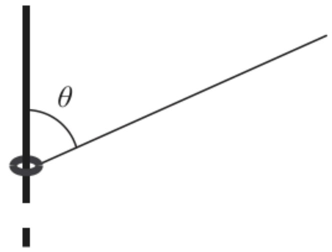

Figure 3

A small ring of mass 0.2 kg is attached to one end of a light inextensible string.

The ring is **threaded** onto a fixed rough vertical rod.

The string is taut and makes an angle θ with the rod, as shown in Figure 3, where $\tan\theta = \frac{12}{5}$

Given that the ring is in equilibrium and that the tension in the string is 10 N,

(a) find the magnitude of the frictional force acting on the ring,

(3)

(b) state the direction of the frictional force acting on the ring.

(1)

The coefficient of friction between the ring and the rod is $\frac{1}{4}$

Given that the ring is in equilibrium, and that the tension in the string, T newtons, can now vary,

(c) (i) find the minimum value of T

(ii) find the maximum value of T

(8)

WME01/01 JANUARY 2024

Question 1

6 marks

Forces

1.

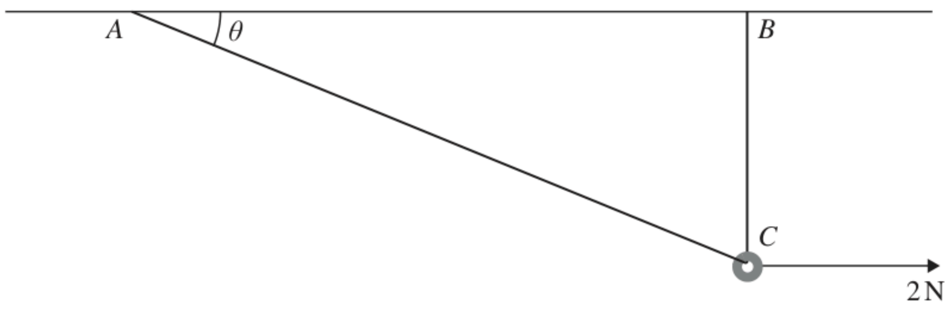

Figure 1

Figure 1 shows a small smooth ring **threaded** onto a light inextensible string.

One end of the string is attached to a fixed point A on a horizontal ceiling and the other end of the string is attached to a fixed point B on the ceiling.

A horizontal force of magnitude 2 N acts on the ring so that the ring rests in equilibrium at a point C, vertically below B, with the string taut.

The line of action of the horizontal force and the string both lie in the same vertical plane.

The angle that the string makes with the ceiling at A is θ, where $\tan\theta = \frac{3}{4}$

The tension in the string is T newtons. The mass of the ring is M kg.

(a) Find the value of T

(3)

(b) Find the value of M

(3)

Question 4

8 marks

Forces

4.

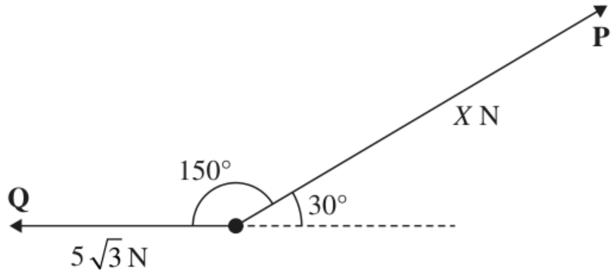

Figure 3

Figure 3 shows two horizontal forces **P** and **Q** acting on a particle.

The angle between the direction of **P** and the direction of **Q** is 150°

Force **P** has magnitude X newtons.

Force **Q** has magnitude $5\sqrt{3}$ N.

The resultant of **P** and **Q** has magnitude $\sqrt{129}$ N.

Find

(i) the value of X.

(ii) the angle between **Q** and the resultant, giving your answer to the nearest degree.

(8)

Question 2

4 marks

Forces

2. Two forces, **P** and **Q**, act on a particle.

- **P** has magnitude 10 N and acts due west
- **Q** has magnitude 8 N and acts on a bearing of 330°

Given that **F** = **P** + **Q**, find the magnitude of **F**.

(4)

Question 1

8 marks

Forces

1. A particle of mass 2.5 kg moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (6\mathbf{i} + 8\mathbf{j})\,\text{N}$$

$$\mathbf{F}_2 = (-16\mathbf{i} + 2\mathbf{j})\,\text{N}$$

$$\mathbf{F}_3 = (-2\mathbf{i} + 8\mathbf{j})\,\text{N}$$

(a) Find the magnitude of the acceleration of the particle.

(4)

A fourth force, $\mathbf{F}_4 = (p\mathbf{i} + p\mathbf{j})\,\text{N}$, where p is a constant, is added.

The resultant of the four forces acts in the direction of the vector $(7\mathbf{i} + 2\mathbf{j})$.

(b) Find the value of p.

(4)

Question 4

7 marks

Forces

4.

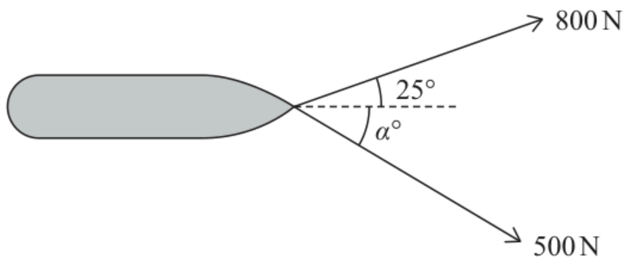

Figure 2

Two ropes are attached to a point on the front of a barge.
The barge is being pulled horizontally in a straight line along the centre of a long straight canal.

One rope makes an angle of 25° with the direction of motion of the barge and has a tension of 800 N.
The other rope makes an angle of α° with the direction of motion of the barge and has a tension of 500 N, as shown in Figure 2.

Both ropes are horizontal.

(a) Find the value of α

(3)

The mass of the barge is 15 tonnes and the resistance to the motion of the barge is a constant force of magnitude 750 N.

(b) Find the acceleration of the barge.

(4)

WME01/01 OCTOBER 2025

Question 3

14 marks

Forces

3. [*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

A particle P of mass 2 kg moves on a smooth horizontal surface under the action of two forces $\mathbf{F}_1$ and $\mathbf{F}_2$, where $\mathbf{F}_1 = (-2\mathbf{i} + 3\mathbf{j})$ N and $\mathbf{F}_2 = (4\mathbf{i} + 2\mathbf{j})$ N.

(a) Find the acceleration of P.

(3)

At time $t = 0$, the velocity of P is $(3\mathbf{i} - 4\mathbf{j})\,\text{m s}^{-1}$

(b) Find the speed of P when $t = 3$ seconds.

(4)

An additional force, $\mathbf{F}_3 = (b\mathbf{i} + c\mathbf{j})$ N, is applied to P.

The resultant of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ is equal to $\lambda(\mathbf{i} + \mathbf{j})$ N, where λ is a constant.

(c) Show that $b - c = 3$

(3)

The resultant of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ has magnitude $10\sqrt{2}$ N.

(d) Find the two possible $\mathbf{F}_3$ forces.

(4)

Question 3

8 marks

Forces

3. A particle moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (2p\mathbf{i} - 3p\mathbf{j})\text{N}$$

$$\mathbf{F}_2 = (q\mathbf{i} + \mathbf{j})\text{N}$$

$$\mathbf{F}_3 = (3\mathbf{i} - q\mathbf{j})\text{N}$$

where p and q are constants.

The resultant force acts in the direction of the vector $(4\mathbf{i} - 5\mathbf{j})$

(a) Show that

$$2p - q = 19$$

(4)

The mass of the particle is 0.5 kg.

Given that $p = 7$

(b) find the acceleration of the particle.

(4)

Question 4

4.

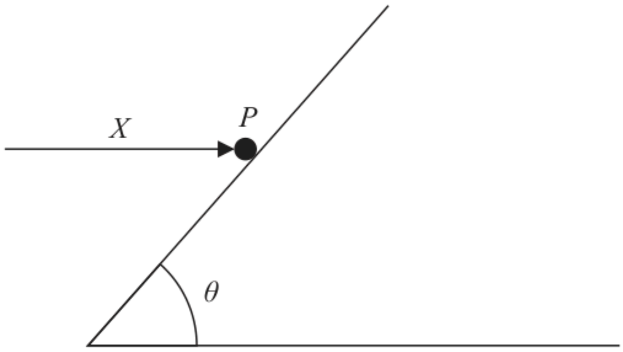

Figure 1

A particle, P, of mass km lies on a fixed rough plane. The plane is inclined to the horizontal at an acute angle θ. A horizontal force of magnitude X acts on P, as shown in Figure 1. The line of action of the force lies in the vertical plane which contains the line of greatest slope of the inclined plane that passes through P. The coefficient of friction between P and the inclined plane is μ.

When $X = mg$, the particle P is in equilibrium and on the point of sliding down the plane.

(a) Show that $\mu = \dfrac{k\tan\theta - 1}{k + \tan\theta}$

(10)

(b) Deduce that, when $k = 1$, θ must be greater than 45°

(2)

Question 7

7. Two forces, **F** and **G**, act on a particle. The force **F** has magnitude 4 N and acts in a direction with a bearing of 120° and the force **G** has magnitude 6 N and acts due north.

Given that $\mathbf{P} = 2\mathbf{F} + \mathbf{G}$, find

(i) the magnitude of **P**

(ii) the direction of **P**, giving your answer as a bearing to the nearest degree.

(7)

WME01/01 JANUARY 2020

Question 7

18 marks

Forces

Also in Forces

Primary: Newton's Second Law

7.

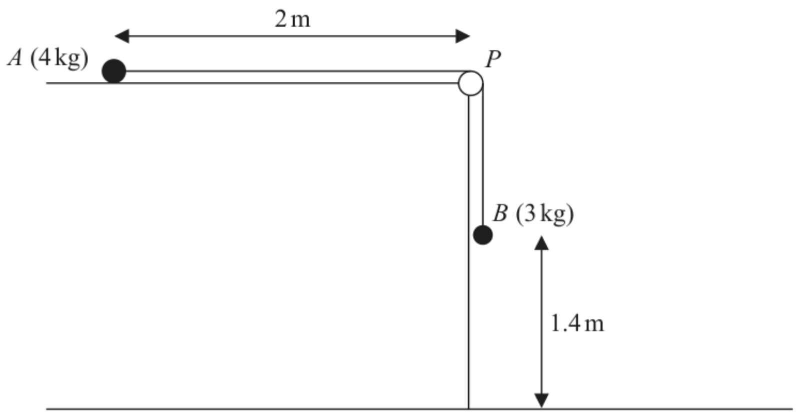

Figure 3

A particle A of mass 4 kg is held at rest on a rough horizontal table. Particle A is attached to one end of a string that passes over a pulley P. The pulley is fixed at the edge of the table. The other end of the string is attached to a particle B, of mass 3 kg, which hangs freely below P.

The part of the string from A to P is perpendicular to the edge of the table and A, P and B all lie in the same vertical plane.

The string is modelled as being light and inextensible and the pulley is modelled as being small, smooth and light.

The system is released from rest with the string taut. At the instant of release, A is 2 m from the edge of the table and B is 1.4 m above a horizontal floor, as shown in Figure 3.

After descending with constant acceleration for 2 seconds, B hits the floor and does not rebound.

(a) Show that the acceleration of A before B hits the floor is $0.7\,\text{m s}^{-2}$

(2)

(b) State which of the modelling assumptions you have used in order to answer part (a).

(1)

(c) Find the magnitude of the resultant force exerted on the pulley by the string.

(4)

The coefficient of friction between A and the table is μ.

(d) Find the value of μ.

(6)

(e) Determine, by calculation, whether or not A reaches the pulley.

(5)

(Total 18 marks)

WME01/01 JANUARY 2021

Question 5

7 marks

Forces

Also in Forces

Primary: Working with Vectors

5. A particle is acted upon by two forces **F** and **G**. The force **F** has magnitude 8 N and acts in a direction with a bearing of 240°. The force **G** has magnitude 10 N and acts due South.

Given that $\mathbf{R} = \mathbf{F} + \mathbf{G}$, find

(i) the magnitude of **R**,

(ii) the direction of **R**, giving your answer as a bearing to the nearest degree.

(7)

9 marks

WME01/01 MAY/JUNE 2021

Forces

Question 3

Also in Forces

Primary: Working with Vectors

3. [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors.*]

Three forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, are given by

$$\mathbf{F}_1 = (5\mathbf{i} + 2\mathbf{j})\,\text{N} \qquad \mathbf{F}_2 = (-3\mathbf{i} + \mathbf{j})\,\text{N} \qquad \mathbf{F}_3 = (a\mathbf{i} + b\mathbf{j})\,\text{N}$$

where a and b are constants.

The forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ act on a particle P of mass 4 kg.

Given that P rests in equilibrium on a smooth horizontal surface under the action of these three forces,

(a) find the size of the angle between the direction of $\mathbf{F}_3$ and the direction of $-\mathbf{j}$.

(4)

The force $\mathbf{F}_3$ is now removed and replaced by the force $\mathbf{F}_4$ given by $\mathbf{F}_4 = \lambda(\mathbf{i} + 3\mathbf{j})\,\text{N}$, where λ is a positive constant.

When the three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_4$ act on P, the acceleration of P has magnitude $3.25\,\text{m}\,\text{s}^{-2}$

(b) Find the value of λ.

(5)

WME01/01 OCTOBER 2021

Question 1

6 marks

Forces

Also in Forces

Primary: Moments

1.

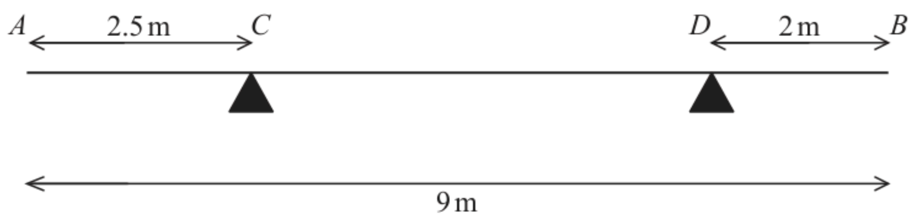

Figure 1

A non-uniform rod AB has length 9 m and mass M kg.

The rod rests in equilibrium in a horizontal position on two supports, one at C where $AC = 2.5$ m and the other at D where $DB = 2$ m, as shown in Figure 1.

The magnitude of the force acting on the rod at D is twice the magnitude of the force acting on the rod at C.

The centre of mass of the rod is d metres from A.

Find the value of d.

(6)

WME01/01 JANUARY 2022

Question 5

8 marks

Forces

Also in Forces

Primary: Resolving Forces, Inclined Planes

5.

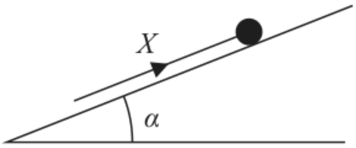

Figure 3

A particle of mass m rests in equilibrium on a fixed rough plane under the action of a force of magnitude X. The force acts up a line of greatest slope of the plane, as shown in Figure 3.

The plane is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{3}{4}$

The coefficient of friction between the particle and the plane is μ.

- When $X = 2P$, the particle is on the point of sliding up the plane.
- When $X = P$, the particle is on the point of sliding down the plane.

Find the value of μ.

(8)

WME01/01 MAY/JUNE 2022

Question 5

9 marks

Forces

Also in Forces

Primary: Moments

5.

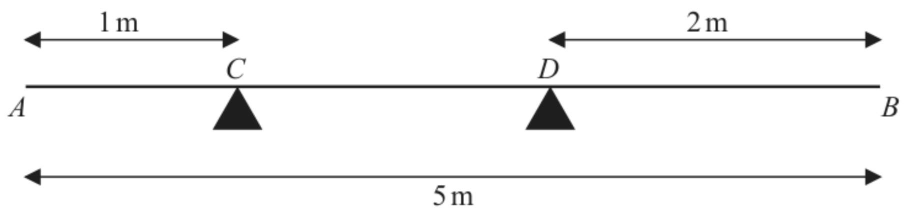

Figure 2

A uniform rod AB has length 5 m and mass 5 kg. The rod rests in equilibrium in a horizontal position on two supports C and D, where $AC = 1\text{ m}$ and $DB = 2\text{ m}$, as shown in Figure 2.

A particle of mass 10 kg is placed on the rod at A and a particle of mass M kg is placed on the rod at B. The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the magnitude of the reaction on the rod at C.

(3)

(b) Find, in terms of M, the magnitude of the reaction on the rod at D.

(3)

(c) Hence, or otherwise, find the range of possible values of M.

(3)

WME01/01 OCTOBER 2022

Question 3

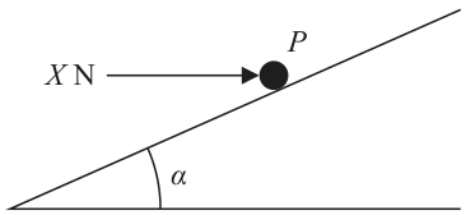

Figure 2

A rough plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$

A particle P of mass 2 kg is held in equilibrium on the plane by a horizontal force of magnitude X newtons, as shown in Figure 2. The force acts in a vertical plane which contains a line of greatest slope of the inclined plane.

(a) Show that when $X = 14.7$ there is no frictional force acting on P

(3)

The coefficient of friction between P and the plane is 0.5

(b) Find the smallest possible value of X.

(8)

10 marks

Forces

WME01/01 MAY/JUNE 2023

Question 2

Also in Forces

Primary: Working with Vectors

[*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors*.]

2. A particle P rests in equilibrium on a smooth horizontal plane.

A system of **three** forces, $\mathbf{F}_1$ N, $\mathbf{F}_2$ N and $\mathbf{F}_3$ N where

$$\mathbf{F}_1 = (3c\mathbf{i} + 4c\mathbf{j})$$
$$\mathbf{F}_2 = (-14\mathbf{i} + 7\mathbf{j})$$

is applied to P.

Given that P remains in equilibrium,

(a) find $\mathbf{F}_3$ in terms of c, **i** and **j**.

(2)

The force $\mathbf{F}_3$ is **removed** from the system.

Given that $c = 2$

(b) find the size of the angle between the direction of **i** and the direction of the resultant force acting on P.

(4)

The mass of P is m kg.

Given that the magnitude of the acceleration of P is $8.5\,\text{m}\,\text{s}^{-2}$

(c) find the value of m.

(4)

WME01/01 JANUARY 2024

Question 5

10 marks

Forces

Also in Forces

Primary: Moments

5.

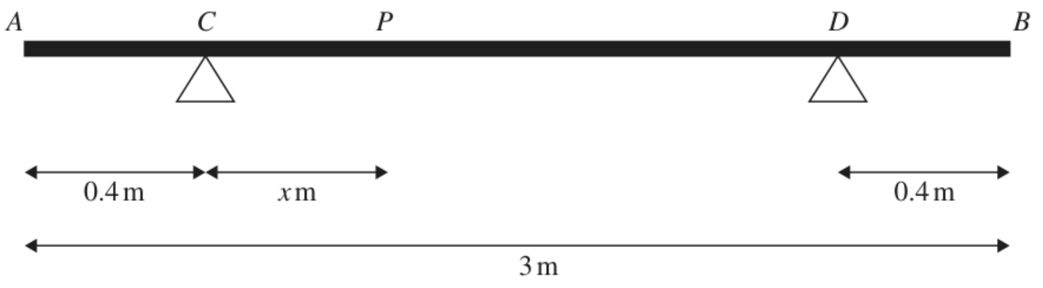

Figure 4

A beam AB has mass 30 kg and length 3 m.

The beam rests on supports at C and D where $AC = 0.4$ m and $DB = 0.4$ m, as shown in Figure 4.

A person of mass 55 kg stands on the beam between C and D.

The person is modelled as a particle at the point P, where $CP = x$ metres and $0 < x < 2.2$

The beam is modelled as a uniform rod resting in equilibrium in a horizontal position.

Using the model,

(a) show that the magnitude of the reaction at C is $(686 - 245x)$ N.

(3)

The magnitude of the reaction at C is **four** times the magnitude of the reaction at D.

Using the model,

(b) find the value of x

(4)

The person steps off the beam and places a package of mass M kg at A.

The package is modelled as a particle at the point A.

The beam is now on the point of tilting about C.

Using the model,

(c) find the value of M

(3)

WME01/01 MAY/JUNE 2024

Question 4

6 marks

Forces

Also in Forces

Primary: Moments

4.

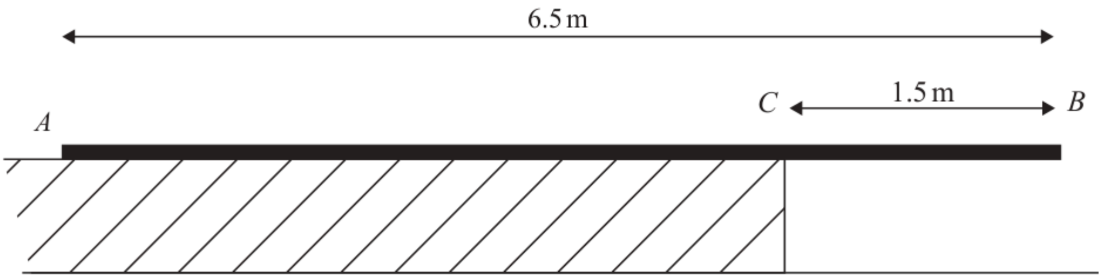

Figure 2

A non-uniform rod AB has length 6.5 m and mass 1.2 kg. The centre of mass of the rod is 3 m from A. The rod rests on a horizontal step and overhangs the end of the step C by 1.5 m, as shown in Figure 2.

The rod is perpendicular to the edge of the step.

A particle of mass 4 kg is placed on the rod at B and another particle, whose mass is M kg, is placed on the rod at D, where $AD = 0.5$ m.

The rod remains in equilibrium in a horizontal position.

(a) Find the smallest possible value of M.

(3)

The particle at B **and** the particle at D are now **removed**.

A new particle is placed on the rod at the point E, where $EB = 0.9$ m.

