"Knowing the path is good but not enough, walking the path with determination leads to destiny"

AS EDEXCEL MECHANICS (WME01) CLASSIFIED QUESTIONS

2019 – 2023

TOPIC-1: ALGEBRA		
S. NO	**TOPICS**	**PAGE NUMBER**
1.1	Uniform Accelerated Motion	3 – 31
1.2	Vector	33 – 50
1.3	Connected Particles	52 – 72
1.4	Inclined Plane/Slope	74 – 92
1.5	Static of Particle	93 – 102
1.6	Moment	104 – 116
1.7	Equilibrium	118 – 135
1.8	Momentum	137 - 149

Note:

Mechanics M1

There are no formulae given for M1 in addition to those candidates are expected to know.

1.1 Uniform Accelerated Motion:

Reference Notes:

Q1.

A car moves along a straight horizontal road with constant acceleration a ms $^{-2}$ 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 ms $^{-1}$

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 ms $^{-1}$

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

(Total for question = 8 marks)

(**Q02 WME01/01, June 2021**)

Q2.

Unless otherwise indicated, whenever a numerical value of g is required, take $g = 9.8$ m s^{-2} and give your answer to either 2 significant figures or 3 significant figures.

A car is moving along a straight horizontal road with constant acceleration a m s^{-2} ($a > 0$). At time $t = 0$ the car passes the point P moving with speed u m s^{-1}. In the next 4 s, the car travels 76 m and then in the following 6 s it travels a further 219 m.

Find

(i) the value of u,

(ii) the value of a.

(Total for question = 7 marks)

(**Q01 WME11/01, Specimen papers**)

Q3.

A small stone is projected vertically upwards with speed 20 m 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)

(Total for question = 6 marks)

(**Q01 WME01/01, Jan 2021**)

Q4.

A car is moving at a constant speed of 25 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 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 m s^{-1}.

In a **second** model, the car is assumed to decelerate uniformly at 6 m s^{-2} from A until it reaches a speed of 13 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 m s^{-1} from A until time $t = 0.2$, the car then decelerates uniformly at 6 m s^{-2} until it reaches a speed of 13 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)

(Total for question = 10 marks)

(**Q03 WME01/01, Oct 2021**)

Extra Space for working:

Q5.

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 m s^{-1}

Given that *PQ* = 220 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)

(Total for question = 7 marks)

(**Q02 WME01/01, June 2022**)

Q6.

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)

(Total for question = 8 marks)

(**Q03 WME01/01, June 2023**)

Q7.

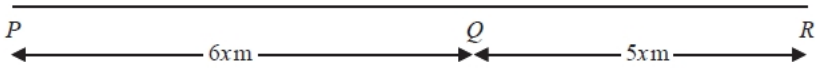


Figure 2

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 m s^{-1}

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

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

(Total for question = 9 marks)

(**Q05 WME01/01, Jan 2023**)

Extra Space for working:

Q8.

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 m s^{-2} up to a speed of 4 m s^{-1} and then maintains this speed until he crosses the finish line.

Beth accelerates at 1 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)

(Total for question = 13 marks)

(**Q07 WME01/01, June 2022**)

Extra Space for working:

Q9.

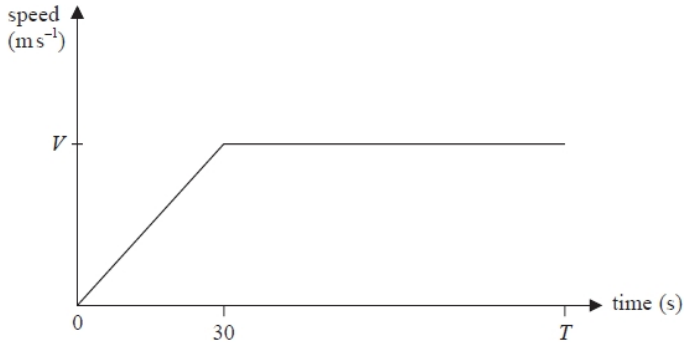


Figure 2

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 ***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.]

(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.

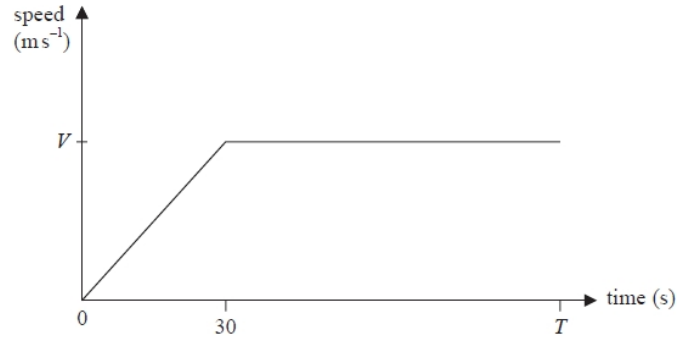


Figure 2

(Total for question = 11 marks)

(**Q05 WME01/01, June 2023**)

Extra Space for working:

Q10.

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

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

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

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

(2)

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

(b) Show that

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

(3)

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

(5)

(Total for question = 10 marks)

(**Q04 WME01/01, Oct 2023**)

Extra Space for working:

Q11.

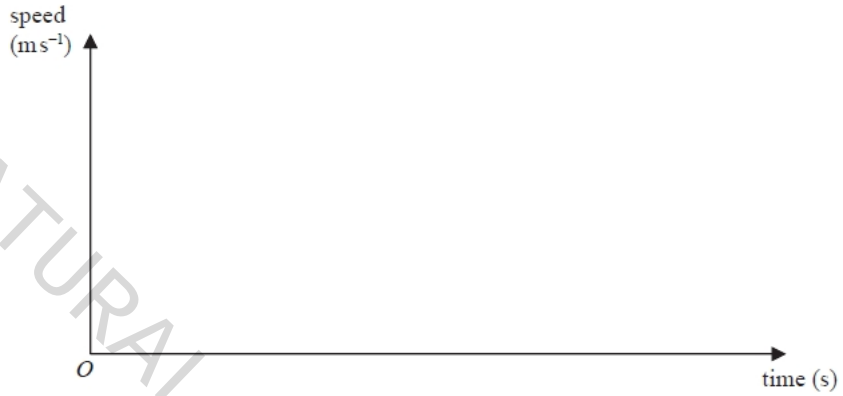
A train travels along a straight horizontal track between two stations *A* and *B*.

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

The train then travels at a constant speed of 20 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 below

(3)

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

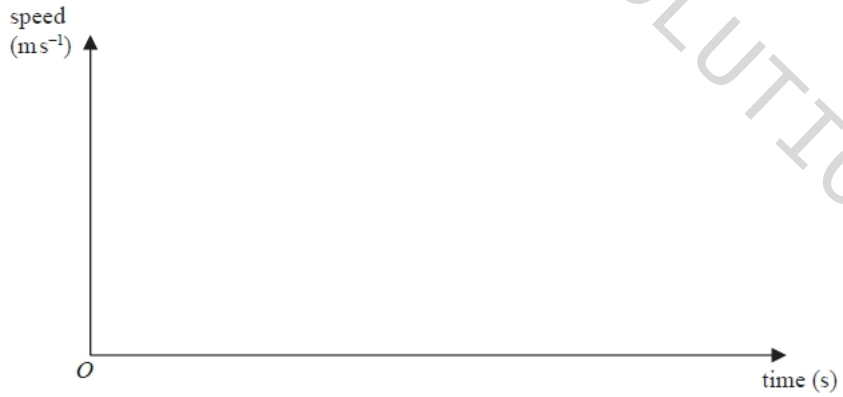
(b) Find the value of *T*

(5)

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

(2)

(Total for question = 10 marks)



(**Q01 WME01/01, Jan 2023**)

Extra Space for working:

Extra Space for working:

Q12.

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 ms $^{-2}$ 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 ms $^{-2}$ 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 for question = 13 marks)

(**Q08 WME01/01, June 2021**)

Extra Space for working:

Q13.

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 m s^{-2} for *T* seconds ($T < 6$), until his speed is reduced to *V* m s^{-1}. He then moves with this constant speed *V* m 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)

(Total for question = 12 marks)

(**Q07 WME01/01, Jan 2021**)

Extra Space for working:

Q14.