The rod remains in equilibrium in a horizontal position but is on the point of tilting about C.

(b) Find the magnitude of the force acting on the rod at C.

(3)

WME01/01 JANUARY 2025

Question 6

12 marks

Forces

Also in Forces

Primary: Resolving Forces, Inclined Planes

6.

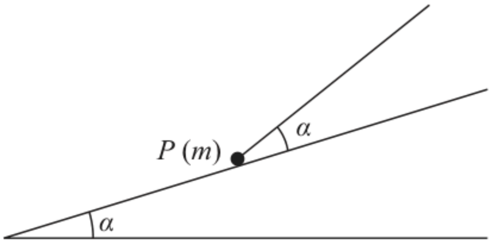

Figure 3

A particle P of mass m is held in equilibrium on a fixed rough inclined plane by a light inextensible string.

The plane is inclined at an angle α to the horizontal, where $\alpha < 45°$
The string is inclined to the plane at angle α, as shown in Figure 3.

The string lies in a vertical plane that contains a line of greatest slope of the inclined plane.

When the tension in the string is $0.75\,mg$, P is on the point of moving up the plane.

(a) Find an expression for the magnitude of the frictional force acting on P, giving your answer in terms of m, g and α.

(3)

The coefficient of friction between P and the plane is $\frac{1}{2}$

(b) Show that

$$\tan\alpha = \frac{2}{5}$$

(6)

The string breaks.

(c) Determine whether P remains at rest. You must justify your reasoning.

(3)

WME01/01 MAY/JUNE 2025

Question 5

6 marks

Forces

Also in Forces

Primary: Moments

5.

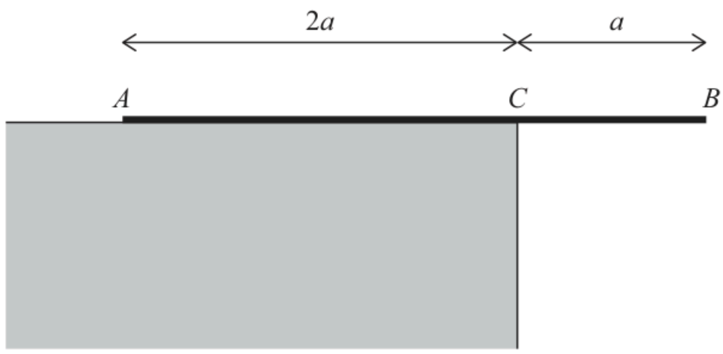

Figure 3

A non-uniform rod AB of length $3a$ rests in equilibrium on a horizontal ledge and overhangs the edge of the ledge at C.
The point C is such that $AC = 2a$ and $CB = a$, as shown in Figure 3.

The rod has weight W.

The distance of the centre of mass of the rod from A is d.

The rod is perpendicular to the edge of the ledge.

When a force of magnitude P, **acting vertically upwards**, is applied to the rod at B, the rod is on the point of tilting about A.

When the force applied at B is replaced by a force of magnitude $1.25P$, **acting vertically downwards** at B, the rod is on the point of tilting about C.

Find d in terms of a.

(6)

TOPIC

Newton's Second Law

WME01/01 OCTOBER 2019

7 marks

Question 3

Newton's Second Law

3. A car of mass 800 kg is towing a trailer of mass 400 kg up a straight road using a towbar. The towbar is parallel to the road and parallel to the direction of motion of the car. The road is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{1}{7}$. The engine of the car produces a constant driving force of magnitude D newtons. The resistance to the motion of the car from non-gravitational forces is modelled as a single force of magnitude 420 N. The resistance to the motion of the trailer from non-gravitational forces is modelled as a single force of magnitude 300 N. The car and trailer are modelled as particles and the towbar is modelled as a light rod.

Given that the tension in the towbar is 2060 N, find the value of D.

(7)

WME01/01 JANUARY 2020

Question 7

18 marks

Newton's Second Law

7.

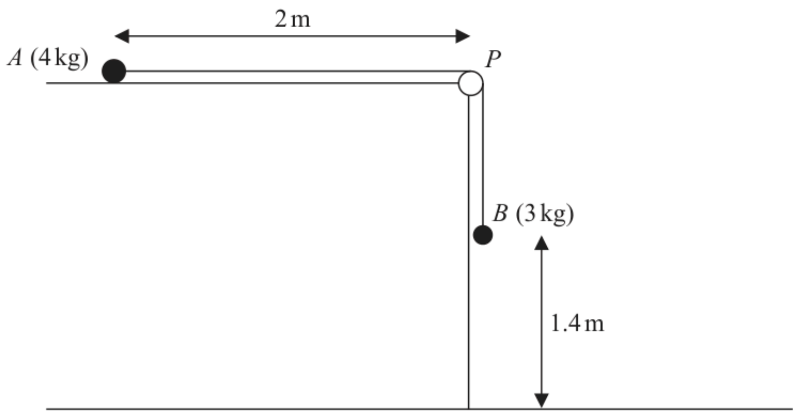

Figure 3

A particle A of mass 4 kg is held at rest on a rough horizontal table. Particle A is attached to one end of a string that passes over a pulley P. The pulley is fixed at the edge of the table. The other end of the string is attached to a particle B, of mass 3 kg, which hangs freely below P.

The part of the string from A to P is perpendicular to the edge of the table and A, P and B all lie in the same vertical plane.

The string is modelled as being light and inextensible and the pulley is modelled as being small, smooth and light.

The system is released from rest with the string taut. At the instant of release, A is 2 m from the edge of the table and B is 1.4 m above a horizontal floor, as shown in Figure 3.

After descending with constant acceleration for 2 seconds, B hits the floor and does not rebound.

(a) Show that the acceleration of A before B hits the floor is $0.7\,\text{m s}^{-2}$

(2)

(b) State which of the modelling assumptions you have used in order to answer part (a).

(1)

(c) Find the magnitude of the resultant force exerted on the pulley by the string.

(4)

The coefficient of friction between A and the table is μ.

(d) Find the value of μ.

(6)

(e) Determine, by calculation, whether or not A reaches the pulley.

(5)

(Total 18 marks)

6 marks

Question 4

Newton's Second Law

4.

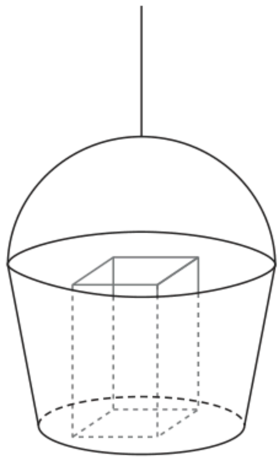

Figure 1

Figure 1 shows a large bucket used by a crane on a building site to move materials between the ground and the top of the building. The mass of the bucket is 15 kg.

The bucket is attached to a vertical cable with the bottom of the bucket horizontal. The cable is modelled as light and inextensible.

When the bucket is on the ground, a bag of cement of mass 25 kg is placed in the bucket.

The bucket with the bag of cement moves vertically upwards with constant acceleration $0.2\,\text{m}\,\text{s}^{-2}$. Air resistance is modelled as being negligible.

(a) Find the tension in the cable.

(3)

At the top of the building, the bag of cement is removed. A box of tools of mass 12 kg is now placed in the bucket.

Later on the bucket with the box of tools is moving vertically downwards with constant deceleration $0.1\,\text{m}\,\text{s}^{-2}$. Air resistance is again modelled as being negligible.

(b) Find the magnitude of the normal reaction between the bucket and the box of tools.

(3)

WME01/01 MAY/JUNE 2022

7 marks

Question 3

Newton's Second Law

3. A tractor of mass 6 tonnes is dragging a large block of mass 2 tonnes along rough horizontal ground. The cable connecting the tractor to the block is horizontal and parallel to the direction of motion.

The cable is modelled as being light and inextensible.

The driving force of the tractor is 7400 N and the resistance to the motion of the tractor is 200 N. The resistance to the motion of the block is R newtons, where R is a constant.

Given that the tension in the cable is 6000 N and the tractor is accelerating,

(a) find the value of R.

(6)

(b) State how you have used the fact that the cable is modelled as being inextensible.

(1)

WME01/01 OCTOBER 2022

6 marks

Question 4

Newton's Second Law

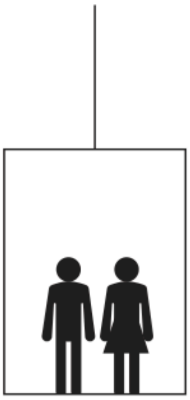

Figure 3

Two children, Alan and Bhavana, are standing on the horizontal floor of a lift, as shown in Figure 3.

The lift has mass 250 kg. The lift is raised vertically upwards with constant acceleration by a vertical cable which is attached to the top of the lift. The cable is modelled as being light and inextensible. While the lift is accelerating upwards, the tension in the cable is 3616 N.

As the lift accelerates upwards, the floor of the lift exerts a force of magnitude 565 N on Alan and a force of magnitude 226 N on Bhavana.

Air resistance is modelled as being negligible and Alan and Bhavana are modelled as particles.

(a) By considering the forces acting on the lift only, find the acceleration of the lift.

(3)

(b) Find the mass of Alan.

(3)

13 marks

Question 7

Newton's Second Law

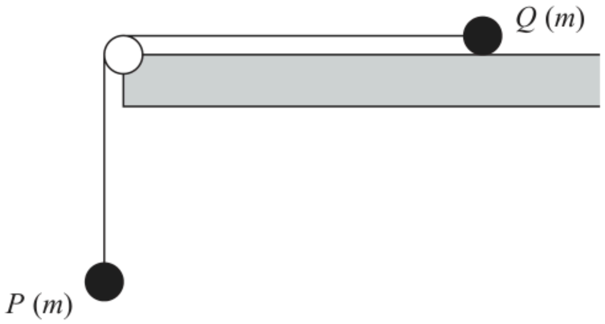

Figure 4

A particle P of mass m is attached to one end of a light inextensible string. Another particle Q, also of mass m, is attached to the other end of the string. The string passes over a small smooth pulley which is fixed at the edge of a rough horizontal table. Particle Q is held at rest on the table and particle P hangs vertically below the pulley with the string taut, as shown in Figure 4.

The pulley, P and Q all lie in the same vertical plane.

The coefficient of friction between Q and the table is μ, where $\mu < 1$

Particle Q is released from rest.

The tension in the string before Q hits the pulley is kmg, where k is a constant.

(a) Find k in terms of μ.

(7)

Given that Q is initially a distance d from the pulley,

(b) find, in terms of d, g and μ, the time taken by Q, after release, to reach the pulley.

(4)

(c) Describe what would happen if $\mu \geqslant 1$, giving a reason for your answer.

(2)

WME01/01 JANUARY 2023

7 marks

Question 7

Newton's Second Law

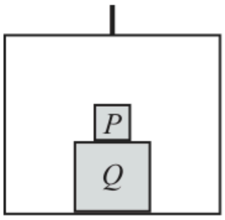

Figure 4

A simple lift operates by means of a vertical cable which is attached to the top of the lift.
The lift has mass m
A box Q is placed on the floor of the lift.
A box P is placed directly on top of box Q, as shown in Figure 4.

The cable is modelled as being light and inextensible and air resistance is modelled as being negligible.

The tension in the cable is $\frac{42mg}{5}$

The lift and its contents move vertically upwards with acceleration $\frac{2g}{5}$

Using the model,

(a) find, in terms of m, the combined mass of boxes P and Q

(4)

During the motion of the lift, the force exerted on box P by box Q is $\frac{14mg}{5}$

Using the model,

(b) find, in terms of m, the mass of box P

(3)

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11 marks

Question 7

Newton's Second Law

7.

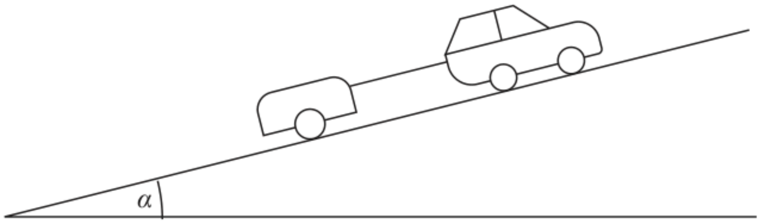

Figure 4

A car of mass 1200 kg is towing a trailer of mass 600 kg up a straight road, as shown in Figure 4.

The road is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{12}$

The driving force produced by the engine of the car is 3000 N.

The car moves with acceleration $0.75\,\text{m s}^{-2}$

The non-gravitational resistance to motion of

- the **car** is modelled as a constant force of magnitude $2R$ newtons
- the **trailer** is modelled as a constant force of magnitude R newtons

The car and the trailer are modelled as particles.
The tow bar between the car and trailer is modelled as a light rod that is parallel to the direction of motion.

Using the model,

(a) show that the value of R is 60

(4)

(b) find the tension in the tow bar.

(3)

When the car and trailer are moving at a speed of $12\,\text{m s}^{-1}$, the tow bar breaks.

Given that the non-gravitational resistance to motion of the trailer remains unchanged,

(c) use the model to find the further distance moved by the trailer before it first comes to rest.

(4)

WME01/01 MAY/JUNE 2024

Question 3

6 marks

Newton's Second Law

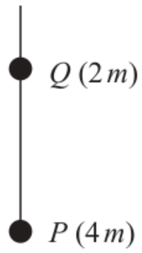

Figure 1

Two particles, P and Q, have masses $4m$ and $2m$ respectively. The particles are connected by a light inextensible string. A second light inextensible string has one end attached to Q. Both strings are taut and vertical, as shown in Figure 1.

The particles are **accelerating** vertically **downwards**.

Given that the tension in the string connecting the two particles is $3mg$, find, in terms of m and g, the tension in the upper string.

(6)

WME01/01 OCTOBER 2024

Question 5

13 marks

Newton's Second Law

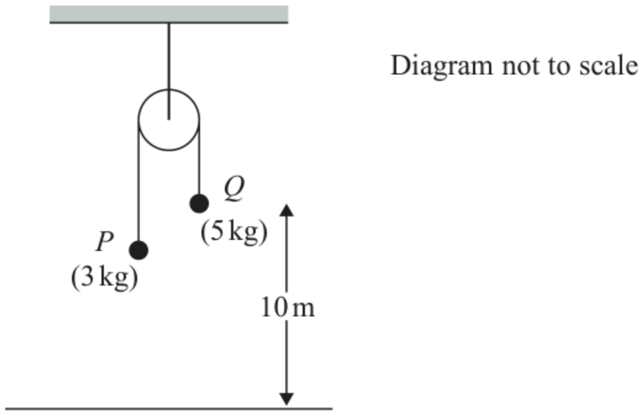

Figure 3

Two particles, P and Q, have masses 3 kg and 5 kg respectively. The particles are connected by a light inextensible string which passes over a small smooth fixed pulley.

The particles are released from rest with the string taut and the hanging parts of the string vertical, as shown in Figure 3.

Immediately after the particles are released from rest, P moves upwards with acceleration $a\,\text{m s}^{-2}$ and the tension in the string is T newtons.

(a) Write down an equation of motion for P.

(2)

(b) Find the value of T.

(4)

The total force acting on the pulley due to the string has magnitude F newtons.

(c) Find the value of F.

(2)

Initially, Q is 10 m above horizontal ground and P is more than 2 m below the pulley.

At the instant when Q has descended a distance of 2 m, the string breaks and Q falls to the ground.

(d) Find the speed of Q at the instant it hits the ground.

(5)

WME01/01 JANUARY 2025

Question 7

15 marks

Newton's Second Law

7.

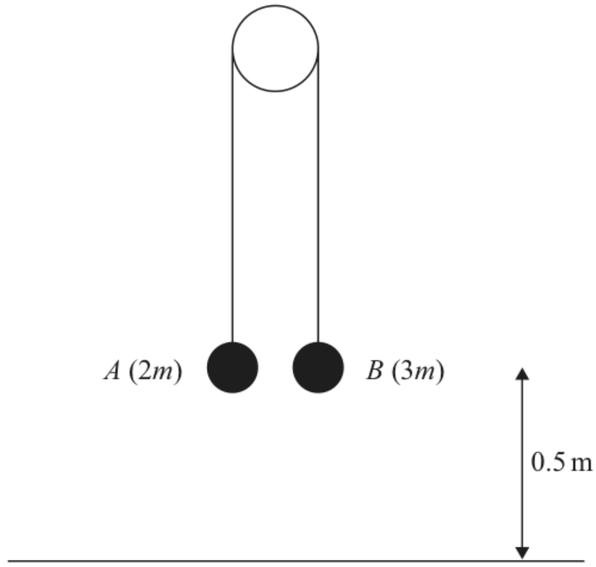

Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$.
The other end is attached to a particle B of mass $3m$.
The string passes over a small smooth fixed pulley.
The string is taut and both straight parts of the string are vertical.
Both particles are held at a distance 0.5 m above a horizontal surface, as shown in Figure 4.

The system is released from rest and B moves downwards.

(a) Find the tension in the string in terms of m and g.

(5)

(b) Find the speed of B at the instant it strikes the surface.

(4)

In the subsequent motion, A does not reach the pulley and B does not rebound after it strikes the surface.

(c) Find the time from the instant when the system is released from rest to the instant when A first reaches a height of 1.06 m above the surface.

(6)

WME01/01 MAY/JUNE 2025

Question 8

17 marks

Newton's Second Law

8.

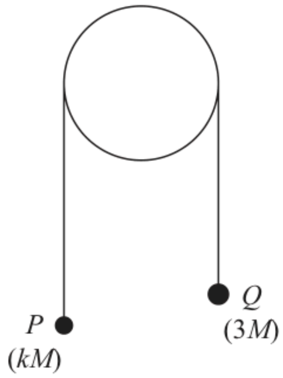

Figure 5

Two small balls, P and Q, have masses kM and $3M$ respectively, where $k < 3$

The balls are attached to the ends of a light inextensible string that passes over a fixed light smooth pulley.

The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 5.

The system is released from rest and, in the subsequent motion, P moves with an acceleration of magnitude $\frac{1}{5}g$

The balls are modelled as particles.

(a) Write down an equation of motion for P.

(2)

(b) Find the value of k.

(3)

Given that $M = 0.5$ kg,

(c) find the magnitude of the force exerted on the pulley by the string while Q is moving downwards.

(3)

At the instant when the system is released, P is more than 2.5 m from the pulley and Q is 2.5 m above horizontal ground.
After hitting the ground, Q rebounds with a speed of $0.4\,\text{m s}^{-1}$

(d) Find the magnitude of the impulse received by Q when it hits the ground.

(5)

In the subsequent motion, P does not hit the pulley.

(e) Find the total time from when the balls are released until P first comes to rest.

(4)

WME01/01 OCTOBER 2019

Question 1

6 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Momentum, Impulse & Collisions

1. Two particles, P and Q, have masses $3m$ and $2m$ respectively. The particles are connected by a light inextensible string. Initially P and Q are at rest on a smooth horizontal plane with the string slack.

Particle P is then projected along the plane directly away from Q with speed $4u$. At the same instant, particle Q is projected along the plane in the opposite direction with speed $3u$.

Find

(a) the common speed of the particles immediately after the string becomes taut,
(3)

(b) the magnitude of the impulse exerted on Q at the instant when the string becomes taut.
(3)

WME01/01 OCTOBER 2019

Question 5

8 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

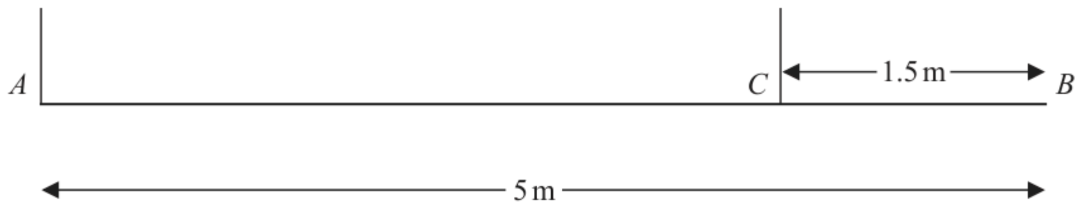

Figure 2

A non-uniform beam, *AB*, has length 5 m and mass 12 kg. The beam is suspended in a horizontal position by two vertical ropes. One rope is attached to the beam at *A*. The other rope is attached to the beam at *C*, where $CB = 1.5$ m, as shown in Figure 2. The distance of the centre of mass of the beam from *A* is 1.75 m. The beam is modelled as a non-uniform rod and the ropes are modelled as light inextensible strings.

A particle of mass *M* kg is now placed on the beam at *B* and the beam remains in equilibrium in a horizontal position.

(a) Find the largest possible value of *M*.

(3)

The particle at *B* is now removed and a particle of mass 15 kg is now placed on the beam at the point *D*, where $AD = x$ metres. The beam remains in equilibrium in a horizontal position.

Given that the tension in the rope attached to the beam at *C* is now twice the tension in the rope attached to the beam at *A*,

(b) find the value of *x*.

(5)

WME01/01 OCTOBER 2019

Question 6

12 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Kinematics Graphs

6. An athlete runs a 200 m race along a straight horizontal track.

In a model of the motion of the athlete, air resistance is ignored, the athlete starts from rest at time $t = 0$ seconds and moves with uniform acceleration $0.8\,\text{m s}^{-2}$ for T seconds, reaching a speed of $V\,\text{m s}^{-1}$. She then maintains this speed until she crosses the finishing line.

The total time from when the athlete starts to when she crosses the finishing line is 30 s.

(a) Sketch a speed-time graph for the model of the motion of the athlete from the instant when she starts to the instant when she crosses the finishing line.

(2)

(b) Write down an expression for V in terms of T.

(1)

(c) Show that $T^2 - kT + 500 = 0$, where k is a constant to be found.

(4)

(d) Hence find the value of T, justifying your answer carefully.

(3)

(e) Considering your speed-time graph or otherwise, state two ways, apart from including air resistance, in which the model could be made to be more realistic.

(2)

WME01/01 JANUARY 2020

Question 2

7 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

2.