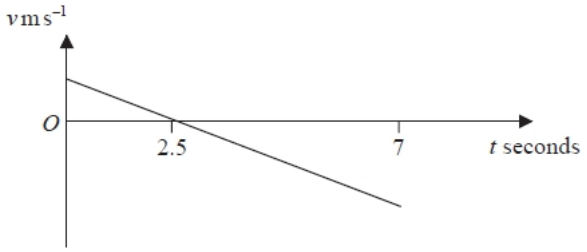


Figure 3

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 $0 \leq t \leq 7$

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

(2)

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

(3)

(Total for question = 5 marks)

(**Q06 WME01/01, Oct 2021**)

Q15.

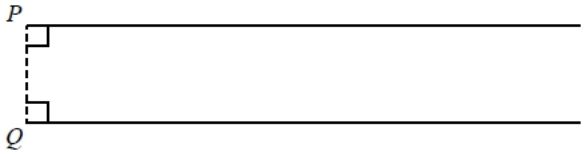


Figure 2

Two cars, *A* and *B*, move on parallel straight horizontal tracks. Initially *A* and *B* are both at rest with A at the point *P* and *B* at the point *Q*, as shown in Figure 2. At time $t = 0$ seconds, A starts to move with constant acceleration a m s^{-2} for 3.5 s, reaching a speed of 14 m s^{-1}. Car A then moves with constant speed 14 m s^{-1}.

(a) Find the value of *a*.

(2)

Car *B* also starts to move at time $t = 0$ seconds, in the same direction as car *A*. Car *B* moves with a constant acceleration of 3 m s^{-2}. At time $t = T$ seconds, *B* overtakes *A*. At this instant *A* is moving with constant speed.

(b) On a diagram, sketch, on the same axes, a speed-time graph for the motion of *A* for the interval $0 \leq t \leq T$ and a speed-time graph for the motion of *B* for the interval $0 \leq t \leq T$.

(3)

(c) Find the value of *T*.

(8)

(d) Find the distance of car *B* from the point *Q* when *B* overtakes *A*.

(1)

(e) On a new diagram, sketch, on the same axes, an acceleration-time graph for the motion of *A* for the interval $0 \leq t \leq T$ and an acceleration-time graph for the motion of *B* for the interval $0 \leq t \leq T$.

(3)

(Total for question = 17 marks)

(**Q06 WME11/01, Specimen papers**)

Extra Space for working:

Q16.

A block *A* of mass 9 kg is released from rest from a point *P* which is a height *h* metres above horizontal soft ground. The block falls and strikes another block *B* of mass 1.5 kg which is on the ground vertically below *P*. The speed of *A* immediately before it strikes *B* is 7 m s^{-1}. The blocks are modelled as particles.

(a) Find the value of *h*.

(2)

Immediately after the impact the blocks move downwards together with the same speed and both come to rest after sinking a vertical distance of 12 cm into the ground. Assuming that the resistance offered by the ground has constant magnitude *R* newtons,

(b) find the value of *R*.

(8)

(Total for question = 10 marks)

(**Q03 WME11/01, Specimen papers**)

Q17.

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)

(Total for question = 8 marks)

(**Q04 WME01/01, Jan 2022**)

Q18.

A small ball is projected vertically upwards with speed 29.4 m 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 m s^{-1}

(3)

(b) Find the time for which the ball is moving with a speed of more than 29.4 m 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)

(Total for question = 9 marks)

(**Q05 WME01/01, Oct 2022**)

Q19.

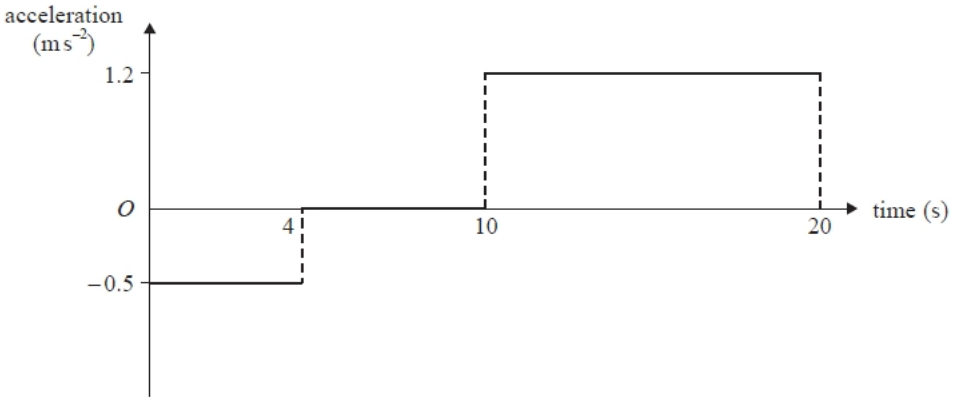


Figure 2

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 m s^{-1}

At time $t = 20$ s, the car passes through *B* with speed v 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)

(Total for question = 10 marks)

(Q02 WME01/01, Oct 2023)

1.2 Vector:

Reference Notes:

Q1.

[*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)

(Total for question = 9 marks)

(**Q06 WME01/01, Oct 2022**)

Q2.

[*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**i** + 12**j**) kmh^{-1} and the velocity of *B* is (*p***i** + *q***j**) kmh^{-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**i** + 6**j**) km and *B* is at the point with position vector (16**i** + 6**j**)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 for question = 16 marks)

(**Q08 WME01/01, Oct 2022**)

Extra Space for working:

Q3.

The position vector, **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 **r** and the vector **j**, when $t = 2$

(3)

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

(5)

(Total for question = 8 marks)

(**Q04 WME01/01, Oct 2021**)

Q4.

[*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**i** + 9**j**) km.

At 7.36 am the ship is at the point with position vector (4**i** + 6**j**) km.

(a) Show that the velocity of the ship is (10**i** – 5**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 for question = 12 marks)

(**Q08 WME01/01, Oct 2021**)

Extra Space for working:

Q5.

[*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 $(\mathbf{i} - \mathbf{j})$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 $\mathbf{j}$.

(2)

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

(Total for question = 12 marks)

(**Q06 WME01/01, Jan 2022**)

Extra Space for working:

Q6.

[*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**i** – 10**j**) km h^{-1}

At time *t* hours, the position vector of *A* is **r** km.

At time *t* = 0, *A* is at the point with position vector (13**i** + 5**j**) km.

(a) Find **r** in terms of *t*.

(2)

Another ship *B* moves with constant velocity (15**i** + 14**j**) km h^{-1}

At time *t* = 0, *B* is at the point with position vector (3**i** – 5**j**) km.

(b) Show that, at time *t* hours,

$\overrightarrow{AB}$ = [(12*t* − 10)**i** + (24*t* − 10)**j**]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 for question = 14 marks)

(**Q08 WME01/01, Jan 2022**)

Extra Space for working:

Q7.

A particle P is moving with constant acceleration.

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

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

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

(Total for question = 6 marks)

(**Q06 WME01/01, June 2022**)

Q8.

[*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 $15\mathbf{i}$ m s^{-1} and the velocity of *Q* is $(20\mathbf{i} - 20\mathbf{j})$ 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 **p** m and the position vector of *Q* is **q** m.

(b) Show that

$\overrightarrow{PQ} = [5t\mathbf{i} + (200 - 20t)\mathbf{j}]$ 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 for question = 17 marks)

(**Q08 WME01/01, June 2022**)

Extra Space for working:

Q9.

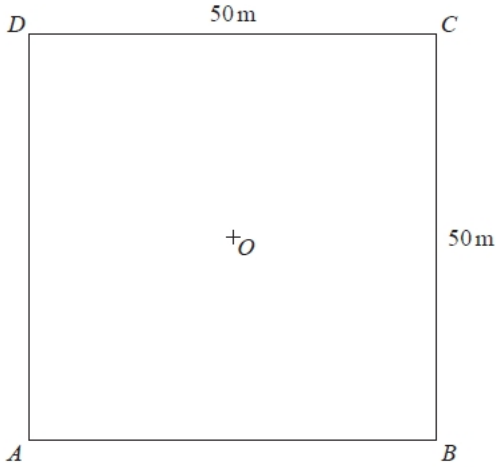


Figure 5

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)

(Total for question = 9 marks)

(Q08 WME01/01, June 2023)

Extra Space for working:

Q10.

Two forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, act on a particle A.

$\mathbf{F}_1 = (2\mathbf{i} - 3\mathbf{j})$ N and $\mathbf{F}_2 = (p\mathbf{i} + q\mathbf{j})$ N, where p and q are constants.

Given that the resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ is parallel to $(\mathbf{i} + 2\mathbf{j})$,

(a) show that $2p - q + 7 = 0$

(5)

Given that $q = 11$ and that the mass of A is 2 kg, and that $\mathbf{F}_1$ and $\mathbf{F}_2$ are the only forces acting on A,

(b) find the magnitude of the acceleration of A.