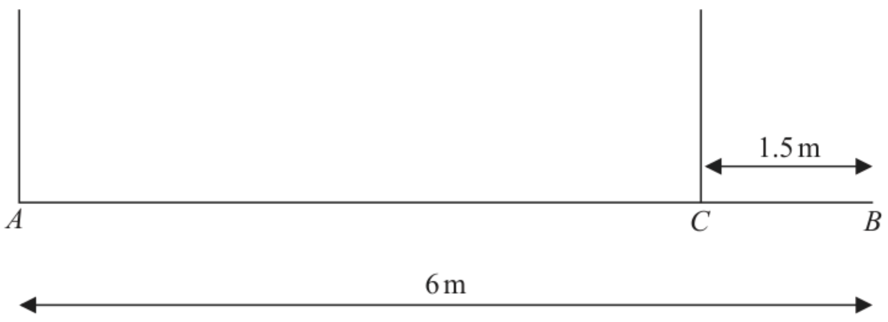

Figure 1

A non-uniform beam AB has length 6 m and weight W newtons. The beam is supported in equilibrium in a horizontal position by two vertical ropes, one attached to the beam at A and the other attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 1.

The centre of mass of the beam is 2.625 m from A.

The ropes are modelled as light strings. The beam is modelled as a non-uniform rod.

Given that the tension in the rope attached at C is 20 N greater than the tension in the rope attached at A,

(a) find the value of W.

(6)

(b) State how you have used the fact that the beam is modelled as a rod.

(1)

WME01/01 JANUARY 2020

Question 4

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

4.

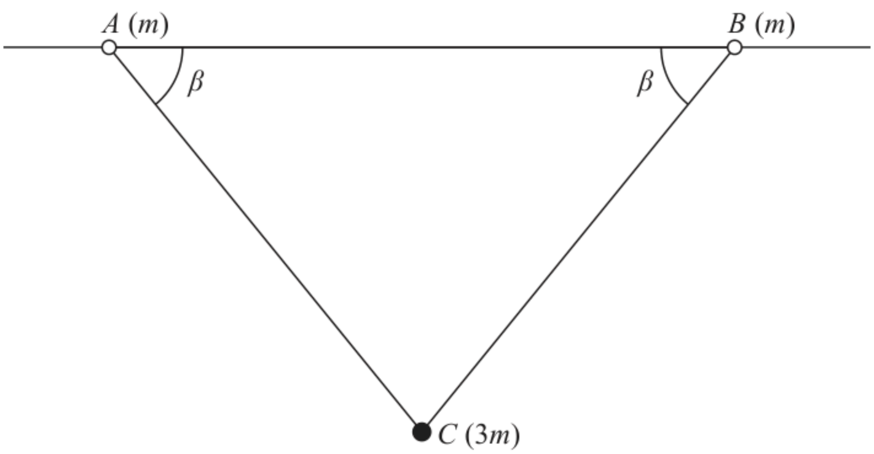

Figure 2

Two identical small rings, A and B, each of mass m, are threaded onto a rough horizontal wire. The rings are connected by a light inextensible string. A particle C of mass $3m$ is attached to the midpoint of the string. The particle C hangs in equilibrium below the wire with angle $BAC = \beta$, as shown in Figure 2.

The tension in each of the parts, AC and BC, of the string is T

(a) By considering particle C, find T in terms of m, g and β

(2)

(b) Find, in terms of m and g, the magnitude of the normal reaction between the wire and A.

(3)

The coefficient of friction between each ring and the wire is $\frac{4}{5}$

The two rings, A and B, are on the point of sliding along the wire towards each other.

(c) Find the value of $\tan\beta$

(5)

WME01/01 JANUARY 2021

Question 4

6 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

4.

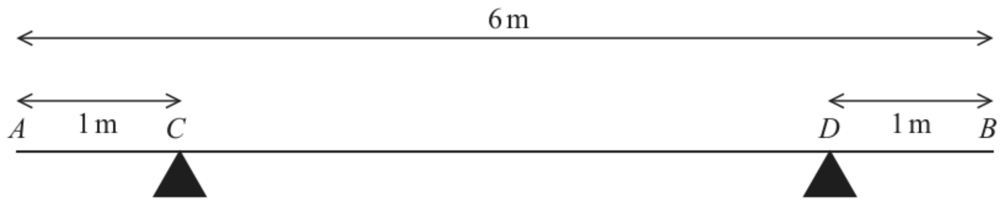

Figure 2

A metal girder AB has weight W newtons and length 6 m. The girder rests in a horizontal position on two supports C and D where $AC = DB = 1$ m, as shown in Figure 2.

When a force of magnitude 900 N is applied vertically upwards to the girder at A, the girder is about to tilt about D.

When a force of magnitude 1500 N is applied vertically upwards to the girder at B, the girder is about to tilt about C.

The girder is modelled as a non-uniform rod whose centre of mass is a distance x metres from A.

Find the value of x.

(6)

WME01/01 JANUARY 2021

Question 8

17 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

8.

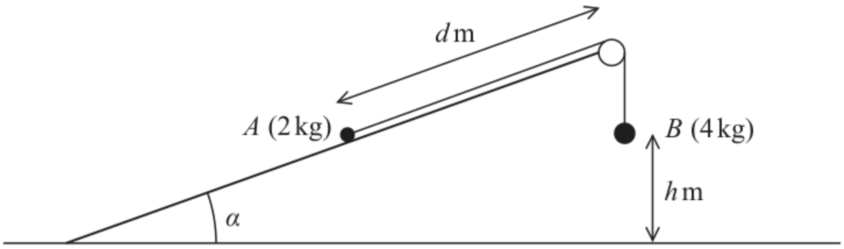

Figure 3

Two particles, A and B, have masses 2 kg and 4 kg respectively. The particles are connected by a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a rough plane. The plane is inclined to the horizontal ground at an angle α where $\tan\alpha = \frac{3}{4}$. The particle A is held at rest on the plane at a distance d metres from the pulley. The particle B hangs freely at rest, vertically below the pulley, at a distance h metres above the ground, as shown in Figure 3. The part of the string between A and the pulley is parallel to a line of greatest slope of the plane. The coefficient of friction between A and the plane is $\frac{1}{4}$

The system is released from rest with the string taut and B descends.

(a) Find the tension in the string as B descends.

(9)

On hitting the ground, B immediately comes to rest.

Given that A comes to rest before reaching the pulley,

(b) find, in terms of h, the range of possible values of d.

(7)

(c) State one physical factor, other than air resistance, that could be taken into account to make the model described above more realistic.

(1)

(Total 17 marks)

8 marks

Newton's Second Law

WME01/01 MAY/JUNE 2021

Question 2

Also in Newton's Second Law

Primary: Constant Acceleration in 1D

2. A car moves along a straight horizontal road with constant acceleration $a\,\text{m s}^{-2}$ where $a > 0$

The car is modelled as a particle.

At time $t = 0$, the car passes point A and is moving with speed $u\,\text{m s}^{-1}$

In the first three seconds after passing A the car travels 20 m.

In the fourth second after passing A the car travels 10 m.

The speed of the car as it passes point B is $20\,\text{m s}^{-1}$

Find the time taken for the car to travel from A to B.

(8)

WME01/01 MAY/JUNE 2021

Question 3

9 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Working with Vectors

3. [*In this question* **i** *and* **j** *are perpendicular horizontal unit vectors.*]

Three forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, are given by

$$\mathbf{F}_1 = (5\mathbf{i} + 2\mathbf{j})\,\text{N} \qquad \mathbf{F}_2 = (-3\mathbf{i} + \mathbf{j})\,\text{N} \qquad \mathbf{F}_3 = (a\mathbf{i} + b\mathbf{j})\,\text{N}$$

where a and b are constants.

The forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ act on a particle P of mass 4 kg.

Given that P rests in equilibrium on a smooth horizontal surface under the action of these three forces,

(a) find the size of the angle between the direction of $\mathbf{F}_3$ and the direction of $-\mathbf{j}$.

(4)

The force $\mathbf{F}_3$ is now removed and replaced by the force $\mathbf{F}_4$ given by $\mathbf{F}_4 = \lambda(\mathbf{i} + 3\mathbf{j})\,\text{N}$, where λ is a positive constant.

When the three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_4$ act on P, the acceleration of P has magnitude $3.25\ \text{m s}^{-2}$

(b) Find the value of λ.

(5)

Question 2

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Momentum, Impulse & Collisions

2. A particle P of mass $2m$ is moving on a rough horizontal plane when it collides directly with a particle Q of mass $4m$ which is at rest on the plane. The speed of P immediately before the collision is $3u$. The speed of Q immediately after the collision is $2u$.

(a) Find, in terms of u, the speed of P immediately after the collision.

(3)

(b) State clearly the direction of motion of P immediately after the collision.

(1)

Following the collision, Q comes to rest after travelling a distance $\frac{6u^2}{g}$ along the plane.

The coefficient of friction between Q and the plane is μ.

(c) Find the value of μ.

(6)

WME01/01 OCTOBER 2021

Question 5

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

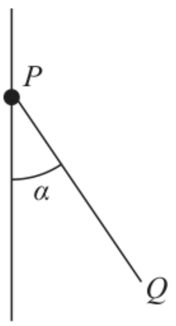

Figure 2

A small bead of mass 0.2 kg is attached to the end P of a light rod PQ. The bead is threaded onto a fixed vertical rough wire.

The bead is held in equilibrium with the rod PQ inclined to the wire at an angle α, where $\tan\alpha = \frac{4}{3}$, as shown in Figure 2.

The thrust in the rod is T newtons.

The bead is modelled as a particle.

(a) Find the magnitude and direction of the friction force acting on the bead when $T = 2.5$

(3)

The coefficient of friction between the bead and the wire is μ.

Given that the greatest possible value of T is 6.125

(b) find the value of μ.

(7)

WME01/01 OCTOBER 2021

Question 7

14 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

7.

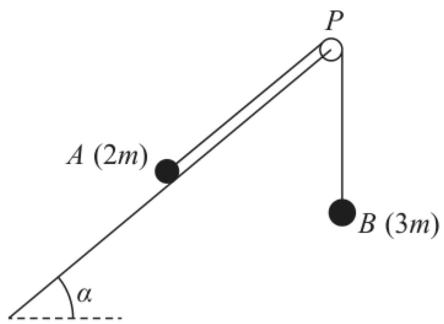

Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$. The other end of the string is attached to a particle B of mass $3m$. The string passes over a small, smooth, light pulley P which is fixed at the top of a rough inclined plane. The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

Particle A is held at rest on the plane with the string taut and B hanging freely below P, as shown in Figure 4. The section of the string AP is parallel to a line of greatest slope of the plane.

The coefficient of friction between A and the plane is $\frac{1}{2}$

Particle A is released and begins to move up the plane.

For the motion before A reaches the pulley,

(a) (i) write down an equation of motion for A,

(ii) write down an equation of motion for B,

(4)

(b) find, in terms of g, the acceleration of A,

(5)

(c) find the magnitude of the force exerted on the pulley by the string.

(4)

(d) State how you have used the information that P is a smooth pulley.

(1)

WME01/01 JANUARY 2022

Question 6

12 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Working with Vectors

6. [*In this question* **i** *and* **j** *are horizontal unit vectors*.]

A particle P of mass 2 kg moves under the action of two forces, $(p\mathbf{i} + q\mathbf{j})$ N and $(2q\mathbf{i} + p\mathbf{j})$ N, where p and q are constants.

Given that the acceleration of P is $(\mathbf{i} - \mathbf{j})\,\mathrm{m\,s^{-2}}$

(a) find the value of p and the value of q.

(5)

(b) Find the size of the angle between the direction of the acceleration and the vector **j**.

(2)

At time $t = 0$, the velocity of P is $(3\mathbf{i} - 4\mathbf{j})\,\mathrm{m\,s^{-1}}$

At $t = T$ seconds, P is moving in the direction of the vector $(11\mathbf{i} - 13\mathbf{j})$.

(c) Find the value of T.

(5)

WME01/01 JANUARY 2022

Question 7

13 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

7.

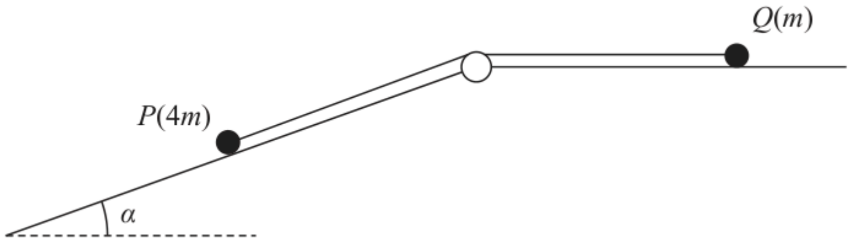

Figure 4

A particle P of mass $4m$ lies on the surface of a fixed rough inclined plane.

The plane is inclined to the horizontal at an angle α where $\tan\alpha = \frac{3}{4}$

The particle P is attached to one end of a light inextensible string.

The string passes over a small smooth pulley that is fixed at the top of the plane. The other end of the string is attached to a particle Q of mass m which lies on a smooth horizontal plane.

The string lies along the horizontal plane and in the vertical plane that contains the pulley and a line of greatest slope of the inclined plane.

The system is released from rest with the string taut, as shown in Figure 4, and P moves down the plane.

The coefficient of friction between P and the plane is $\frac{1}{4}$

For the motion before Q reaches the pulley

(a) write down an equation of motion for Q,

(1)

(b) find, in terms of m and g, the tension in the string,

(7)

(c) find the magnitude of the force exerted on the pulley by the string.

(4)

(d) State where in your working you have used the information that the string is light.

(1)

12 marks

WME01/01 MAY/JUNE 2022

Newton's Second Law

Question 4

Also in Newton's Second Law

Primary: Forces

4.

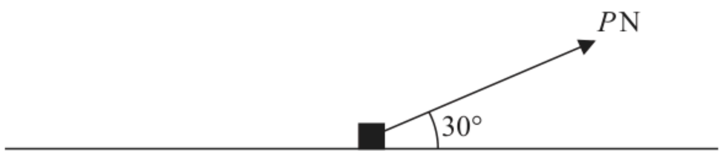

Figure 1

A small block of mass 5 kg lies at rest on a rough horizontal plane.

The coefficient of friction between the block and the plane is $\frac{3}{7}$

A force of magnitude P newtons is applied to the block in a direction which makes an angle of 30° with the plane, as shown in Figure 1.

The block is modelled as a particle.

Given that $P = 14$

(a) find the magnitude of the frictional force exerted on the block by the plane and describe what happens to the block, justifying your answer.

(6)

The value of P is now changed so that the block is on the point of slipping along the plane.

(b) Find the value of P

(6)

WME01/01 OCTOBER 2022

Question 2

6 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

Figure 1

A uniform rod AB has length $2a$ and mass M. The rod is held in equilibrium in a horizontal position by two vertical light strings which are attached to the rod at C and D, where $AC = \frac{2}{5}a$ and $DB = \frac{3}{5}a$, as shown in Figure 1.

A particle P is placed on the rod at B.

The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the largest possible mass of the particle P

(3)

Given that the mass of P is $\frac{1}{2}M$

(b) find, in terms of M and g, the tension in the string that is attached to the rod at C.

(3)

WME01/01 OCTOBER 2022

Question 6

9 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Working with Vectors

6. [*In this question,* **i** *and* **j** *are horizontal unit vectors.*]

A particle A of mass 0.5 kg is at rest on a smooth horizontal plane.

At time $t = 0$, two forces, $\mathbf{F}_1 = (-3\mathbf{i} + 2\mathbf{j})$ N and $\mathbf{F}_2 = (p\mathbf{i} + q\mathbf{j})$ N, where p and q are constants, are applied to A.

Given that A moves in the direction of the vector $(\mathbf{i} - 2\mathbf{j})$,

(a) show that $2p + q - 4 = 0$

(4)

Given that $p = 5$

(b) find the speed of A at time $t = 4$ seconds.

(5)

WME01/01 JANUARY 2023

Question 4

8 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

4.

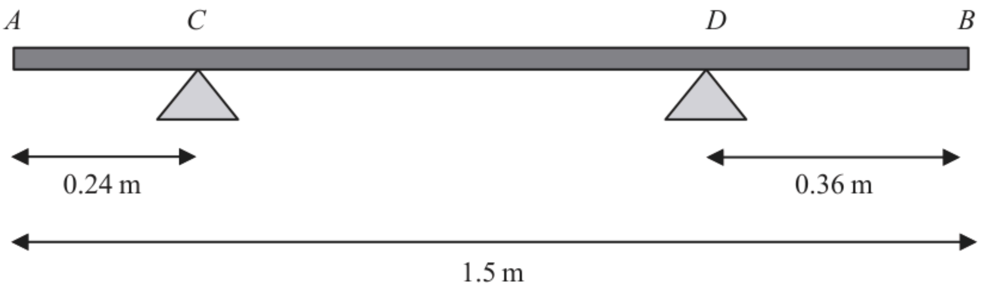

Figure 1

A branch *AB*, of length 1.5 m, rests horizontally in equilibrium on two supports.

The two supports are at the points *C* and *D*, where $AC = 0.24\,\text{m}$ and $DB = 0.36\,\text{m}$, as shown in Figure 1.

When a force of 150 N is applied vertically upwards at *B*, the branch is on the point of tilting about *C*.

When a force of 225 N is applied vertically downwards at *B*, the branch is on the point of tilting about *D*.

The branch is modelled as a non-uniform rod *AB* of weight *W* newtons.

The distance from the point *C* to the centre of mass of the rod is *x* metres.

Use the model to find

(i) the value of *W*

(ii) the value of *x*

(8)

WME01/01 JANUARY 2023

Question 5

9 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Constant Acceleration in 1D

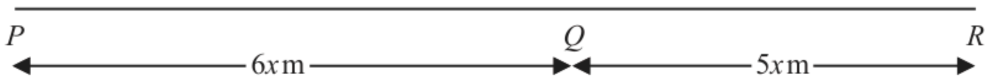

Figure 2

Three points P, Q and R are on a horizontal road where PQR is a straight line.

The point Q is between P and R, with $PQ = 6x$ metres and $QR = 5x$ metres, as shown in Figure 2.

A vehicle moves along the road from P to Q with constant acceleration.

The vehicle is modelled as a particle.

At time $t = 0$, the vehicle passes P with speed $u\,\text{m s}^{-1}$

At time $t = 12$ s, the vehicle passes Q with speed $2u\,\text{m s}^{-1}$

Using the model,

(a) show that $x = 3u$

(2)

As the vehicle passes Q, the acceleration of the vehicle changes instantaneously to $1.5\,\text{m s}^{-2}$

The vehicle continues to move with a constant acceleration of $1.5\,\text{m s}^{-2}$ and passes R with speed $3u\,\text{m s}^{-1}$

Using the model,

(b) find the value of u,

(3)

(c) find the distance travelled by the vehicle during the first 14 seconds after passing P

(4)

WME01/01 JANUARY 2023

Question 8

15 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

8.

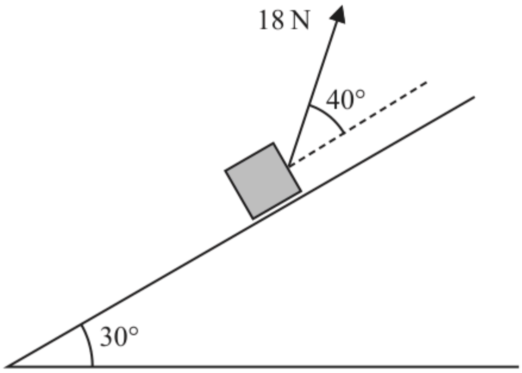

Figure 5

A parcel of mass 2 kg is pulled up a rough inclined plane by the action of a constant force.

The force has magnitude 18 N and acts at an angle of 40° to the plane.

The line of action of the force lies in a vertical plane containing a line of greatest slope of the inclined plane.

The plane is inclined at an angle of 30° to the horizontal, as shown in Figure 5.

The coefficient of friction between the plane and the parcel is 0.3

The parcel is modelled as a particle P

(a) Find the acceleration of P

(8)

The points A and B lie on a line of greatest slope of the plane, where $AB = 5\,\text{m}$ and B is above A. Particle P passes through A with speed $2\,\text{m}\,\text{s}^{-1}$ in the direction AB.

(b) Find the speed of P as it passes through B.

(3)

The force of 18 N is removed at the instant P passes through B. As a result, P comes to rest at the point C.

(c) Determine whether P will remain at rest at C. You must show all stages of your working clearly.

(4)

WME01/01 MAY/JUNE 2023

Question 2

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Working with Vectors

[*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

2. A particle P rests in equilibrium on a smooth horizontal plane.

A system of **three** forces, $\mathbf{F}_1$ N, $\mathbf{F}_2$ N and $\mathbf{F}_3$ N where

$$\mathbf{F}_1 = (3c\mathbf{i} + 4c\mathbf{j})$$
$$\mathbf{F}_2 = (-14\mathbf{i} + 7\mathbf{j})$$

is applied to P.

Given that P remains in equilibrium,

(a) find $\mathbf{F}_3$ in terms of c, **i** and **j**.

(2)

The force $\mathbf{F}_3$ is **removed** from the system.

Given that $c = 2$

(b) find the size of the angle between the direction of **i** and the direction of the resultant force acting on P.

(4)

The mass of P is m kg.

Given that the magnitude of the acceleration of P is $8.5\,\text{m s}^{-2}$

(c) find the value of m.

(4)

8 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Constant Acceleration in 1D

WME01/01 MAY/JUNE 2023

Question 3

3. Two students observe a book of mass 0.2 kg fall vertically from rest from a shelf that is 1.5 m above the floor.

Student A suggests that the book is modelled as a particle falling freely under gravity.

(a) Use student A's model to find the time taken for the book to reach the floor.

(3)

Student B suggests an improved model where the book is modelled as a particle experiencing a constant resistance to motion of magnitude R newtons.

Given that the time taken for the book to reach the floor is 0.6 seconds,

(b) use student B's model to find the value of R

(5)

WME01/01 MAY/JUNE 2023

Question 4

12 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

4.