(5)

(Total for question = 10 marks)

(**Q05 WME11/01, Specimen papers**)

Q11.

A particle P is moving with constant acceleration $(-4\mathbf{i} + \mathbf{j})\text{ms}^{-2}$

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

(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)

(Total for question = 10 marks)

(**Q03 WME01/01, Jan 2023**)

Extra Space for working:

1.3 Connected Particles:

Reference Notes:

Q1.

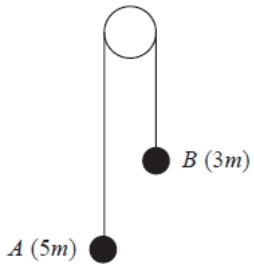


Figure 4

One end of a light inextensible string is attached to a particle A of mass $5m$. The other end of the string is attached to a particle B of mass $3m$. The string passes over a small, smooth, light fixed pulley. Particle A is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 4.

Particle A is released.

(a) Find, in terms of m and g, the magnitude of the force exerted on the pulley by the string while A is falling and before B hits the pulley.

(8)

(b) State how, in your solution to part (a), you have used the fact that the pulley is smooth.

(1)

(Total for question = 9 marks)

(**Q07 WME01/01, Oct 2020**)

Q2.

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)

(Total for question = 6 marks)

(**Q01 WME01/01, Oct 2019**)

Q3.

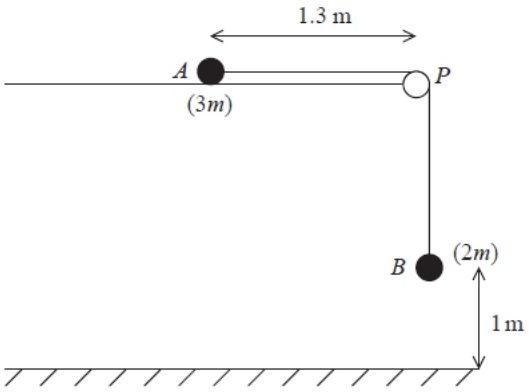


Figure 3

A particle *A* of mass 3*m* is held at rest on a rough horizontal table. The particle is attached to one end of a light inextensible string. The string passes over a small smooth pulley *P* which is fixed at the edge of the table. The other end of the string is attached to a particle *B* of mass 2*m*, which hangs freely, vertically below *P*. The system is released from rest, with the string taut, when *A* is 1.3 m from *P* and *B* is 1 m above the horizontal floor, as shown in Figure 3.

Given that *B* hits the floor 2 s after release and does not rebound,

(a) find the acceleration of *A* during the first two seconds,

(2)

(b) find the coefficient of friction between *A* and the table,

(8)

(c) determine whether *A* reaches the pulley.

(6)

(Total for question = 16 marks)

(**Q08 WME01/01, Jan 2015**)

Extra Space for working:

Q4.

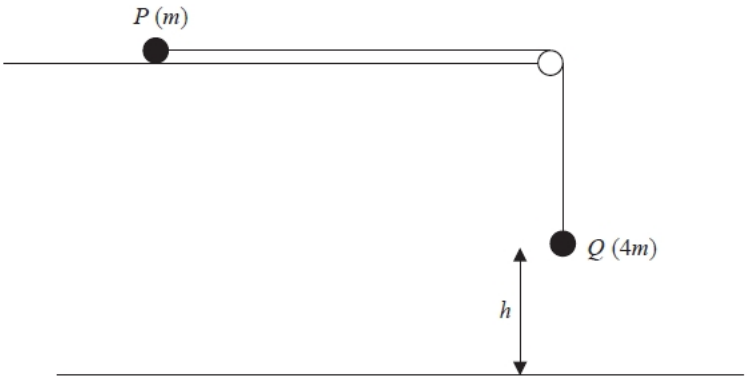


Figure 3

Two particles P and Q have masses m and $4m$ respectively. The particles are attached to the ends of a light inextensible string. Particle P is held at rest on a rough horizontal table.
The string lies along the table and passes over a small smooth light pulley which is fixed at the edge of the table. Particle Q hangs at rest vertically below the pulley, at a height h above a horizontal plane, as shown in Figure 3. The coefficient of friction between P and the table is 0.5. Particle P is released from rest with the string taut and slides along the table.

(a) Find, in terms of mg, the tension in the string while both particles are moving.

(8)

The particle P does not reach the pulley before Q hits the plane.

(b) Show that the speed of Q immediately before it hits the plane is $\sqrt{1.4gh}$

(2)

When Q hits the plane, Q does not rebound and P continues to slide along the table.
Given that P comes to rest before it reaches the pulley,

(c) show that the total length of the string must be greater than $2.4h$

(6)

(Total for question = 16 marks)

(**Q08 WME01/01, June 2015**)

Extra Space for working:

Q5.

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.

(Total for question = 7 marks)

(**Q03 WME01/01, Oct 2019**)

Q6.

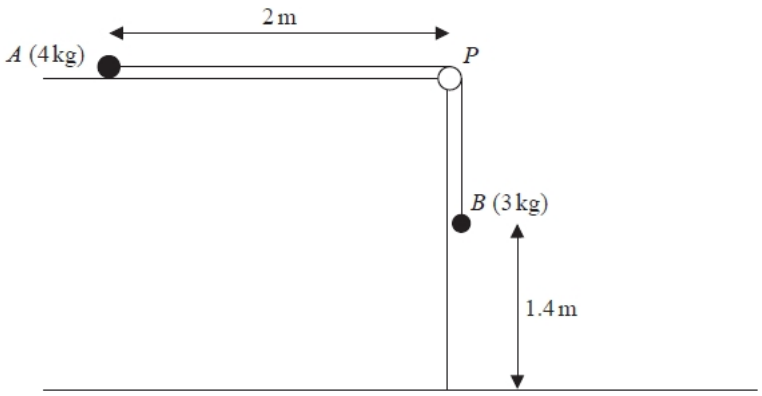


Figure 3

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 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 for question = 18 marks)

(**Q07 WME01/01, Jan 2020**)

Extra Space for working:

Q7.

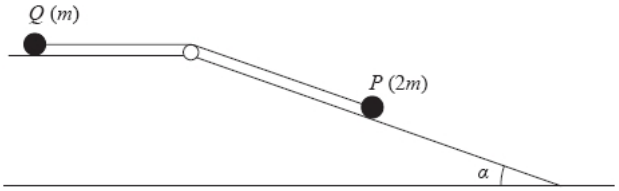


Figure 4

Two particles, *P* and *Q*, with masses 2*m* and *m* respectively, are attached to the ends of a light inextensible 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* is on the surface of a smooth inclined plane. The top of the plane coincides with the edge of the table. The plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$, as shown in Figure 4. The string lies in a vertical plane containing the pulley and a line of greatest slope of the plane. The coefficient of friction between *Q* and the table is $\frac{1}{2}$. Particle *Q* is released from rest with the string taut and *P* begins to slide down the plane.

(a) By writing down an equation of motion for each particle,

(i) find the initial acceleration of the system,
(ii) find the tension in the string.

(10)

Suppose now that the coefficient of friction between *Q* and the table is μ and when *Q* is released it remains at rest.

(b) Find the smallest possible value of μ.

(4)

(Total for question = 14 marks)

(**Q08 WME01/01, June 2017**)

Extra Space for working:

Q8.

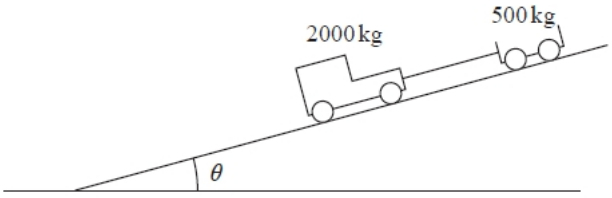


Figure 3

A railway truck of mass 500 kg is pushed up a straight track by a railway engine of mass 2000 kg. The track is inclined to the horizontal at an angle θ, where $\sin\theta = \frac{1}{14}$, as shown in Figure 3. The engine produces a constant driving force of magnitude 3050 N. The truck experiences a constant resistance to motion of magnitude 100 N and the engine experiences a constant resistance to motion of magnitude 200 N. The engine and the truck are connected by a coupling which is modelled as a light rod that is parallel to the track.

Find

(i) the acceleration of the system,

(ii) the magnitude of the force exerted on the truck by the coupling.

(8)

(Total for question = 8 marks)

(**Q04 WME01/01, June 2019**)

Q9.