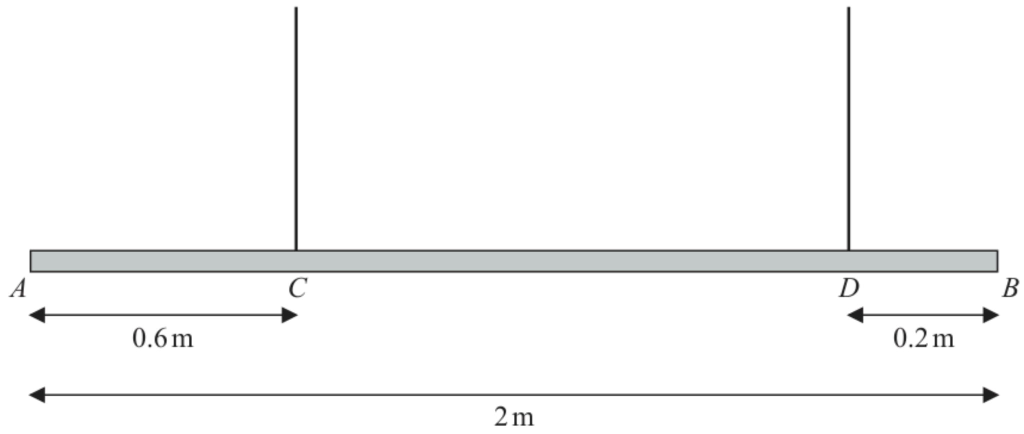

Figure 1

Figure 1 shows a beam AB, of mass m kg and length 2 m, suspended by two light vertical ropes.
The ropes are attached to the points C and D on the beam, where $AC = 0.6$ m and $DB = 0.2$ m
The beam is in equilibrium in a horizontal position.

A particle of mass pm kg is attached to the beam at A and the beam remains in equilibrium in a horizontal position.

The beam is modelled as a uniform rod.

(a) Given that the tension in the rope attached at C is four times the tension in the rope attached at D, use the model to find the exact value of p.

(7)

The particle of mass pm kg at A is removed and replaced by a particle of mass qm kg at A.
The beam remains in equilibrium in a horizontal position but is now on the point of tilting.

(b) Using the model, find the exact value of q

(4)

(c) State how you have used the modelling assumption that the beam is uniform.

(1)

WME01/01 MAY/JUNE 2023

Question 5

11 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Kinematics Graphs

5.

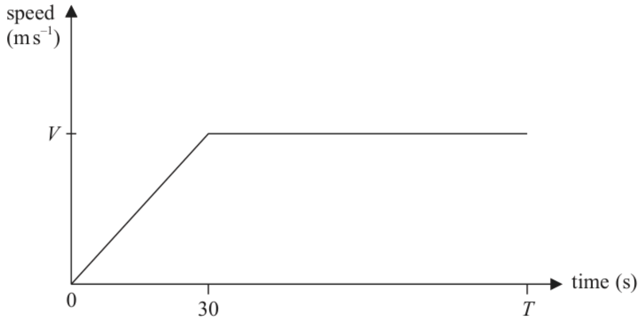

Figure 2

The speed-time graph in Figure 2 illustrates the motion of a car travelling along a straight horizontal road.
At time $t = 0$, the car starts from rest and accelerates uniformly for 30 s until it reaches a speed of V m s^{-1}
The car then travels at a constant speed of V m s^{-1} until time $t = T$ seconds.

(a) Show that the distance travelled by the car between $t = 0$ and $t = T$ seconds is $V(T - 15)$ metres.

(2)

A motorbike also travels along the same road.

- The motorbike starts from rest at time $\boldsymbol{t} = \mathbf{10}$ **s** and accelerates uniformly for 40 s
- The acceleration of the motorbike is the **same** as the acceleration of the car
- The motorbike then travels at a constant speed for a further 10 s before decelerating uniformly until it reaches a speed of V m s^{-1} at time T seconds

(b) On Figure 2, sketch a speed-time graph for the motion of the motorbike.

[*If you need to redraw your sketch, there is a copy of Figure 2 on page 15.*]

(2)

(c) Show that the constant speed of the motorbike is $\frac{4V}{3}$ m s^{-1}

(2)

At time $t = T$ seconds, the distance travelled by each vehicle is the same.

(d) Find the value of T

(5)

Only use this copy of Figure 2 if you need to redraw your sketch.

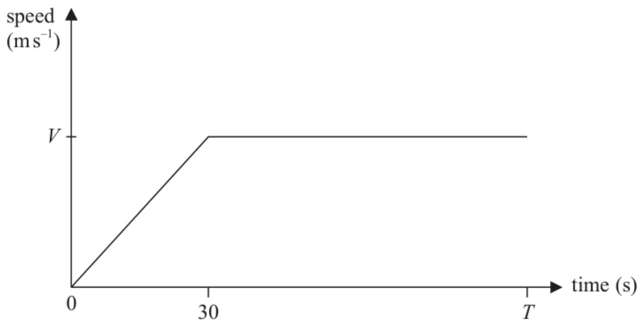

Figure 2

(Total for Question 5 is 11 marks)

WME01/01 MAY/JUNE 2023

Question 6

7 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

6.

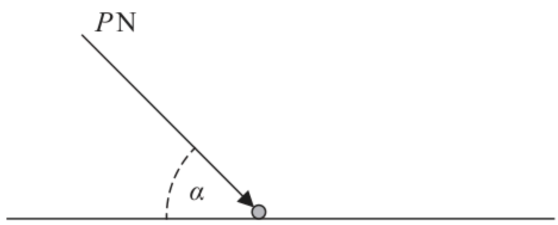

Figure 3

A particle of weight W newtons lies at rest on a rough horizontal surface, as shown in Figure 3.
A force of magnitude P newtons is applied to the particle.

The force acts at an angle α to the horizontal, where $\tan \alpha = \frac{4}{3}$

The coefficient of friction between the particle and the surface is $\frac{1}{4}$

Given that the particle does not move, show that

$$P \leqslant \frac{5W}{8}$$

(7)

WME01/01 OCTOBER 2023

Question 1

5 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

1.

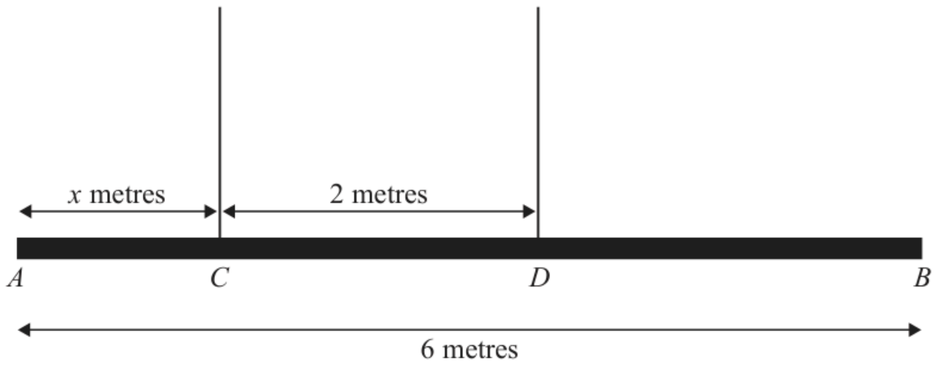

Figure 1

Figure 1 shows a beam AB with weight 24 N and length 6 m.

The beam is suspended by two light vertical ropes. The ropes are attached to the points C and D on the beam where $AC = x$ metres and $CD = 2$ m.

The tension in the rope attached to the beam at C is double the tension in the rope attached to the beam at D.

The beam is modelled as a uniform rod, resting horizontally in equilibrium.

Find

(i) the tension in the rope attached to the beam at D.

(ii) the value of x.

(5)

WME01/01 OCTOBER 2023

Question 3

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Momentum, Impulse & Collisions

3. A hammer is used to hit a tent peg into soft ground.

The hammer has mass 1.8 kg and the tent peg has mass 0.2 kg.

The hammer and tent peg are both modelled as particles and the impact is modelled as a direct collision.

Immediately before the impact, the tent peg is stationary and the hammer is moving vertically downwards with speed $10\,\text{m s}^{-1}$

Immediately after the impact, the hammer and tent peg move together, vertically downwards, with the **same** speed $v\,\text{m s}^{-1}$

(a) Find the value of v

(2)

(b) Find the magnitude of the impulse exerted on the tent peg by the hammer, stating the units of your answer.

(3)

The ground exerts a constant vertical resistive force of magnitude R newtons, bringing the hammer and tent peg to rest after they travel a distance of 12 cm.

(c) Find the value of R.

(5)

WME01/01 OCTOBER 2023

Question 7

13 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

7.

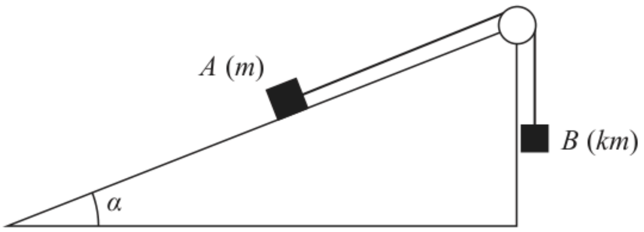

Figure 4

Figure 4 shows a block A of mass m held at rest on a rough plane.
The plane is inclined at an angle α to the horizontal and the coefficient of friction between the block and the plane is μ.

One end of a light inextensible string is now attached to A. The string passes over a small smooth pulley which is fixed at the top of the plane.
The other end of the string is attached to a block B of mass km.
Block B hangs vertically below the pulley, with the string taut.

The string from A to the pulley lies along a line of greatest slope of the plane.

Both A and B are modelled as particles.

When the system is released from rest, A moves up the plane and the tension in the string is $\frac{4mg}{3}$

Given that $\mu = \frac{1}{3}$ and $\tan\alpha = \frac{7}{24}$

(a) (i) find the magnitude of the acceleration of A, giving your answer in terms of g,

(ii) find the value of k.

(9)

(b) Find the magnitude of the resultant force exerted on the pulley by the string, giving your answer in terms of m and g.

(4)

WME01/01 JANUARY 2024

Question 3

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Constant Acceleration in 1D

3. A van travels with constant acceleration along a straight horizontal road.

The van passes a point A with speed $u\,\text{m}\,\text{s}^{-1}$ and 20 seconds later passes a point B with speed $28\,\text{m}\,\text{s}^{-1}$

The distance AB is 400 m.

(a) Show that $u = 12$

(2)

(b) Find the time taken for the van to travel from A to the midpoint of AB.

(5)

The van has mass 1200 kg.

During its motion the van experiences a constant resistive force of magnitude 260 N

(c) Find the magnitude of the driving force exerted by the engine of the van as it travels from A to B.

(3)

WME01/01 MAY/JUNE 2024

Question 1

5 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Momentum, Impulse & Collisions

1. Two particles, A and B, have masses m and $3m$ respectively. The particles are connected by a light inextensible string. Initially A and B are at rest on a smooth horizontal plane with the string slack.

Particle A is then projected along the plane away from B with speed U.

Given that the common speed of the particles immediately after the string becomes taut is S

(a) find S in terms of U.

(2)

(b) Find, in terms of m and U, the magnitude of the impulse exerted on A immediately after the string becomes taut.

(3)

WME01/01 MAY/JUNE 2024

Question 5

14 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Constant Acceleration in 1D

5. A parachute is used to deliver a box of supplies. The parachute is attached to the box.

- the parachute and box are dropped from rest from a helicopter that is hovering at a height of 520 m above the ground
- the parachute and box fall vertically and freely under gravity for 5 seconds, then the parachute opens
- from the instant the parachute opens, it provides a resistance to motion of magnitude 3200 N
- the parachute and box continue to fall vertically downwards after the parachute opens
- the parachute and box are modelled throughout the motion as a particle P of mass 250 kg

(a) Find the distance fallen by P in the first 5 seconds.

(2)

(b) Find the speed with which P lands on the ground.

(7)

(c) Find the total time from the instant when P is dropped from the helicopter to the instant when P lands on the ground.

(3)

(d) Sketch a speed-time graph for the motion of P from the instant when P is dropped from the helicopter to the instant when P lands on the ground.

(2)

WME01/01 MAY/JUNE 2024

Question 8

15 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

8.

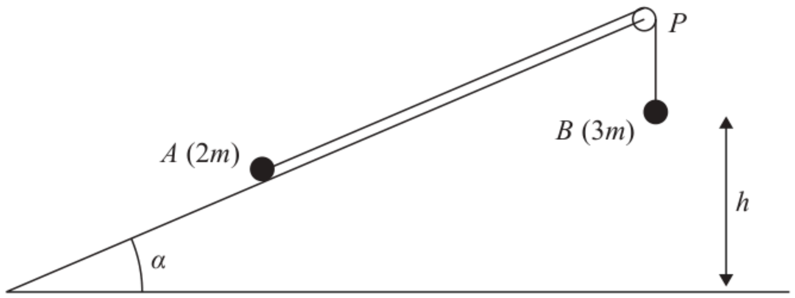

Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$. The other end of the string is attached to a particle B of mass $3m$. Particle A is held at rest on a rough plane which is inclined to horizontal ground at an angle α, where $\tan\alpha = \frac{5}{12}$

The string passes over a small smooth pulley P which is fixed at the top of the plane. Particle B hangs vertically below P with the string taut, at a height h above the ground, as shown in Figure 4.

The part of the string between A and P lies along a line of greatest slope of the plane. The two particles, the string and the pulley all lie in the same vertical plane.

The coefficient of friction between A and the plane is $\frac{11}{36}$

The particle A is released from rest and begins to move up the plane.

(a) Show that the frictional force acting on A as it moves up the plane is $\frac{22mg}{39}$ **(3)**

(b) Write down an equation of motion for B. **(2)**

(c) Show that the acceleration of A immediately after its release is $\frac{1}{3}g$ **(4)**

In the subsequent motion, A comes to rest before it reaches the pulley.

(d) Find, in terms of h, the total distance travelled by A from when it was released from rest to when it first comes to rest again. **(6)**

WME01/01 OCTOBER 2024

Question 2

9 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

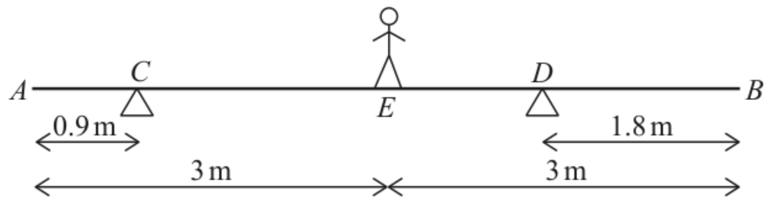

Figure 1

A non-uniform beam AB has length 6 m and mass 50 kg. The beam rests horizontally on two supports at C and D, where $AC = 0.9$ m and $DB = 1.8$ m.

A child of mass 25 kg stands on the beam at E, where $AE = EB = 3$ m, as shown in Figure 1.

The beam is in equilibrium.

The magnitude of the normal reaction between the beam and the support at C is R_C newtons.

The magnitude of the normal reaction between the beam and the support at D is R_D newtons.

The beam is modelled as a rod and the child is modelled as a particle.

The centre of mass of the beam is between C and D and is a distance x metres from D.

Given that $2R_D = 3R_C$

(a) show that $x = 1.38$

(6)

The child remains at E and a block of mass M kg is placed on the beam at B.

The block is modelled as a particle.

Given that the beam is on the point of tilting,

(b) find the value of M.

(3)

WME01/01 JANUARY 2025

Question 1

8 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

1. A particle of mass 2.5 kg moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (6\mathbf{i} + 8\mathbf{j})\,\text{N}$$

$$\mathbf{F}_2 = (-16\mathbf{i} + 2\mathbf{j})\,\text{N}$$

$$\mathbf{F}_3 = (-2\mathbf{i} + 8\mathbf{j})\,\text{N}$$

(a) Find the magnitude of the acceleration of the particle.

(4)

A fourth force, $\mathbf{F}_4 = (p\mathbf{i} + p\mathbf{j})\,\text{N}$, where p is a constant, is added.

The resultant of the four forces acts in the direction of the vector $(7\mathbf{i} + 2\mathbf{j})$.

(b) Find the value of p.

(4)

WME01/01 JANUARY 2025

Question 4

10 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

4.

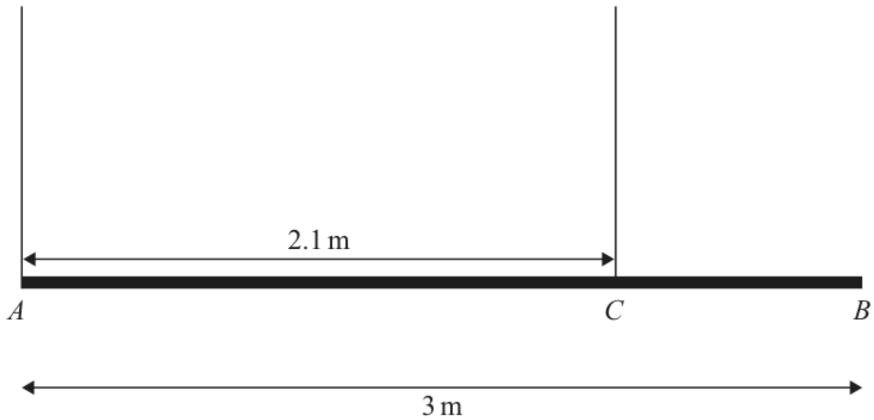

Figure 2

A uniform rod AB has length 3 m and weight W newtons.
The rod is suspended by two light vertical ropes.
One rope is attached to the rod at A and the other rope is attached to the rod at C, where $AC = 2.1$ m.

The rod is in equilibrium in a horizontal position, as shown in Figure 2.

The tension in the rope at C is 350 N.

(a) Show that $W = 490$

(3)

A particle P of weight 210 N is attached to the rod at a distance d metres from A.
The tension in the rope at C is now 600 N.
The rod remains in equilibrium in a horizontal position.

(b) Find the value of d.

(3)

Particle P is removed from the rod.
A particle Q of weight X newtons is now attached at B.
The rod remains in equilibrium in a horizontal position and is now on the point of tilting.

(c) Find the value of X.

(4)

WME01/01 MAY/JUNE 2025

Question 4

7 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

4.

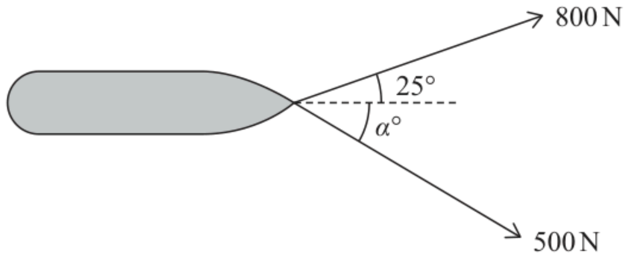

Figure 2

Two ropes are attached to a point on the front of a barge.
The barge is being pulled horizontally in a straight line along the centre of a long straight canal.

One rope makes an angle of 25° with the direction of motion of the barge and has a tension of 800 N.
The other rope makes an angle of $\alpha°$ with the direction of motion of the barge and has a tension of 500 N, as shown in Figure 2.

Both ropes are horizontal.

(a) Find the value of α

(3)

The mass of the barge is 15 tonnes and the resistance to the motion of the barge is a constant force of magnitude 750 N.

(b) Find the acceleration of the barge.

(4)

WME01/01 OCTOBER 2025

Question 1

7 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

1.

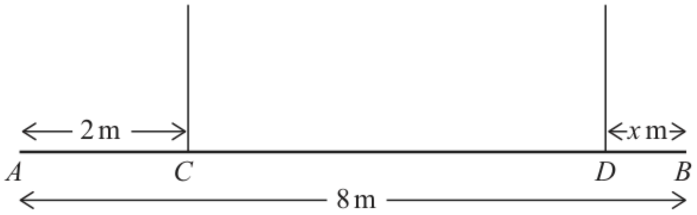

Figure 1

Figure 1 shows a sketch of a beam AB, with weight 240 N and length 8 m.

The beam is held in equilibrium in a horizontal position by two vertical ropes. The ropes are attached to the beam at the points C and D, where $AC = 2$ m and $DB = x$ metres.

The beam is modelled as a uniform rod and the ropes are modelled as light inextensible strings.

The tension in the rope at D is 90 N.

(a) Show that $x = \dfrac{2}{3}$

(3)

The rope at C will break if its tension exceeds 183 N. The rope at D cannot break.
A package of weight W newtons is now attached to the beam at A.
The beam remains horizontal and in equilibrium.

The package is modelled as a particle.

It is given that the rope at C does not break.

(b) Find the greatest possible value of W.

(4)

WME01/01 OCTOBER 2025

Question 3

14 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

3. [*In this question* **i** *and* **j** *are horizontal perpendicular unit vectors.*]

A particle P of mass 2 kg moves on a smooth horizontal surface under the action of two forces $\mathbf{F}_1$ and $\mathbf{F}_2$, where $\mathbf{F}_1 = (-2\mathbf{i} + 3\mathbf{j})$ N and $\mathbf{F}_2 = (4\mathbf{i} + 2\mathbf{j})$ N.

(a) Find the acceleration of P.

(3)

At time $t = 0$, the velocity of P is $(3\mathbf{i} - 4\mathbf{j})\,\text{m s}^{-1}$

(b) Find the speed of P when $t = 3$ seconds.

(4)

An additional force, $\mathbf{F}_3 = (b\mathbf{i} + c\mathbf{j})$ N, is applied to P.

The resultant of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ is equal to $\lambda(\mathbf{i} + \mathbf{j})$ N, where λ is a constant.

(c) Show that $b - c = 3$

(3)

The resultant of $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ has magnitude $10\sqrt{2}$ N.

(d) Find the two possible $\mathbf{F}_3$ forces.

(4)

WME01/01 OCTOBER 2025

Question 5

13 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

5.

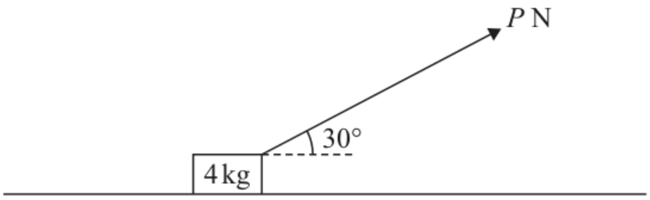

Figure 3

A box of mass 4 kg is placed on a rough horizontal surface.