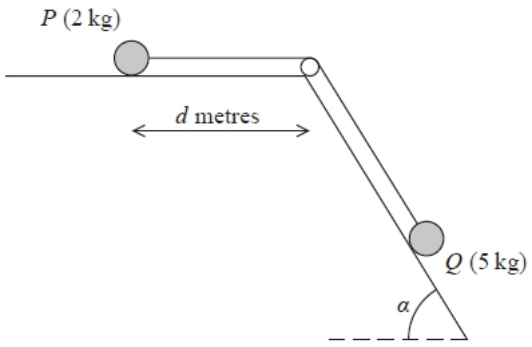


Figure 3

A particle P of mass 2 kg is attached to one end of a light inextensible string. A particle Q of mass 5 kg is attached to the other end of the string. The string passes over a small smooth light pulley. The pulley is fixed at a point on the intersection of a rough horizontal table and a fixed smooth inclined plane. The string lies along the table and also lies in a vertical plane which contains a line of greatest slope of the inclined plane. This plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$. Particle P is at rest on the table, a distance d metres from the pulley. Particle Q is on the inclined plane with the string taut, as shown in Figure 3. The coefficient of friction between P and the table is $\frac{1}{4}$.

The system is released from rest and P slides along the table towards the pulley.

Assuming that P has not reached the pulley and that Q remains on the inclined plane,

(a) write down an equation of motion for P,

(2)

(b) write down an equation of motion for Q,

(2)

(c) (i) find the acceleration of P,

(ii) find the tension in the string.

(5)

When P has moved a distance 0.5 m from its initial position, the string breaks. Given that P comes to rest just as it reaches the pulley,

(d) find the value of d.

(7)

(Total for question = 16 marks)

(**Q07 WME01/01, Jan 2016**)

Extra Space for working:

Q10.

A block *A* of mass 9 kg is released from rest from a point *P* which is a height *h* metres above horizontal soft ground. The block falls and strikes another block *B* of mass 1.5 kg which is on the ground vertically below *P*. The speed of *A* immediately before it strikes *B* is 7 m s^{-1}. The blocks are modelled as particles.

(a) Find the value of *h*.

(2)

Immediately after the impact the blocks move downwards together with the same speed and both come to rest after sinking a vertical distance of 12 cm into the ground. Assuming that the resistance offered by the ground has constant magnitude *R* newtons,

(b) find the value of *R*.

(8)

(Total for question = 10 marks)

(**Q03 WME01/01, June 2016**)

Q11.

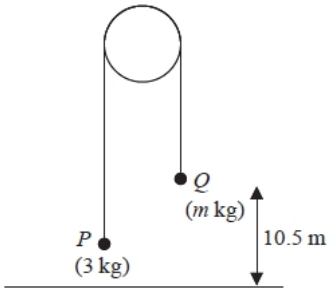


Figure 5

Two particles P and Q have masses 3kg and m kg respectively ($m > 3$). The particles are connected by a light inextensible string which passes over a smooth light fixed pulley. The system is held at rest with the string taut and the hanging parts of the string vertical. The particle Q is at a height of 10.5 m above the horizontal ground, as shown in Figure 5. The system is released from rest and Q moves downwards. In the subsequent motion P does not reach the pulley. After the system is released, the tension in the string is 33.6 N.

(a) Show that the magnitude of the acceleration of P is 1.4 m s^{-2}.

(3)

(b) Find the value of m.

(3)

The system is released from rest at time $t = 0$. At time T_1 seconds after release, Q strikes the ground and does not rebound. The string goes slack and P continues to move upward

(c) Find the value of T_1

(3)

At time T_2 seconds after release, P comes to instantaneous rest.

(d) Find the value of T_2

(3)

At time T_3 seconds after release ($T_3 > T_1$) the string becomes taut again.

(e) Sketch a velocity-time graph for the motion of P in the interval $0 \leq t \leq T_3$

(2)

(Total for question = 14 marks)

(Q07 WME01/01, Jan 2017)

Extra Space for working:

Q12.

A truck of mass 2400 kg is pulling a trailer of mass *M* kg along a straight horizontal road. The tow bar, connecting the truck to the trailer, is horizontal and parallel to the direction of motion. The tow bar is modelled as being light and inextensible. The resistance forces acting on the truck and the trailer are constant and of magnitude 400 N and 200 N respectively. The acceleration of the truck is 0.5 m s^{-2} and the tension in the tow bar is 600 N.