A force of magnitude P newtons, acting at 30° to the horizontal, is applied to the box, as shown in Figure 3.

The coefficient of friction between the box and the surface is $\frac{2}{3}$

The box is modelled as a particle.

(a) Find the value of P when the box is on the point of sliding along the surface.

(6)

The value of P is now increased to 25 and the box moves along the surface.

Find

(b) the acceleration of the box,

(5)

(c) the speed of the box when it has moved 1.5 m.

(2)

WME01/01 OCTOBER 2025

Question 7

14 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

7.

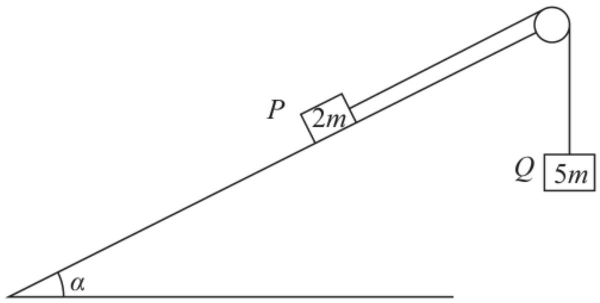

Figure 5

A block P of mass $2m$ is held at rest on a fixed rough plane.

The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{5}{12}$

One end of a light inextensible string is attached to P.
The string is parallel to a line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top of the plane.
The other end of the string is attached to a block Q of mass $5m$.
Block Q hangs vertically below the pulley, as shown in Figure 5.

The system is released from rest with the string taut and block P moves up the plane.

Immediately after the system is released, the tension in the string is T and the acceleration of the blocks is a.

The blocks are modelled as particles and air resistance is ignored.

(a) Write down an equation of motion for Q.

(2)

The coefficient of friction between P and the plane is $\frac{1}{8}$

(b) Find T in terms of m and g.

(7)

(c) State how the solution to part (b) uses the fact that the string is inextensible.

(1)

The magnitude of the force exerted on the pulley by the string is kmg.

(d) Find the value of k to 3 significant figures.

(4)

WME01/01 JANUARY 2026

Question 3

8 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Forces

3. A particle moves on a smooth horizontal plane under the action of three horizontal forces, $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, where

$$\mathbf{F}_1 = (2p\mathbf{i} - 3p\mathbf{j})\text{N}$$

$$\mathbf{F}_2 = (q\mathbf{i} + \mathbf{j})\text{N}$$

$$\mathbf{F}_3 = (3\mathbf{i} - q\mathbf{j})\text{N}$$

where p and q are constants.

The resultant force acts in the direction of the vector $(4\mathbf{i} - 5\mathbf{j})$

(a) Show that

$$2p - q = 19$$

(4)

The mass of the particle is 0.5 kg.

Given that $p = 7$

(b) find the acceleration of the particle.

(4)

WME01/01 JANUARY 2026

Question 4

9 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Moments

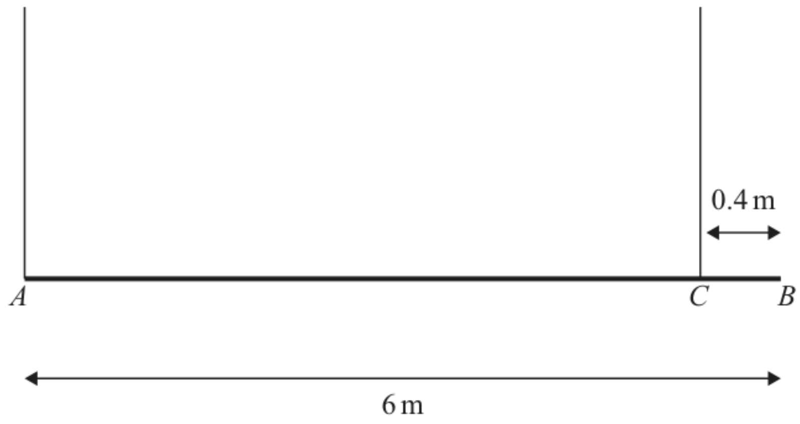

Figure 2

Figure 2 shows a uniform rod AB of length 6 m suspended by two light vertical ropes.

The first rope is attached to the rod at A.
The second rope is attached to the rod at the point C, where $CB = 0.4$ m.

The rod has mass 30 kg.

A particle of mass 20 kg is now attached to the rod at B.

The rod is in equilibrium in a horizontal position.

(a) Find

(i) the tension in the rope attached to the rod at C,
(ii) the tension in the rope attached to the rod at A.

(6)

The particle of mass 20 kg at B is removed and replaced by a particle of mass M kg.

The rod remains in equilibrium in a horizontal position.

(b) Find the exact maximum value of M.

(3)

WME01/01 JANUARY 2026

Question 7

14 marks

Newton's Second Law

Also in Newton's Second Law

Primary: Resolving Forces, Inclined Planes

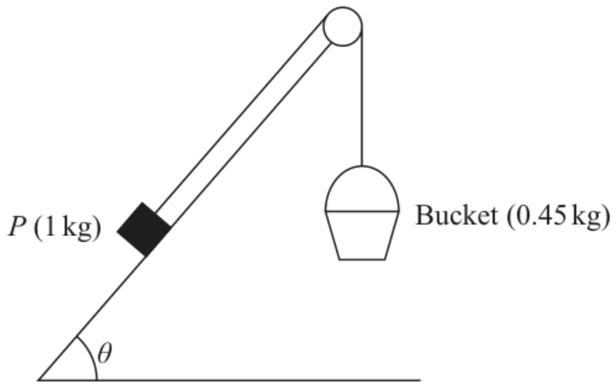

Figure 3

A rough plane is inclined at an angle θ to the horizontal, where $\tan\theta = \frac{4}{3}$

One end of a light inextensible string is attached to a package P.
The string passes over a smooth pulley that is fixed at the top of the plane.
The string from P to the pulley lies along a line of greatest slope of the plane.
The other end of the string is attached to a bucket.
The package P has mass 1 kg and is **held** at rest on the plane.
The bucket has mass 0.45 kg and hangs vertically below the pulley with the string taut, as shown in Figure 3.

The coefficient of friction between P and the plane is μ

When a small block of mass 0.2 kg is placed in the bucket, the system is released and remains at rest in **limiting equilibrium**, with P on the point of slipping down the plane.

(a) Show that $\mu = \frac{1}{4}$

(7)

Additional identical blocks of mass 0.2 kg are added one at a time into the bucket until P starts to move **up** the plane.
At the instant when P starts to move up the plane, there are a **total** of n blocks in the bucket.

(b) Find

(i) the value of n

(ii) the magnitude of the initial acceleration of P

(7)

TOPIC

Resolving Forces, Inclined Planes

Question 4

4.

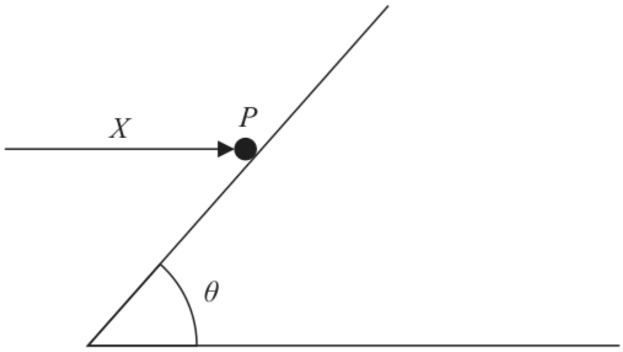

Figure 1

A particle, P, of mass km lies on a fixed rough plane. The plane is inclined to the horizontal at an acute angle θ. A horizontal force of magnitude X acts on P, as shown in Figure 1. The line of action of the force lies in the vertical plane which contains the line of greatest slope of the inclined plane that passes through P. The coefficient of friction between P and the inclined plane is μ.

When $X = mg$, the particle P is in equilibrium and on the point of sliding down the plane.

(a) Show that $\mu = \dfrac{k\tan\theta - 1}{k + \tan\theta}$

(10)

(b) Deduce that, when $k = 1$, θ must be greater than 45°

(2)

WME01/01 JANUARY 2021

17 marks

Question 8

Resolving Forces, Inclined Planes

8.

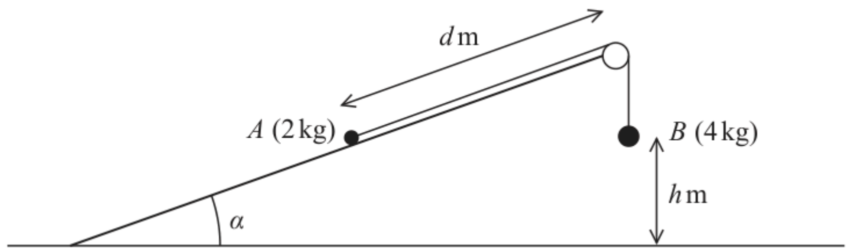

Figure 3

Two particles, A and B, have masses 2 kg and 4 kg respectively. The particles are connected by a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a rough plane. The plane is inclined to the horizontal ground at an angle α where $\tan\alpha = \frac{3}{4}$. The particle A is held at rest on the plane at a distance d metres from the pulley. The particle B hangs freely at rest, vertically below the pulley, at a distance h metres above the ground, as shown in Figure 3. The part of the string between A and the pulley is parallel to a line of greatest slope of the plane. The coefficient of friction between A and the plane is $\frac{1}{4}$

The system is released from rest with the string taut and B descends.

(a) Find the tension in the string as B descends.

(9)

On hitting the ground, B immediately comes to rest.

Given that A comes to rest before reaching the pulley,

(b) find, in terms of h, the range of possible values of d.

(7)

(c) State one physical factor, other than air resistance, that could be taken into account to make the model described above more realistic.

(1)

(Total 17 marks)

Question 6

13 marks

Resolving Forces, Inclined Planes

6. A fixed rough plane is inclined at an angle θ to the horizontal, where $\tan\theta = \frac{5}{12}$

A particle of mass 6 kg is projected with speed $5\ \mathrm{m\,s^{-1}}$ from a point A on the plane, up a line of greatest slope of the plane.

The coefficient of friction between the particle and the plane is $\frac{1}{4}$

(a) Find the magnitude of the frictional force acting on the particle as it moves up the plane.

(3)

The particle comes to instantaneous rest at the point B.

(b) Find the distance AB.

(5)

The particle now slides down the plane from B. At the instant when the particle passes through the point C on the plane, the speed of the particle is again $5\ \mathrm{m\,s^{-1}}$

(c) Find the distance BC.

(5)

Question 7

14 marks

Resolving Forces, Inclined Planes

7.

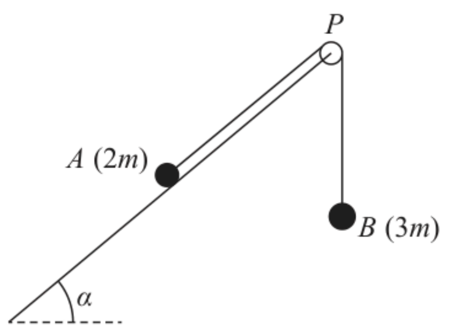

Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$. The other end of the string is attached to a particle B of mass $3m$. The string passes over a small, smooth, light pulley P which is fixed at the top of a rough inclined plane. The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

Particle A is held at rest on the plane with the string taut and B hanging freely below P, as shown in Figure 4. The section of the string AP is parallel to a line of greatest slope of the plane.

The coefficient of friction between A and the plane is $\frac{1}{2}$

Particle A is released and begins to move up the plane.

For the motion before A reaches the pulley,

(a) (i) write down an equation of motion for A,

(ii) write down an equation of motion for B,

(4)

(b) find, in terms of g, the acceleration of A,

(5)

(c) find the magnitude of the force exerted on the pulley by the string.

(4)

(d) State how you have used the information that P is a smooth pulley.

(1)

WME01/01 JANUARY 2022

8 marks

Question 5

Resolving Forces, Inclined Planes

5.

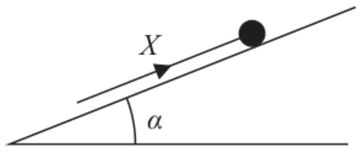

Figure 3

A particle of mass m rests in equilibrium on a fixed rough plane under the action of a force of magnitude X. The force acts up a line of greatest slope of the plane, as shown in Figure 3.

The plane is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{3}{4}$

The coefficient of friction between the particle and the plane is μ.

- When $X = 2P$, the particle is on the point of sliding up the plane.
- When $X = P$, the particle is on the point of sliding down the plane.

Find the value of μ.

(8)

WME01/01 JANUARY 2022

13 marks

Question 7

Resolving Forces, Inclined Planes

7.

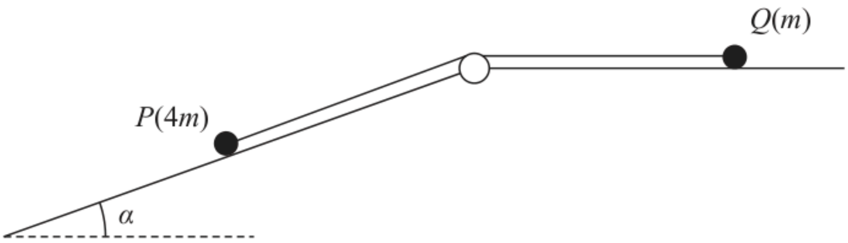

Figure 4

A particle P of mass $4m$ lies on the surface of a fixed rough inclined plane.

The plane is inclined to the horizontal at an angle α where $\tan\alpha = \frac{3}{4}$

The particle P is attached to one end of a light inextensible string.

The string passes over a small smooth pulley that is fixed at the top of the plane. The other end of the string is attached to a particle Q of mass m which lies on a smooth horizontal plane.

The string lies along the horizontal plane and in the vertical plane that contains the pulley and a line of greatest slope of the inclined plane.

The system is released from rest with the string taut, as shown in Figure 4, and P moves down the plane.

The coefficient of friction between P and the plane is $\frac{1}{4}$

For the motion before Q reaches the pulley

(a) write down an equation of motion for Q,

(1)

(b) find, in terms of m and g, the tension in the string,

(7)

(c) find the magnitude of the force exerted on the pulley by the string.

(4)

(d) State where in your working you have used the information that the string is light.

(1)

Question 3

11 marks

Resolving Forces, Inclined Planes

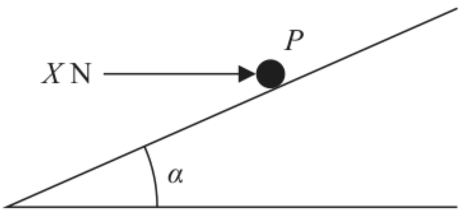

Figure 2

A rough plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$

A particle P of mass 2 kg is held in equilibrium on the plane by a horizontal force of magnitude X newtons, as shown in Figure 2. The force acts in a vertical plane which contains a line of greatest slope of the inclined plane.

(a) Show that when $X = 14.7$ there is no frictional force acting on P

(3)

The coefficient of friction between P and the plane is 0.5

(b) Find the smallest possible value of X.

(8)

Question 8

8.

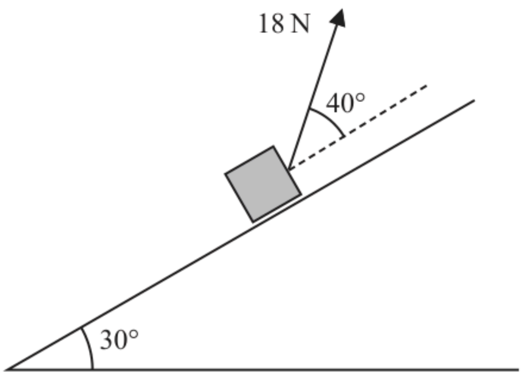

Figure 5

A parcel of mass 2 kg is pulled up a rough inclined plane by the action of a constant force.

The force has magnitude 18 N and acts at an angle of 40° to the plane.

The line of action of the force lies in a vertical plane containing a line of greatest slope of the inclined plane.

The plane is inclined at an angle of 30° to the horizontal, as shown in Figure 5.

The coefficient of friction between the plane and the parcel is 0.3

The parcel is modelled as a particle P

(a) Find the acceleration of P

(8)

The points A and B lie on a line of greatest slope of the plane, where $AB = 5\,\text{m}$ and B is above A. Particle P passes through A with speed $2\,\text{m}\,\text{s}^{-1}$ in the direction AB.

(b) Find the speed of P as it passes through B.

(3)

The force of 18 N is removed at the instant P passes through B. As a result, P comes to rest at the point C.

(c) Determine whether P will remain at rest at C. You must show all stages of your working clearly.

(4)

Question 7

7.

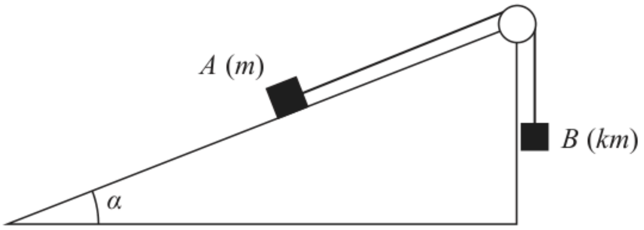

Figure 4

Figure 4 shows a block A of mass m held at rest on a rough plane.
The plane is inclined at an angle α to the horizontal and the coefficient of friction between the block and the plane is μ.

One end of a light inextensible string is now attached to A. The string passes over a small smooth pulley which is fixed at the top of the plane.
The other end of the string is attached to a block B of mass km.
Block B hangs vertically below the pulley, with the string taut.

The string from A to the pulley lies along a line of greatest slope of the plane.

Both A and B are modelled as particles.

When the system is released from rest, A moves up the plane and the tension in the string is $\dfrac{4mg}{3}$

Given that $\mu = \dfrac{1}{3}$ and $\tan\alpha = \dfrac{7}{24}$

(a) (i) find the magnitude of the acceleration of A, giving your answer in terms of g,

(ii) find the value of k.

(9)

(b) Find the magnitude of the resultant force exerted on the pulley by the string, giving your answer in terms of m and g.

(4)

WME01/01 JANUARY 2024

12 marks

Question 8

Resolving Forces, Inclined Planes

8.

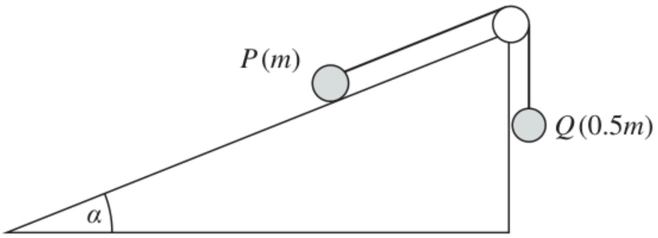

Figure 5

A fixed rough plane is inclined at an angle α to the horizontal, where $\tan\alpha = \dfrac{5}{12}$

A small smooth pulley is fixed at the top of the plane.

One end of a light inextensible string is attached to a particle P which is at rest on the plane. The string passes over the pulley and the other end of the string is attached to a particle Q which hangs vertically below the pulley, as shown in Figure 5.

Particle P has mass m and particle Q has mass $0.5m$

The string from P to the pulley lies along a line of greatest slope of the plane.

The coefficient of friction between P and the plane is μ.

The system is in **limiting equilibrium** with the string taut and P is on the point of slipping **up** the plane.

(a) Find the value of μ.

(8)

The string breaks and P begins to move down the plane.

When particle P has travelled a distance of 0.8 m down the plane, the speed of P is $V\,\text{m s}^{-1}$

(b) Find the value of V.

(4)

Question 6

12 marks

Resolving Forces, Inclined Planes

6.

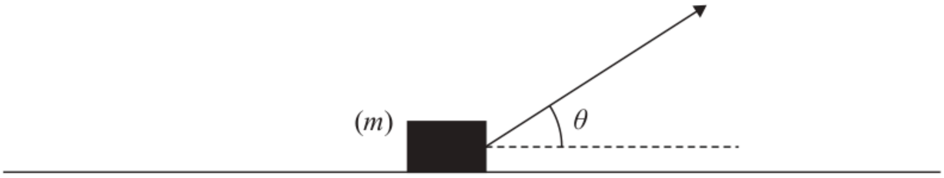

Figure 3

A box of mass m lies on a rough horizontal plane. The box is pulled along the plane in a straight line at **constant speed** by a light rope. The rope is inclined at an angle θ to the plane, as shown in Figure 3.

The coefficient of friction between the box and the plane is $\frac{1}{3}$

The box is modelled as a particle.

Given that $\tan\theta = \frac{3}{4}$

(a) find, in terms of m and g, the tension in the rope.

(7)

The rope is now removed and the box is placed at rest on the plane.
The box is then projected horizontally along the plane with speed u.

The box is again modelled as a particle.

When the box has moved a distance d along the plane, the speed of the box is $\frac{1}{2}u$.

(b) Find d in terms of u and g.

(5)

WME01/01 MAY/JUNE 2024

15 marks

Question 8

Resolving Forces, Inclined Planes

8.

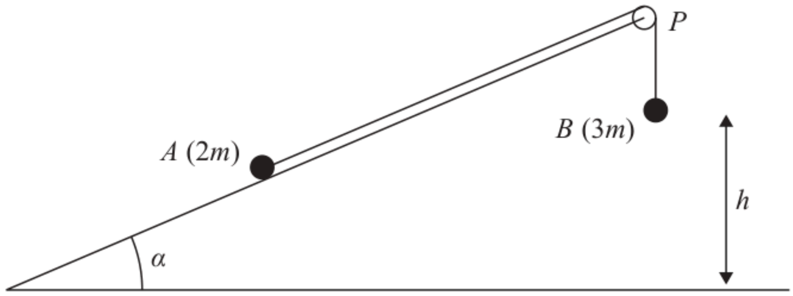

Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$. The other end of the string is attached to a particle B of mass $3m$. Particle A is held at rest on a rough plane which is inclined to horizontal ground at an angle α, where $\tan\alpha = \frac{5}{12}$

The string passes over a small smooth pulley P which is fixed at the top of the plane. Particle B hangs vertically below P with the string taut, at a height h above the ground, as shown in Figure 4.

The part of the string between A and P lies along a line of greatest slope of the plane. The two particles, the string and the pulley all lie in the same vertical plane.

The coefficient of friction between A and the plane is $\frac{11}{36}$

The particle A is released from rest and begins to move up the plane.

(a) Show that the frictional force acting on A as it moves up the plane is $\frac{22mg}{39}$ **(3)**

(b) Write down an equation of motion for B. **(2)**

(c) Show that the acceleration of A immediately after its release is $\frac{1}{3}g$ **(4)**

In the subsequent motion, A comes to rest before it reaches the pulley.

(d) Find, in terms of h, the total distance travelled by A from when it was released from rest to when it first comes to rest again. **(6)**

Question 6

12 marks

Resolving Forces, Inclined Planes

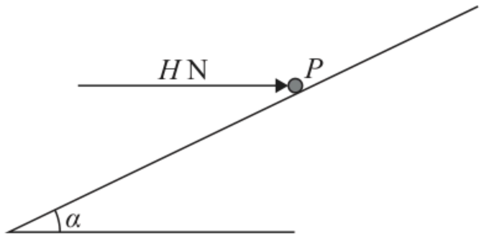

Figure 4

A particle P of mass 5 kg lies on the surface of a rough plane.

The plane is inclined at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$

The particle is held in equilibrium by a horizontal force of magnitude H newtons, as shown in Figure 4.

The horizontal force acts in a vertical plane containing a line of greatest slope of the inclined plane.

The coefficient of friction between the particle and the plane is $\frac{1}{4}$

(a) Find the smallest possible value of H.

(6)

The horizontal force is now removed, and P starts to slide down the slope.

In the first T seconds after P is released from rest, P slides 1.5 m down the slope.

(b) Find the value of T.

(6)

WME01/01 JANUARY 2025

12 marks

Question 6

Resolving Forces, Inclined Planes

6.

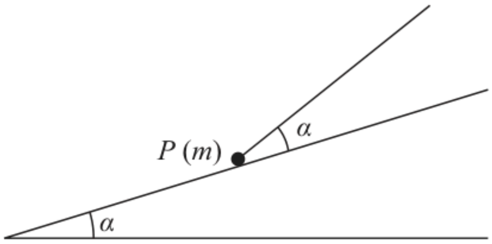

Figure 3

A particle P of mass m is held in equilibrium on a fixed rough inclined plane by a light inextensible string.

The plane is inclined at an angle α to the horizontal, where $\alpha < 45°$
The string is inclined to the plane at angle α, as shown in Figure 3.

The string lies in a vertical plane that contains a line of greatest slope of the inclined plane.

When the tension in the string is $0.75\,mg$, P is on the point of moving up the plane.

(a) Find an expression for the magnitude of the frictional force acting on P, giving your answer in terms of m, g and α.

(3)

The coefficient of friction between P and the plane is $\frac{1}{2}$

(b) Show that

$$\tan\alpha = \frac{2}{5}$$

(6)

The string breaks.

(c) Determine whether P remains at rest. You must justify your reasoning.

(3)

WME01/01 MAY/JUNE 2025

11 marks

Question 6

Resolving Forces, Inclined Planes

6.

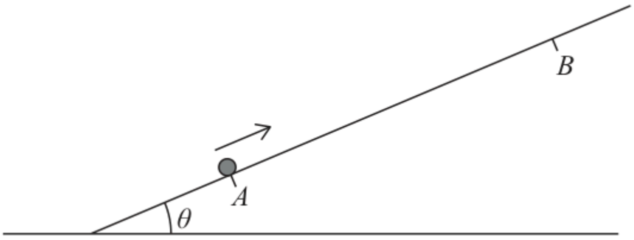

Figure 4

Figure 4 shows a rough plane inclined at an angle θ to the horizontal, where $\tan\theta = \frac{3}{4}$

The points A and B lie on a line of greatest slope of the plane, with B above A.

A package P of mass m is projected up the plane from A towards B.

The coefficient of friction between the plane and the package is $\frac{1}{4}$

The package P is modelled as a particle.

(a) Show that the **deceleration** of P, as it moves from A to B, is $\frac{4}{5}g$

(6)

The package P comes to rest at B.

Given that P is projected from A with speed $U\,\text{m s}^{-1}$ and that $AB = 1.5\,\text{m}$,

(b) find the value of U.

(2)

On reaching B, P is held at rest there by a force of magnitude X newtons acting up the plane in the direction AB.

Given that the mass of P is $2\,\text{kg}$,

(c) find the smallest possible value of X.

(3)

WME01/01 OCTOBER 2025

Question 5

13 marks

Resolving Forces, Inclined Planes

5.

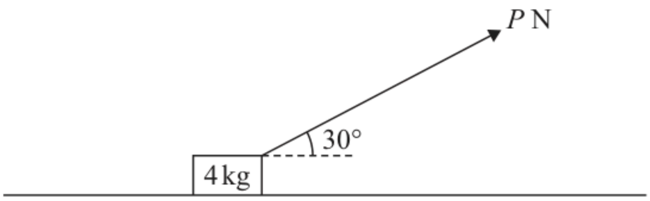

Figure 3

A box of mass 4 kg is placed on a rough horizontal surface.

A force of magnitude P newtons, acting at 30° to the horizontal, is applied to the box, as shown in Figure 3.

The coefficient of friction between the box and the surface is $\frac{2}{3}$

The box is modelled as a particle.

(a) Find the value of P when the box is on the point of sliding along the surface.

(6)

The value of P is now increased to 25 and the box moves along the surface.

Find

(b) the acceleration of the box,

(5)

(c) the speed of the box when it has moved 1.5 m.

(2)

14 marks

Question 7

Resolving Forces, Inclined Planes

7.

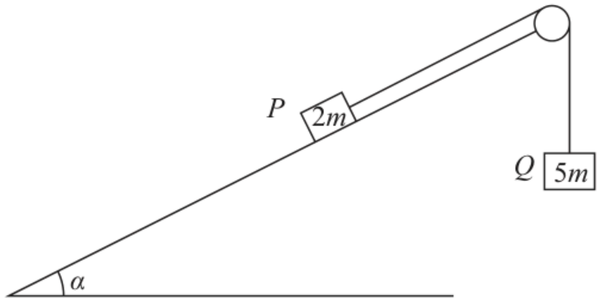

Figure 5

A block P of mass $2m$ is held at rest on a fixed rough plane.

The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{5}{12}$

One end of a light inextensible string is attached to P.
The string is parallel to a line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top of the plane.
The other end of the string is attached to a block Q of mass $5m$.
Block Q hangs vertically below the pulley, as shown in Figure 5.

The system is released from rest with the string taut and block P moves up the plane.

Immediately after the system is released, the tension in the string is T and the acceleration of the blocks is a.

The blocks are modelled as particles and air resistance is ignored.

(a) Write down an equation of motion for Q.

(2)

The coefficient of friction between P and the plane is $\frac{1}{8}$

(b) Find T in terms of m and g.

(7)

(c) State how the solution to part (b) uses the fact that the string is inextensible.

(1)

The magnitude of the force exerted on the pulley by the string is kmg.

(d) Find the value of k to 3 significant figures.

(4)

Question 5

5. The points O, A, B and C are on a rough horizontal surface where $OABC$ is a straight line.

A particle is projected horizontally from O and slides across the surface, passing through A, B and C in that order.

The particle passes through

- A with speed $U\,\text{m}\,\text{s}^{-1}$
- B with speed $\frac{U}{2}\,\text{m}\,\text{s}^{-1}$

The coefficient of friction between the particle and the surface is $\frac{1}{7}$

It takes 0.75 s for the particle to move from A to B.

(a) Show that $U = 2.1$ to 2 significant figures.

(6)

The particle passes through C with speed $\frac{U}{3}\,\text{m}\,\text{s}^{-1}$

(b) Find the time taken to move from B to C.

(3)

(c) Find the distance AC.

(3)

WME01/01 JANUARY 2026

14 marks

Question 7

Resolving Forces, Inclined Planes

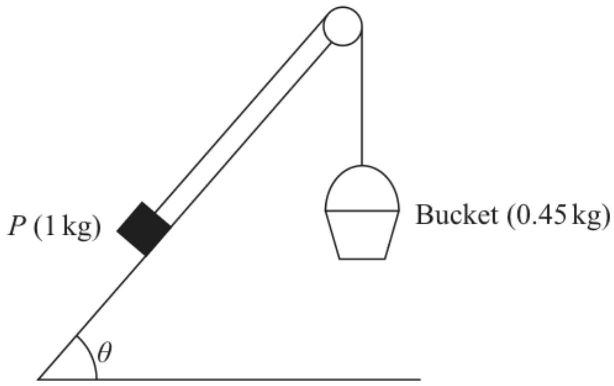

Figure 3

A rough plane is inclined at an angle θ to the horizontal, where $\tan\theta = \frac{4}{3}$

One end of a light inextensible string is attached to a package P.
The string passes over a smooth pulley that is fixed at the top of the plane.
The string from P to the pulley lies along a line of greatest slope of the plane.
The other end of the string is attached to a bucket.
The package P has mass 1 kg and is **held** at rest on the plane.
The bucket has mass 0.45 kg and hangs vertically below the pulley with the string taut, as shown in Figure 3.

The coefficient of friction between P and the plane is μ

When a small block of mass 0.2 kg is placed in the bucket, the system is released and remains at rest in **limiting equilibrium**, with P on the point of slipping down the plane.

(a) Show that $\mu = \frac{1}{4}$

(7)

Additional identical blocks of mass 0.2 kg are added one at a time into the bucket until P starts to move **up** the plane.
At the instant when P starts to move up the plane, there are a **total** of n blocks in the bucket.

(b) Find

(i) the value of n

(ii) the magnitude of the initial acceleration of P

(7)

WME01/01 OCTOBER 2019

Question 3

7 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Newton's Second Law

3. A car of mass 800 kg is towing a trailer of mass 400 kg up a straight road using a towbar. The towbar is parallel to the road and parallel to the direction of motion of the car. The road is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{1}{7}$. The engine of the car produces a constant driving force of magnitude D newtons. The resistance to the motion of the car from non-gravitational forces is modelled as a single force of magnitude 420 N. The resistance to the motion of the trailer from non-gravitational forces is modelled as a single force of magnitude 300 N. The car and trailer are modelled as particles and the towbar is modelled as a light rod.

Given that the tension in the towbar is 2060 N, find the value of D.

(7)

WME01/01 MAY/JUNE 2021

Question 4

6 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Newton's Second Law

4.

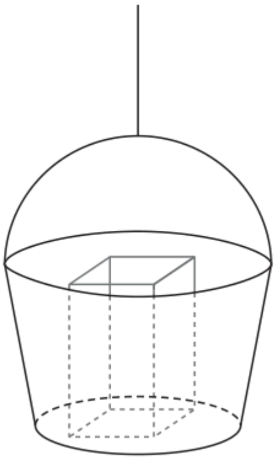

Figure 1

Figure 1 shows a large bucket used by a crane on a building site to move materials between the ground and the top of the building. The mass of the bucket is 15 kg.

The bucket is attached to a vertical cable with the bottom of the bucket horizontal. The cable is modelled as light and inextensible.

When the bucket is on the ground, a bag of cement of mass 25 kg is placed in the bucket.

The bucket with the bag of cement moves vertically upwards with constant acceleration $0.2\,\text{m s}^{-2}$. Air resistance is modelled as being negligible.

(a) Find the tension in the cable.

(3)

At the top of the building, the bag of cement is removed. A box of tools of mass 12 kg is now placed in the bucket.

Later on the bucket with the box of tools is moving vertically downwards with constant deceleration $0.1\,\text{m s}^{-2}$. Air resistance is again modelled as being negligible.

(b) Find the magnitude of the normal reaction between the bucket and the box of tools.

(3)

WME01/01 MAY/JUNE 2021

Question 7

10 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Moments

7.

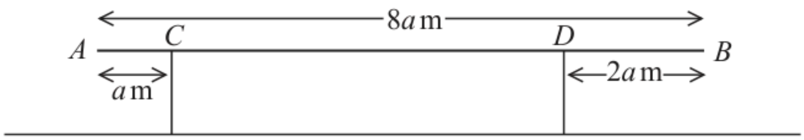

Figure 2

A non-uniform beam AB, of mass 60 kg and length $8a$ metres, rests in equilibrium in a horizontal position on two vertical supports. One support is at C, where $AC = a$ metres and the other support is at D, where $DB = 2a$ metres, as shown in Figure 2.

The magnitude of the normal reaction between the beam and the support at D is three times the magnitude of the normal reaction between the beam and the support at C.

By modelling the beam as a non-uniform rod whose centre of mass is at a distance x metres from A,

(a) find an expression for x in terms of a.

(5)

A box of mass M kg is placed on the beam at E, where $AE = 2a$ metres.

The beam remains in equilibrium in a horizontal position.

The magnitude of the normal reaction between the beam and the support at C is now equal to the magnitude of the normal reaction between the beam and the support at D.

By modelling the box as a particle,

(b) find the value of M.

(5)

WME01/01 OCTOBER 2022

Question 7

13 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Newton's Second Law

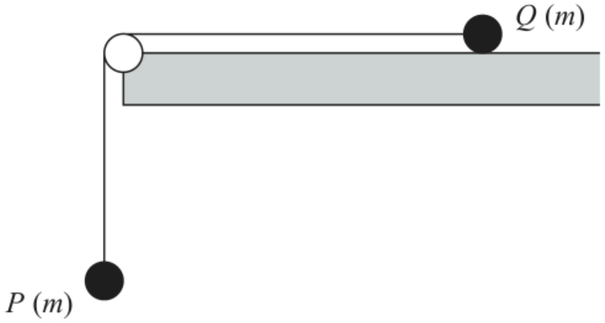

Figure 4

A particle P of mass m is attached to one end of a light inextensible string. Another particle Q, also of mass m, is attached to the other end of the string. The string passes over a small smooth pulley which is fixed at the edge of a rough horizontal table. Particle Q is held at rest on the table and particle P hangs vertically below the pulley with the string taut, as shown in Figure 4.

The pulley, P and Q all lie in the same vertical plane.

The coefficient of friction between Q and the table is μ, where $\mu < 1$

Particle Q is released from rest.

The tension in the string before Q hits the pulley is kmg, where k is a constant.

(a) Find k in terms of μ.

(7)

Given that Q is initially a distance d from the pulley,

(b) find, in terms of d, g and μ, the time taken by Q, after release, to reach the pulley.

(4)

(c) Describe what would happen if $\mu \geqslant 1$, giving a reason for your answer.

(2)

WME01/01 MAY/JUNE 2023

Question 7

11 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Newton's Second Law

7.

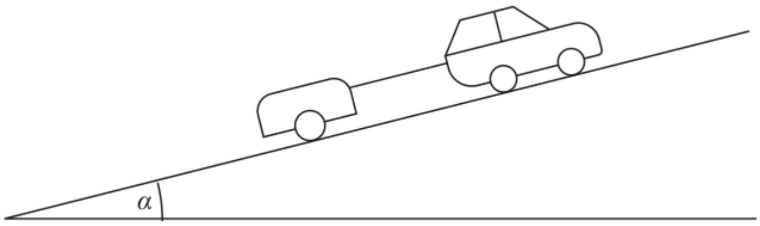

Figure 4

A car of mass 1200 kg is towing a trailer of mass 600 kg up a straight road, as shown in Figure 4.

The road is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{1}{12}$

The driving force produced by the engine of the car is 3000 N.

The car moves with acceleration $0.75\,\text{m}\,\text{s}^{-2}$

The non-gravitational resistance to motion of

- the **car** is modelled as a constant force of magnitude $2R$ newtons
- the **trailer** is modelled as a constant force of magnitude R newtons

The car and the trailer are modelled as particles.
The tow bar between the car and trailer is modelled as a light rod that is parallel to the direction of motion.

Using the model,

(a) show that the value of R is 60

(4)

(b) find the tension in the tow bar.

(3)

When the car and trailer are moving at a speed of $12\,\text{m}\,\text{s}^{-1}$, the tow bar breaks.

Given that the non-gravitational resistance to motion of the trailer remains unchanged,

(c) use the model to find the further distance moved by the trailer before it first comes to rest.

(4)

WME01/01 OCTOBER 2023

Question 5

12 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Forces

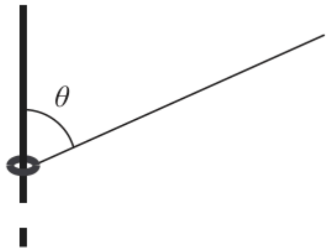

Figure 3

A small ring of mass 0.2 kg is attached to one end of a light inextensible string.

The ring is **threaded** onto a fixed rough vertical rod.

The string is taut and makes an angle θ with the rod, as shown in Figure 3, where $\tan\theta = \frac{12}{5}$

Given that the ring is in equilibrium and that the tension in the string is 10 N,

(a) find the magnitude of the frictional force acting on the ring,

(3)

(b) state the direction of the frictional force acting on the ring.

(1)

The coefficient of friction between the ring and the rod is $\frac{1}{4}$

Given that the ring is in equilibrium, and that the tension in the string, T newtons, can now vary,

(c) (i) find the minimum value of T

(ii) find the maximum value of T

(8)

WME01/01 OCTOBER 2024

Question 2

9 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Moments

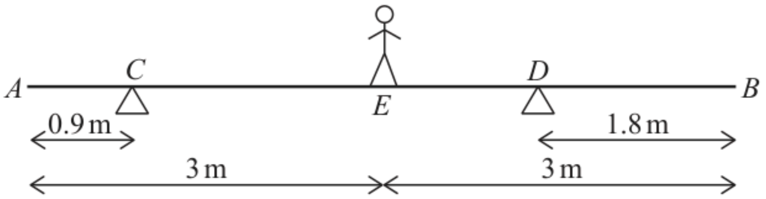

Figure 1

A non-uniform beam AB has length 6 m and mass 50 kg. The beam rests horizontally on two supports at C and D, where $AC = 0.9$ m and $DB = 1.8$ m.

A child of mass 25 kg stands on the beam at E, where $AE = EB = 3$ m, as shown in Figure 1.

The beam is in equilibrium.

The magnitude of the normal reaction between the beam and the support at C is R_C newtons.

The magnitude of the normal reaction between the beam and the support at D is R_D newtons.

The beam is modelled as a rod and the child is modelled as a particle.

The centre of mass of the beam is between C and D and is a distance x metres from D.

Given that $2R_D = 3R_C$

(a) show that $x = 1.38$

(6)

The child remains at E and a block of mass M kg is placed on the beam at B.

The block is modelled as a particle.

Given that the beam is on the point of tilting,

(b) find the value of M.

(3)

WME01/01 JANUARY 2025

Question 3

12 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Momentum, Impulse & Collisions

3.

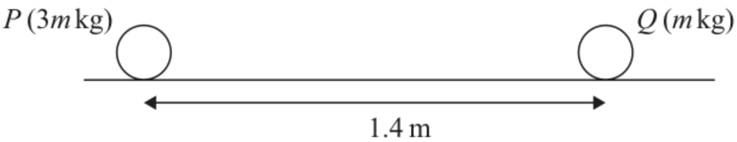

Figure 1

A particle P of mass $3m$ kg and a particle Q of mass m kg are at rest on a rough horizontal surface. The distance between P and Q is 1.4 m, as shown in Figure 1.

An impulse of magnitude λ N s is now applied to P in the direction PQ.
Immediately after the impulse is applied, the speed of P is $5\,\text{m}\,\text{s}^{-1}$

(a) Find λ in terms of m.

(2)

Immediately before P collides with Q, the speed of P is $2.5\,\text{m}\,\text{s}^{-1}$
The coefficient of friction between P and the surface is μ

(b) Find the value of μ

(7)

Immediately after P collides with Q, the speed of Q is $2.1\,\text{m}\,\text{s}^{-1}$

(c) Find the speed of P immediately after the collision.

(3)

WME01/01 OCTOBER 2025

Question 2

8 marks

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Momentum, Impulse & Collisions

2.

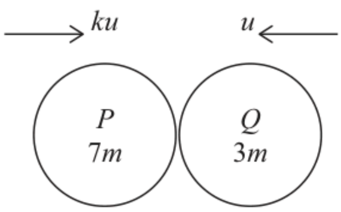

Figure 2

Particle P of mass $7m$ and particle Q of mass $3m$ are moving in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately **before** the collision, the speed of P is ku and the speed of Q is u, as shown in Figure 2.

Immediately **after** the collision, the speed of P is w and the speed of Q is $2w$.

The direction of motion of Q is reversed by the collision.

The impulse received by Q in the collision has magnitude $\frac{7}{2}mu$.

(a) Find w in terms of u.

(3)

(b) Find the two possible values of k.

(5)

6 marks

WME01/01 JANUARY 2026

Resolving Forces, Inclined Planes

Also in Resolving Forces, Inclined Planes

Primary: Momentum, Impulse & Collisions

Question 1

1. A particle P of mass $3m$ and a particle Q of mass $5m$ are on a smooth horizontal surface. The particles move towards each other in opposite directions along the same straight line and collide.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $4u$

The magnitude of the impulse exerted on P by Q in the collision is $\frac{33}{2}mu$

Find

(i) the speed of P immediately after the collision,

(ii) the speed of Q immediately after the collision.

(6)

TOPIC

Momentum, Impulse & Collisions

Question 1

1. Two particles, P and Q, have masses $3m$ and $2m$ respectively. The particles are connected by a light inextensible string. Initially P and Q are at rest on a smooth horizontal plane with the string slack.

Particle P is then projected along the plane directly away from Q with speed $4u$. At the same instant, particle Q is projected along the plane in the opposite direction with speed $3u$.

Find

(a) the common speed of the particles immediately after the string becomes taut,
(3)

(b) the magnitude of the impulse exerted on Q at the instant when the string becomes taut.
(3)

Question 1

8 marks

Momentum, Impulse & Collisions

1. Two particles, P and Q, of mass m_1 and m_2 respectively, are moving on a smooth horizontal plane. The particles are moving towards each other in opposite directions along the same straight line when they collide directly. Immediately before the collision, both particles are moving with speed u.

The direction of motion of each particle is reversed by the collision.

Immediately after the collision, the speed of Q is $\frac{1}{3}u$.

(a) Find, in terms of m_2 and u, the magnitude of the impulse exerted by P on Q in the collision.

(3)

(b) Find, in terms of m_1, m_2 and u, the speed of P immediately after the collision.

(3)

(c) Hence show that $m_2 > \frac{3}{4} m_1$

(2)

Question 2

6 marks

Momentum, Impulse & Collisions

2. Two particles, P and Q, have masses $2m$ and m respectively. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal plane. The particles collide directly.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $2u$.

The magnitude of the impulse exerted on Q by P in the collision is $5mu$.

Find

(a) the speed of P immediately after the collision,

(3)

(b) the speed of Q immediately after the collision.

(3)

Question 1

1. A particle P has mass $3m$ and a particle Q has mass $5m$. The particles are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately before the collision the speed of P is ku, where k is a constant, and the speed of Q is $2u$.

Immediately after the collision the speed of P is u and the speed of Q is $3u$.

The direction of motion of Q is reversed by the collision.

(a) Find, in terms of m and u, the magnitude of the impulse exerted on Q by P in the collision.

(2)

(b) Find the two possible values of k.

(5)

Question 2

2. A particle P of mass $2m$ is moving on a rough horizontal plane when it collides directly with a particle Q of mass $4m$ which is at rest on the plane. The speed of P immediately before the collision is $3u$. The speed of Q immediately after the collision is $2u$.

(a) Find, in terms of u, the speed of P immediately after the collision.

(3)

(b) State clearly the direction of motion of P immediately after the collision.

(1)

Following the collision, Q comes to rest after travelling a distance $\frac{6u^2}{g}$ along the plane.

The coefficient of friction between Q and the plane is μ.

(c) Find the value of μ.

(6)

Question 2

7 marks

Momentum, Impulse & Collisions

2. A particle P has mass km and a particle Q has mass m. The particles are moving towards each other in opposite directions along the same straight line when they collide directly.

Immediately before the collision, P has speed $3u$ and Q has speed u.

As a result of the collision, the direction of motion of each particle is reversed and the speed of each particle is halved.

(a) Find the value of k.

(4)

(b) Find, in terms of m and u, the magnitude of the impulse exerted on Q in the collision.

(3)

Question 1

4 marks

Momentum, Impulse & Collisions

1. Two particles, P and Q, are moving towards each other in opposite directions along the same straight line when they collide directly. Immediately before the collision the speed of Q is $2u$. The mass of Q is $3m$ and the magnitude of the impulse exerted by P on Q in the collision is $4mu$.

Find

(a) the speed of Q immediately after the collision,

(3)

(b) the direction of motion of Q immediately after the collision.

(1)

5 marks

Question 1

Momentum, Impulse & Collisions

1. A railway truck S of mass 20 tonnes is moving along a straight horizontal track when it collides with another railway truck T of mass 30 tonnes which is at rest. Immediately before the collision the speed of S is $4\,\text{m}\,\text{s}^{-1}$

As a result of the collision, the two railway trucks join together.

Find

(a) the common speed of the railway trucks immediately after the collision,

(2)

(b) the magnitude of the impulse exerted on S in the collision, stating the units of your answer.

(3)

Question 2

2. Two particles, A and B, are moving in a straight line in opposite directions towards each other on a smooth horizontal surface when they collide directly.

Particle A has mass $3m$ kg and particle B has mass m kg.

Immediately before the collision, both particles have a speed of $1.5\,\text{m}\,\text{s}^{-1}$

Immediately after the collision, the direction of motion of A is unchanged and the difference between the speed of A and speed of B is $1\,\text{m}\,\text{s}^{-1}$

(a) Find (i) the speed of A immediately after the collision,

(ii) the speed of B immediately after the collision.

(5)

(b) Find, in terms of m, the magnitude of the impulse exerted on B in the collision.

(3)

Question 1

7 marks

Momentum, Impulse & Collisions

1. A particle A has mass 4 kg and a particle B has mass 2 kg.

The particles move towards each other in opposite directions along the same straight line on a smooth horizontal table and collide directly.

Immediately before the collision, the speed of A is $2u \text{ m s}^{-1}$ and the speed of B is $3u \text{ m s}^{-1}$

Immediately after the collision, the speed of B is $2u \text{ m s}^{-1}$

The direction of motion of B is reversed by the collision.

(a) Find, in terms of u, the speed of A immediately after the collision.

(3)

(b) State the direction of motion of A immediately after the collision.

(1)

(c) Find, in terms of u, the magnitude of the impulse received by B in the collision. State the units of your answer.

(3)

WME01/01 OCTOBER 2023

10 marks

Question 3

Momentum, Impulse & Collisions

3. A hammer is used to hit a tent peg into soft ground.

The hammer has mass 1.8 kg and the tent peg has mass 0.2 kg.

The hammer and tent peg are both modelled as particles and the impact is modelled as a direct collision.

Immediately before the impact, the tent peg is stationary and the hammer is moving vertically downwards with speed $10\,\text{m}\,\text{s}^{-1}$

Immediately after the impact, the hammer and tent peg move together, vertically downwards, with the **same** speed $v\,\text{m}\,\text{s}^{-1}$

(a) Find the value of v

(2)

(b) Find the magnitude of the impulse exerted on the tent peg by the hammer, stating the units of your answer.

(3)

The ground exerts a constant vertical resistive force of magnitude R newtons, bringing the hammer and tent peg to rest after they travel a distance of 12 cm.

(c) Find the value of R.

(5)

WME01/01 JANUARY 2024

6 marks

Question 2

Momentum, Impulse & Collisions

2.

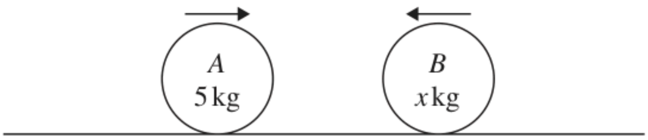

Figure 2

Figure 2 shows two particles, A and B, moving in opposite directions on a smooth horizontal surface. Particle A has mass 5 kg and particle B has mass x kg.

The particles collide directly.

Immediately before the collision, the speed of A is $3\,\text{m s}^{-1}$ and the speed of B is $x\,\text{m s}^{-1}$

Immediately after the collision, the speed of A is $1\,\text{m s}^{-1}$ and its direction of motion is unchanged.

Immediately after the collision, the speed of B is $1.5\,\text{m s}^{-1}$

(a) Find the value of x.

(3)

(b) Find the magnitude of the impulse exerted on A by B in the collision.

(3)

WME01/01 MAY/JUNE 2024

5 marks

Question 1

Momentum, Impulse & Collisions

1. Two particles, A and B, have masses m and $3m$ respectively. The particles are connected by a light inextensible string. Initially A and B are at rest on a smooth horizontal plane with the string slack.

Particle A is then projected along the plane away from B with speed U.

Given that the common speed of the particles immediately after the string becomes taut is S

(a) find S in terms of U.

(2)

(b) Find, in terms of m and U, the magnitude of the impulse exerted on A immediately after the string becomes taut.

(3)

Question 1

1. Particle A has mass $4m$ and particle B has mass $3m$.

The particles are moving in opposite directions along the same straight line on a smooth horizontal surface when they collide directly.

Immediately **before** the collision, the speed of A is $2x$ and the speed of B is x.

Immediately **after** the collision, the speed of A is y and the speed of B is $5y$.

The direction of motion of each particle is reversed as a result of the collision.

(a) Show that $y = \frac{5}{11}x$.

(3)

(b) Find, in terms of m and x, the magnitude of the impulse received by A in the collision.

(3)

Question 3

3.

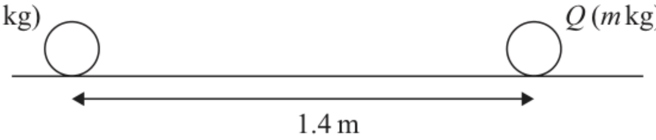

Figure 1

A particle P of mass $3m$ kg and a particle Q of mass m kg are at rest on a rough horizontal surface. The distance between P and Q is 1.4 m, as shown in Figure 1.

An impulse of magnitude λ N s is now applied to P in the direction PQ. Immediately after the impulse is applied, the speed of P is $5\,\text{m s}^{-1}$

(a) Find λ in terms of m.

(2)

Immediately before P collides with Q, the speed of P is $2.5\,\text{m s}^{-1}$
The coefficient of friction between P and the surface is μ

(b) Find the value of μ

(7)

Immediately after P collides with Q, the speed of Q is $2.1\,\text{m s}^{-1}$

(c) Find the speed of P immediately after the collision.

(3)

WME01/01 MAY/JUNE 2025

6 marks

Question 1

Momentum, Impulse & Collisions

1.

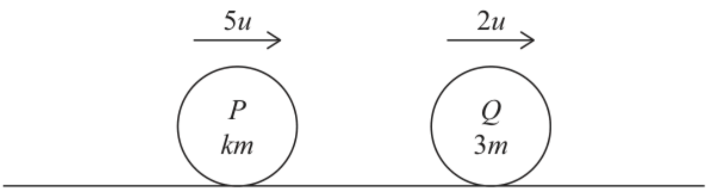

Figure 1

Figure 1 shows two particles, P and Q, moving in the same direction along the same straight line on a smooth horizontal surface.
Particle P has mass km and particle Q has mass $3m$
The particles collide directly.

Immediately before the collision, the speed of P is $5u$ and the speed of Q is $2u$

Immediately after the collision, the speed of P is $2u$ and its direction of motion is unchanged.

Immediately after the collision, the speed of Q is v

The impulse exerted on Q by P in the collision has magnitude $4.5mu$

(a) Find v in terms of u only.

(3)

(b) Find the value of k

(3)

WME01/01 OCTOBER 2025

8 marks

Question 2

Momentum, Impulse & Collisions

2.

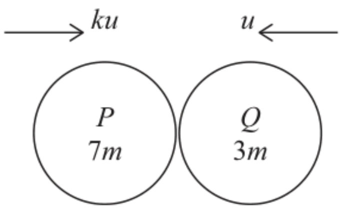

Figure 2

Particle P of mass $7m$ and particle Q of mass $3m$ are moving in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly.

Immediately **before** the collision, the speed of P is ku and the speed of Q is u, as shown in Figure 2.

Immediately **after** the collision, the speed of P is w and the speed of Q is $2w$.

The direction of motion of Q is reversed by the collision.

The impulse received by Q in the collision has magnitude $\frac{7}{2}mu$.

(a) Find w in terms of u.

(3)

(b) Find the two possible values of k.

(5)

Question 1

6 marks

Momentum, Impulse & Collisions

1. A particle P of mass $3m$ and a particle Q of mass $5m$ are on a smooth horizontal surface. The particles move towards each other in opposite directions along the same straight line and collide.

Immediately before the collision, the speed of P is $3u$ and the speed of Q is $4u$

The magnitude of the impulse exerted on P by Q in the collision is $\frac{33}{2}mu$

Find

(i) the speed of P immediately after the collision,

(ii) the speed of Q immediately after the collision.

(6)

9 marks

Momentum, Impulse & Collisions

WME01/01 OCTOBER 2019

Question 2

Also in Momentum, Impulse & Collisions

Primary: Constant Acceleration in 1D

2. A small ball is released from rest from a point that is 40 m above horizontal ground. The ball bounces on the ground and rebounds vertically. Each time the ball bounces on the ground, the speed of the ball is instantaneously reduced by 50%. The ball is modelled as a particle moving freely under gravity, from the instant when it is released until it first hits the ground, and between each successive bounce.

(a) Find the time from the instant when the ball is released from rest to the instant when it hits the ground for the second time.

(5)

(b) Find the maximum height reached by the ball above the ground after the ball's third bounce.

(4)

WME01/01 JANUARY 2024

Question 6

12 marks

Momentum, Impulse & Collisions

Also in Momentum, Impulse & Collisions

Primary: Constant Acceleration in 1D

6. A particle is projected vertically upwards from a point A with speed $24\,\text{m s}^{-1}$

The point A is 2.5 m vertically above the point B.

Point B lies on horizontal ground.

The particle moves freely under gravity until it hits the ground at B with speed $V\,\text{m s}^{-1}$

After hitting the ground the particle does not rebound.

(a) Find the value of V.

(3)

(b) Find the time taken for the particle to reach B.

(3)

The point C is 10 m vertically above A.

(c) Find the length of time for which the particle is above C.

(4)

(d) Sketch a speed-time graph for the motion of the particle from projection to the instant that it reaches B. (No further calculations are required.)

(2)

WME01/01 OCTOBER 2024

Question 7

11 marks

Momentum, Impulse & Collisions

Also in Momentum, Impulse & Collisions

Primary: Constant Acceleration in 1D

7 At time $t = 0$, a small ball A is projected vertically upwards with speed $8\,\mathrm{m\,s^{-1}}$ from a fixed point on horizontal ground.
The ball hits the ground again for the first time at time $t = T_1$ seconds.

Ball A is modelled as a particle moving freely under gravity.

(a) Show that $T_1 = 1.63$ to 3 significant figures.

(2)

After the first impact with the ground, A rebounds to a height of 2 m above the ground.

Given that the mass of A is 0.1 kg,

(b) find the magnitude of the impulse received by A as a result of its first impact with the ground.

(5)

At time $t = 1$ second, another small ball B is projected vertically upwards from another point on the ground with speed $5\,\mathrm{m\,s^{-1}}$

Ball B is modelled as a particle moving freely under gravity.

At time $t = T_2$ seconds ($T_2 > 1$), A and B are at the same height above the ground for the first time.

(c) Find the value of T_2

(4)

WME01/01 MAY/JUNE 2025

Question 8

17 marks

Momentum, Impulse & Collisions

Also in Momentum, Impulse & Collisions

Primary: Newton's Second Law

8.

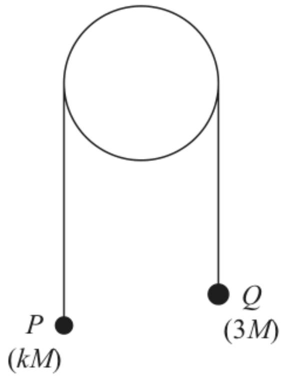

Figure 5

Two small balls, P and Q, have masses kM and $3M$ respectively, where $k < 3$

The balls are attached to the ends of a light inextensible string that passes over a fixed light smooth pulley.

The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 5.

The system is released from rest and, in the subsequent motion, P moves with an acceleration of magnitude $\frac{1}{5}g$

The balls are modelled as particles.

(a) Write down an equation of motion for P.

(2)

(b) Find the value of k.

(3)

Given that $M = 0.5\,\text{kg}$,

(c) find the magnitude of the force exerted on the pulley by the string while Q is moving downwards.

(3)

At the instant when the system is released, P is more than 2.5 m from the pulley and Q is 2.5 m above horizontal ground.
After hitting the ground, Q rebounds with a speed of $0.4\,\text{m}\,\text{s}^{-1}$

(d) Find the magnitude of the impulse received by Q when it hits the ground.

(5)

In the subsequent motion, P does not hit the pulley.

(e) Find the total time from when the balls are released until P first comes to rest.

(4)

TOPIC

Moments

Question 5

8 marks

Moments

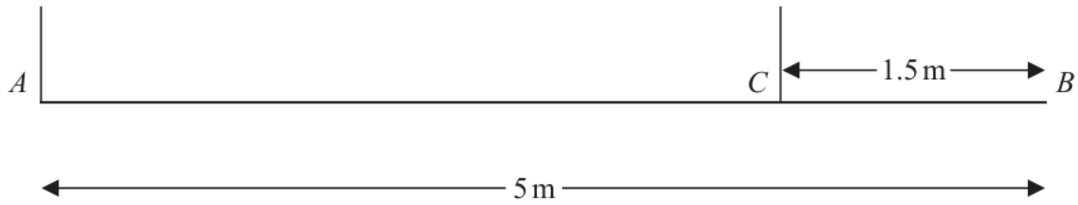

Figure 2

A non-uniform beam, AB, has length 5 m and mass 12 kg. The beam is suspended in a horizontal position by two vertical ropes. One rope is attached to the beam at A. The other rope is attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 2. The distance of the centre of mass of the beam from A is 1.75 m. The beam is modelled as a non-uniform rod and the ropes are modelled as light inextensible strings.

A particle of mass M kg is now placed on the beam at B and the beam remains in equilibrium in a horizontal position.

(a) Find the largest possible value of M.

(3)

The particle at B is now removed and a particle of mass 15 kg is now placed on the beam at the point D, where $AD = x$ metres. The beam remains in equilibrium in a horizontal position.

Given that the tension in the rope attached to the beam at C is now twice the tension in the rope attached to the beam at A,

(b) find the value of x.

(5)

WME01/01 JANUARY 2020

7 marks

Question 2

Moments

2.

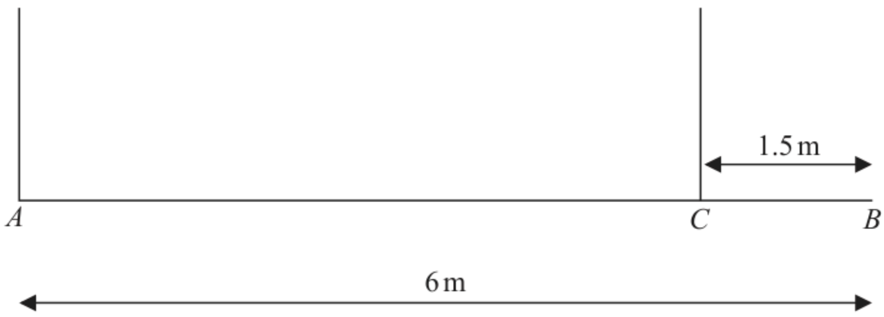

Figure 1

A non-uniform beam AB has length 6 m and weight W newtons. The beam is supported in equilibrium in a horizontal position by two vertical ropes, one attached to the beam at A and the other attached to the beam at C, where $CB = 1.5$ m, as shown in Figure 1.

The centre of mass of the beam is 2.625 m from A.

The ropes are modelled as light strings. The beam is modelled as a non-uniform rod.

Given that the tension in the rope attached at C is 20 N greater than the tension in the rope attached at A,

(a) find the value of W.

(6)

(b) State how you have used the fact that the beam is modelled as a rod.

(1)

WME01/01 JANUARY 2021

6 marks

Question 4

Moments

4.

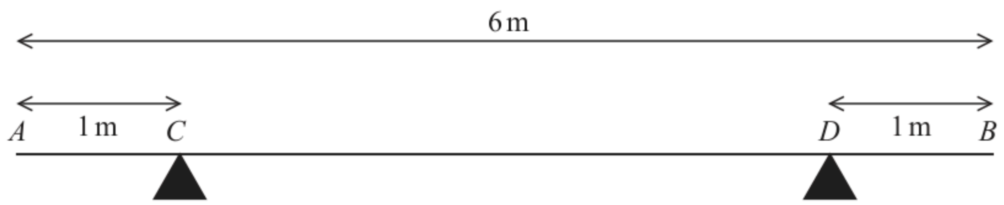

Figure 2

A metal girder AB has weight W newtons and length 6 m. The girder rests in a horizontal position on two supports C and D where $AC = DB = 1$ m, as shown in Figure 2.

When a force of magnitude 900 N is applied vertically upwards to the girder at A, the girder is about to tilt about D.

When a force of magnitude 1500 N is applied vertically upwards to the girder at B, the girder is about to tilt about C.

The girder is modelled as a non-uniform rod whose centre of mass is a distance x metres from A.

Find the value of x.

(6)

Question 7

7.

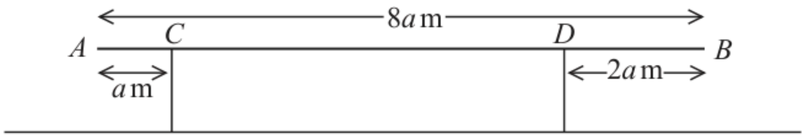

Figure 2

A non-uniform beam AB, of mass 60 kg and length $8a$ metres, rests in equilibrium in a horizontal position on two vertical supports. One support is at C, where $AC = a$ metres and the other support is at D, where $DB = 2a$ metres, as shown in Figure 2.

The magnitude of the normal reaction between the beam and the support at D is three times the magnitude of the normal reaction between the beam and the support at C.

By modelling the beam as a non-uniform rod whose centre of mass is at a distance x metres from A,

(a) find an expression for x in terms of a.

(5)

A box of mass M kg is placed on the beam at E, where $AE = 2a$ metres.

The beam remains in equilibrium in a horizontal position.

The magnitude of the normal reaction between the beam and the support at C is now equal to the magnitude of the normal reaction between the beam and the support at D.

By modelling the box as a particle,

(b) find the value of M.

(5)

WME01/01 OCTOBER 2021

6 marks

Question 1

Moments

1.

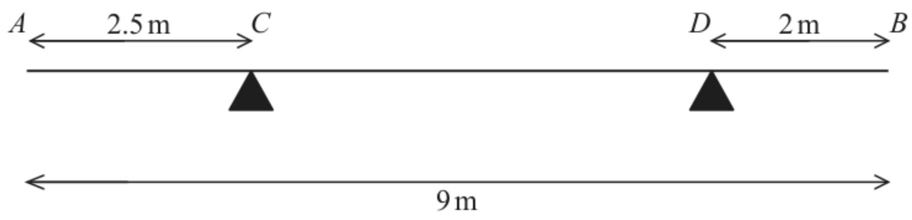

Figure 1

A non-uniform rod AB has length 9 m and mass M kg.

The rod rests in equilibrium in a horizontal position on two supports, one at C where $AC = 2.5$ m and the other at D where $DB = 2$ m, as shown in Figure 1.

The magnitude of the force acting on the rod at D is twice the magnitude of the force acting on the rod at C.

The centre of mass of the rod is d metres from A.

Find the value of d.

(6)

WME01/01 JANUARY 2022

Question 3

7 marks

Moments

3.

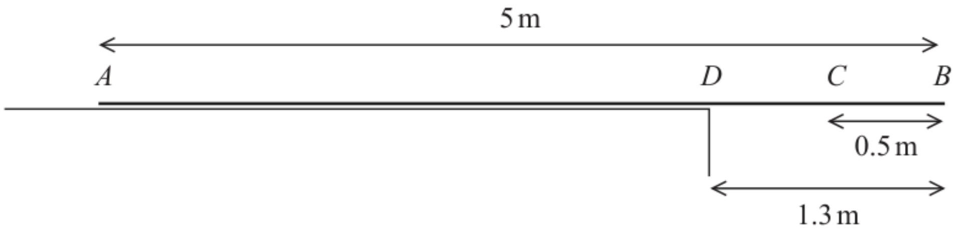

Figure 2

A beam *ADCB* has length 5 m. The beam lies on a horizontal step with the end *A* on the step and the end *B* projecting over the edge of the step. The edge of the step is at the point *D* where $DB = 1.3$ m, as shown in Figure 2.

When a small boy of mass 30 kg stands on the beam at *C*, where $CB = 0.5$ m, the beam is on the point of tilting.

The boy is modelled as a particle and the beam is modelled as a uniform rod.

(a) Find the mass of the beam.

(3)

A block of mass X kg is now placed on the beam at *A*.

The block is modelled as a particle.

(b) Find the smallest value of X that will enable the boy to stand on the beam at *B* without the beam tilting.

(3)

(c) State how you have used the modelling assumption that the block is a particle in your calculations.

(1)

WME01/01 MAY/JUNE 2022

9 marks

Question 5

Moments

5.

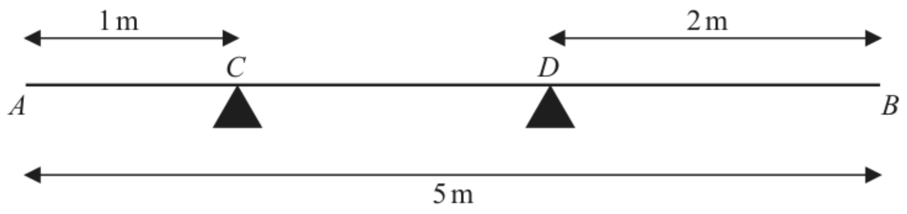

Figure 2

A uniform rod AB has length 5 m and mass 5 kg. The rod rests in equilibrium in a horizontal position on two supports C and D, where $AC = 1\text{ m}$ and $DB = 2\text{ m}$, as shown in Figure 2.

A particle of mass 10 kg is placed on the rod at A and a particle of mass M kg is placed on the rod at B. The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the magnitude of the reaction on the rod at C.

(3)

(b) Find, in terms of M, the magnitude of the reaction on the rod at D.

(3)

(c) Hence, or otherwise, find the range of possible values of M.

(3)

WME01/01 OCTOBER 2022

6 marks

Question 2

Moments

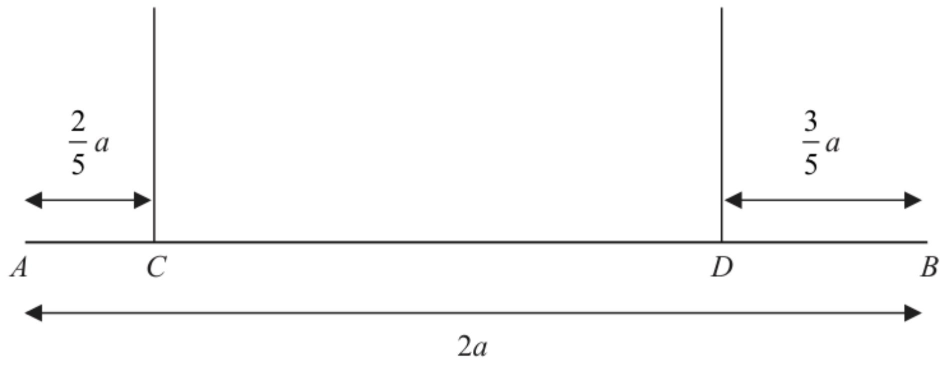

Figure 1

A uniform rod AB has length $2a$ and mass M. The rod is held in equilibrium in a horizontal position by two vertical light strings which are attached to the rod at C and D, where $AC = \frac{2}{5}a$ and $DB = \frac{3}{5}a$, as shown in Figure 1.

A particle P is placed on the rod at B.

The rod remains horizontal and in equilibrium.

(a) Find, in terms of M, the largest possible mass of the particle P

(3)

Given that the mass of P is $\frac{1}{2}M$

(b) find, in terms of M and g, the tension in the string that is attached to the rod at C.

(3)

Question 4

8 marks

Moments

4.

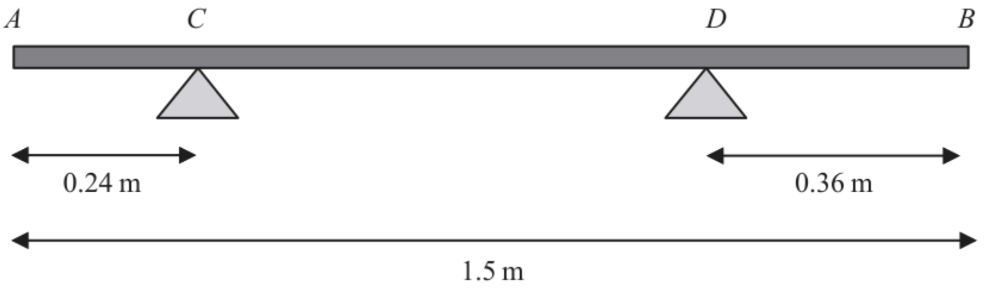

Figure 1

A branch AB, of length 1.5 m, rests horizontally in equilibrium on two supports.

The two supports are at the points C and D, where $AC = 0.24\,\text{m}$ and $DB = 0.36\,\text{m}$, as shown in Figure 1.

When a force of 150 N is applied vertically upwards at B, the branch is on the point of tilting about C.

When a force of 225 N is applied vertically downwards at B, the branch is on the point of tilting about D.

The branch is modelled as a non-uniform rod AB of weight W newtons.

The distance from the point C to the centre of mass of the rod is x metres.

Use the model to find

(i) the value of W

(ii) the value of x

(8)

WME01/01 MAY/JUNE 2023

12 marks

Question 4

Moments

4.

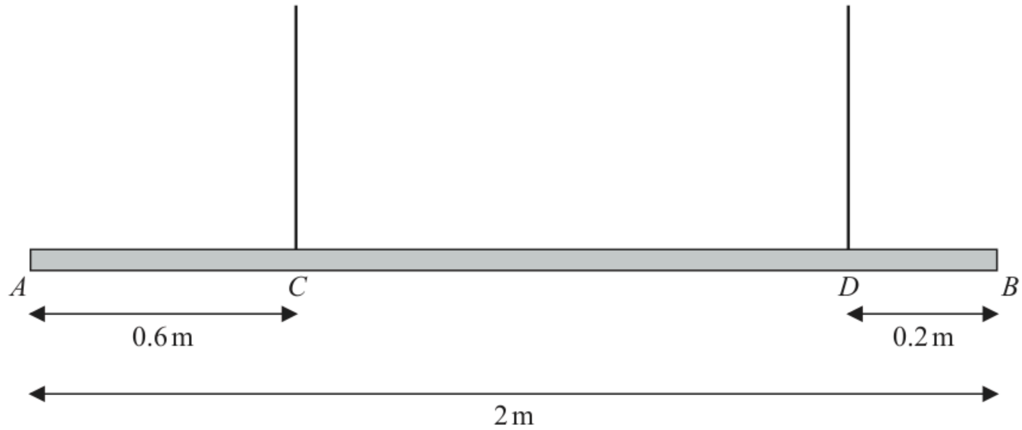

Figure 1

Figure 1 shows a beam AB, of mass m kg and length 2 m, suspended by two light vertical ropes.
The ropes are attached to the points C and D on the beam, where $AC = 0.6$ m and $DB = 0.2$ m
The beam is in equilibrium in a horizontal position.

A particle of mass pm kg is attached to the beam at A and the beam remains in equilibrium in a horizontal position.

The beam is modelled as a uniform rod.

(a) Given that the tension in the rope attached at C is four times the tension in the rope attached at D, use the model to find the exact value of p.

(7)

The particle of mass pm kg at A is removed and replaced by a particle of mass qm kg at A.
The beam remains in equilibrium in a horizontal position but is now on the point of tilting.

(b) Using the model, find the exact value of q

(4)

(c) State how you have used the modelling assumption that the beam is uniform.

(1)

WME01/01 OCTOBER 2023

5 marks

Question 1

Moments

1.

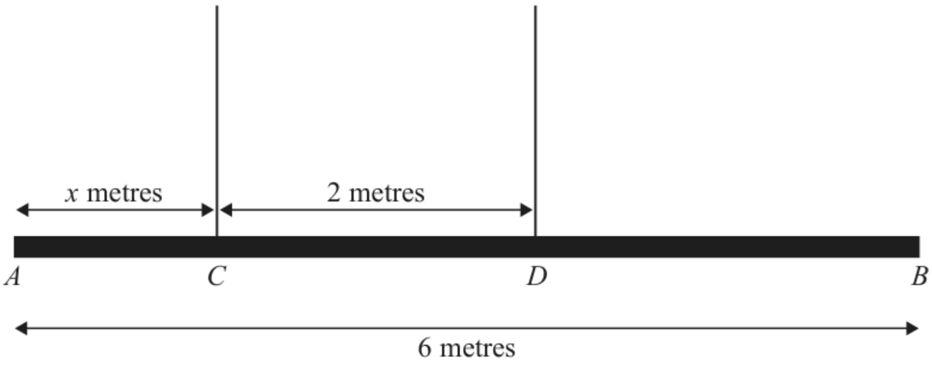

Figure 1

Figure 1 shows a beam AB with weight 24 N and length 6 m.

The beam is suspended by two light vertical ropes. The ropes are attached to the points C and D on the beam where $AC = x$ metres and $CD = 2$ m.

The tension in the rope attached to the beam at C is double the tension in the rope attached to the beam at D.

The beam is modelled as a uniform rod, resting horizontally in equilibrium.

Find

(i) the tension in the rope attached to the beam at D.

(ii) the value of x.

(5)

Question 5

10 marks

Moments

5.

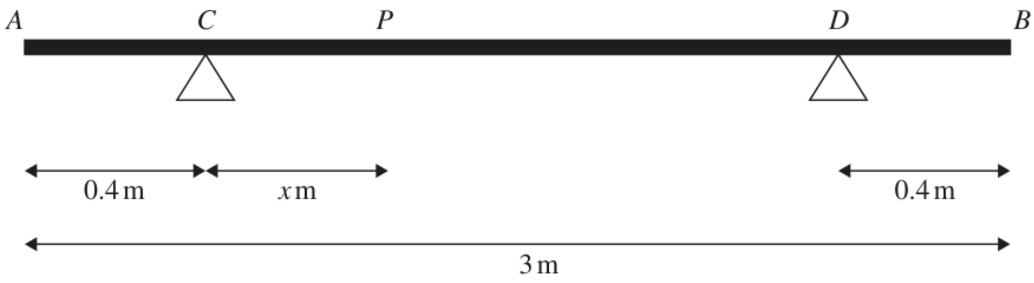

Figure 4

A beam AB has mass 30 kg and length 3 m.

The beam rests on supports at C and D where $AC = 0.4$ m and $DB = 0.4$ m, as shown in Figure 4.

A person of mass 55 kg stands on the beam between C and D.

The person is modelled as a particle at the point P, where $CP = x$ metres and $0 < x < 2.2$

The beam is modelled as a uniform rod resting in equilibrium in a horizontal position.

Using the model,

(a) show that the magnitude of the reaction at C is $(686 - 245x)$ N.

(3)

The magnitude of the reaction at C is **four** times the magnitude of the reaction at D.

Using the model,

(b) find the value of x

(4)

The person steps off the beam and places a package of mass M kg at A.

The package is modelled as a particle at the point A.

The beam is now on the point of tilting about C.

Using the model,

(c) find the value of M

(3)

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Question 4

6 marks

Moments

4.

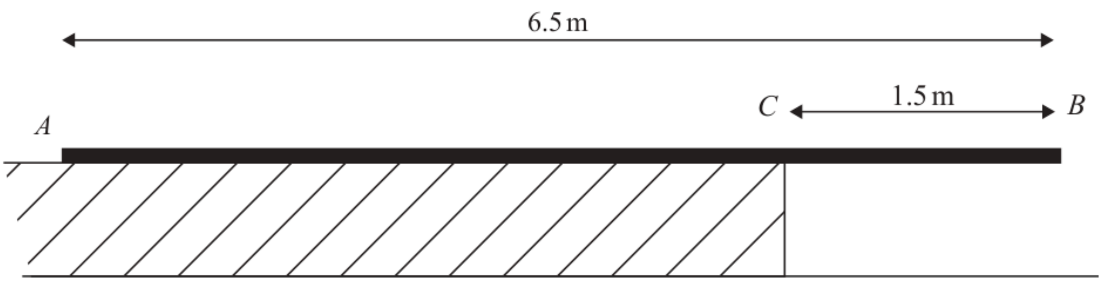

Figure 2

A non-uniform rod AB has length 6.5 m and mass 1.2 kg. The centre of mass of the rod is 3 m from A. The rod rests on a horizontal step and overhangs the end of the step C by 1.5 m, as shown in Figure 2.

The rod is perpendicular to the edge of the step.

A particle of mass 4 kg is placed on the rod at B and another particle, whose mass is M kg, is placed on the rod at D, where $AD = 0.5$ m.

The rod remains in equilibrium in a horizontal position.

(a) Find the smallest possible value of M.

(3)

The particle at B **and** the particle at D are now **removed**.

A new particle is placed on the rod at the point E, where $EB = 0.9$ m.

The rod remains in equilibrium in a horizontal position but is on the point of tilting about C.

(b) Find the magnitude of the force acting on the rod at C.

(3)

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Question 2

9 marks

Moments

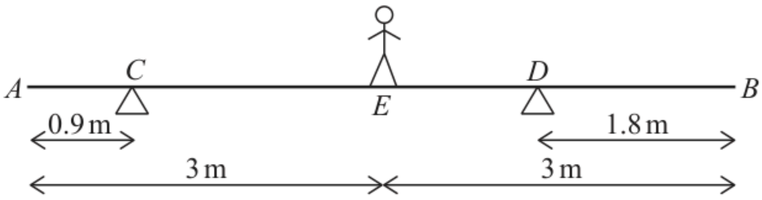

Figure 1

A non-uniform beam AB has length 6 m and mass 50 kg. The beam rests horizontally on two supports at C and D, where $AC = 0.9$ m and $DB = 1.8$ m.

A child of mass 25 kg stands on the beam at E, where $AE = EB = 3$ m, as shown in Figure 1.

The beam is in equilibrium.

The magnitude of the normal reaction between the beam and the support at C is R_C newtons.

The magnitude of the normal reaction between the beam and the support at D is R_D newtons.

The beam is modelled as a rod and the child is modelled as a particle.

The centre of mass of the beam is between C and D and is a distance x metres from D.

Given that $2R_D = 3R_C$

(a) show that $x = 1.38$

(6)

The child remains at E and a block of mass M kg is placed on the beam at B.

The block is modelled as a particle.

Given that the beam is on the point of tilting,

(b) find the value of M.

(3)

4.

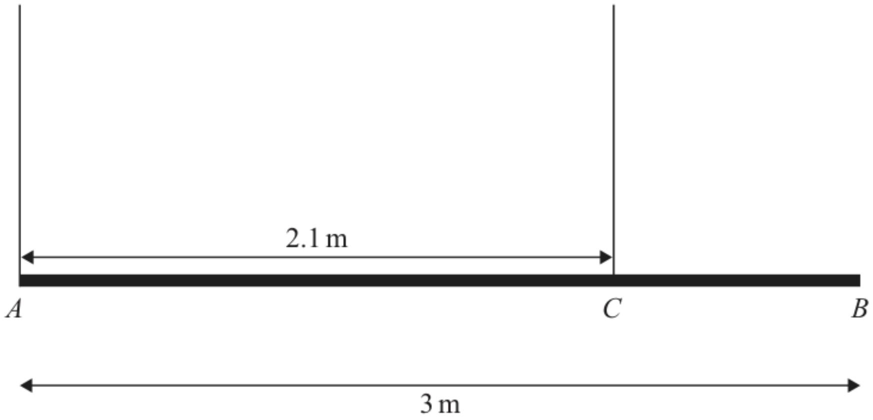

Figure 2

A uniform rod AB has length 3 m and weight W newtons.
The rod is suspended by two light vertical ropes.
One rope is attached to the rod at A and the other rope is attached to the rod at C, where $AC = 2.1$ m.

The rod is in equilibrium in a horizontal position, as shown in Figure 2.

The tension in the rope at C is 350 N.

(a) Show that $W = 490$

(3)

A particle P of weight 210 N is attached to the rod at a distance d metres from A.
The tension in the rope at C is now 600 N.
The rod remains in equilibrium in a horizontal position.

(b) Find the value of d.

(3)

Particle P is removed from the rod.
A particle Q of weight X newtons is now attached at B.
The rod remains in equilibrium in a horizontal position and is now on the point of tilting.

(c) Find the value of X.

(4)

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Question 5

6 marks

Moments

5.

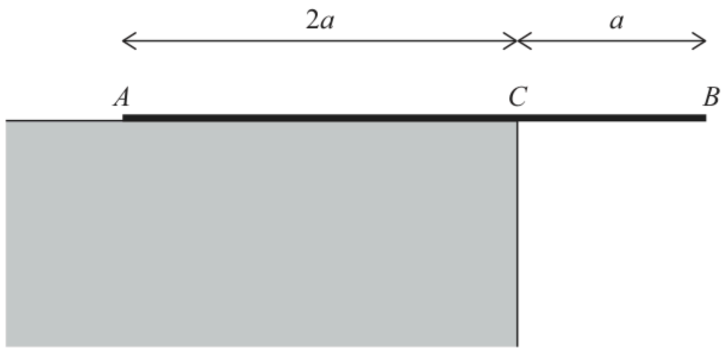

Figure 3

A non-uniform rod AB of length $3a$ rests in equilibrium on a horizontal ledge and overhangs the edge of the ledge at C.
The point C is such that $AC = 2a$ and $CB = a$, as shown in Figure 3.

The rod has weight W.

The distance of the centre of mass of the rod from A is d.

The rod is perpendicular to the edge of the ledge.

When a force of magnitude P, **acting vertically upwards**, is applied to the rod at B, the rod is on the point of tilting about A.

When the force applied at B is replaced by a force of magnitude $1.25P$, **acting vertically downwards** at B, the rod is on the point of tilting about C.

Find d in terms of a.

(6)

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7 marks

Question 1

Moments

1.

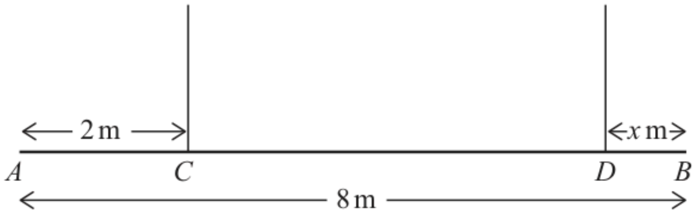

Figure 1

Figure 1 shows a sketch of a beam AB, with weight 240 N and length 8 m.

The beam is held in equilibrium in a horizontal position by two vertical ropes. The ropes are attached to the beam at the points C and D, where $AC = 2$ m and $DB = x$ metres.

The beam is modelled as a uniform rod and the ropes are modelled as light inextensible strings.

The tension in the rope at D is 90 N.

(a) Show that $x = \frac{2}{3}$

(3)

The rope at C will break if its tension exceeds 183 N. The rope at D cannot break.
A package of weight W newtons is now attached to the beam at A.
The beam remains horizontal and in equilibrium.

The package is modelled as a particle.

It is given that the rope at C does not break.

(b) Find the greatest possible value of W.

(4)

Question 4

9 marks

Moments

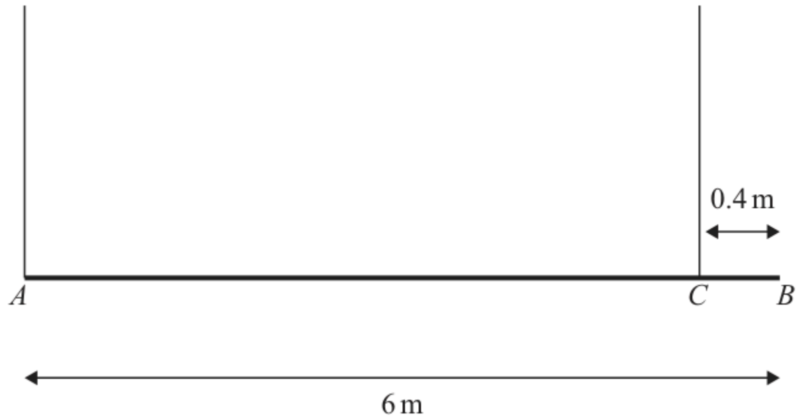

Figure 2

Figure 2 shows a uniform rod AB of length 6 m suspended by two light vertical ropes.

The first rope is attached to the rod at A.
The second rope is attached to the rod at the point C, where $CB = 0.4$ m.

The rod has mass 30 kg.

A particle of mass 20 kg is now attached to the rod at B.

The rod is in equilibrium in a horizontal position.

(a) Find

(i) the tension in the rope attached to the rod at C,
(ii) the tension in the rope attached to the rod at A.

(6)

The particle of mass 20 kg at B is removed and replaced by a particle of mass M kg.

The rod remains in equilibrium in a horizontal position.

(b) Find the exact maximum value of M.

(3)