(a) Find the magnitude of the driving force of the truck.

(3)

(b) Find the value of *M*.

(3)

(c) Explain how you have used the fact that the tow bar is inextensible in your calculations.

(1)

(Total for question = 7 marks)

(**Q01 WME01/01, Jan 2016**)

Q13.

A car pulls a trailer along a straight horizontal road using a light inextensible towbar. The mass of the car is M kg, the mass of the trailer is 600 kg and the towbar is horizontal and parallel to the direction of motion. There is a resistance to motion of magnitude 200 N acting on the car and a resistance to motion of magnitude 100 N acting on the trailer. The driver of the car spots a hazard ahead. Instantly he reduces the force produced by the engine of the car to zero and applies the brakes of the car. The brakes produce a braking force on the car of magnitude 6500 N and the car and the trailer have a constant deceleration of magnitude 4 m s^{-2}.

Given that the resistances to motion on the car and trailer are unchanged and that the car comes to rest after travelling 40.5 m from the point where the brakes were applied, find

(a) the thrust in the towbar while the car is braking,

(3)

(b) the value of M,

(3)

(c) the time it takes for the car to stop after the brakes are applied.

(3)

(Total for question = 9 marks)

(**Q06 WME01/01, June 2018**)

Q14.

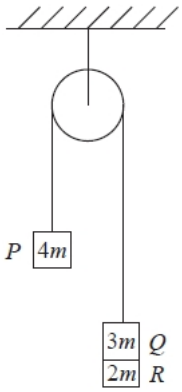


Figure 4

Three particles, P, Q and R, have masses $4m$, $3m$ and $2m$ respectively. Particles P and Q are connected by a light inextensible string that passes over a smooth light fixed pulley. Particle R is attached to particle Q. The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 4. The system is released from rest.

(a) Find

(i) the acceleration of particle P,
(ii) the tension in the string.

(7)

(b) State how you have used the fact that the string is inextensible.

(1)

At the instant when particle P has moved a distance d upwards from its initial position, particle R separates from particle Q and falls away. In the subsequent motion, particles P and Q continue to move and particle P does not reach the pulley.

At the instant when particles R and Q separate, particle Q is at the point A, and it continues to move downwards. Particle Q then comes to instantaneous rest at the point B.

(c) Find, in terms of d, the distance AB.

(8)

(Total for question = 16 marks)

(**Q08 WME01/01, June 2019**)

Extra Space for working:

1.4 Inclined Plane/Slope:

Reference Notes:

Q1.

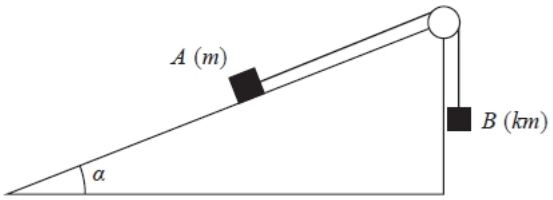


Figure 4

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)

(Total for question = 13 marks)

(Q07 WME01/01, Oct 2023)

Extra Space for working:

Q2.

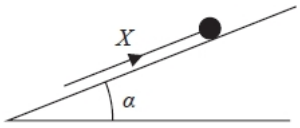


Figure 3

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*.

(Total for question = 8 marks)

(**Q05 WME01/01, Jan 2022**)

Q3.

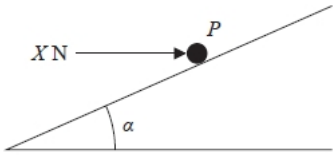


Figure 2

A rough plane is inclined to the horizontal at an angle α, where tan α = 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)

(Total for question = 11 marks)

(**Q03 WME01/01, Oct 2022**)

Extra Space for working:

Q4.

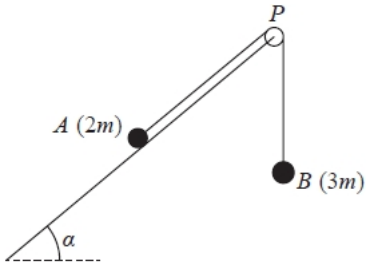


Figure 4

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)

(Total for question = 14 marks)

(Q07 WME01/01, Oct 2021)

Extra Space for working:

Q5.

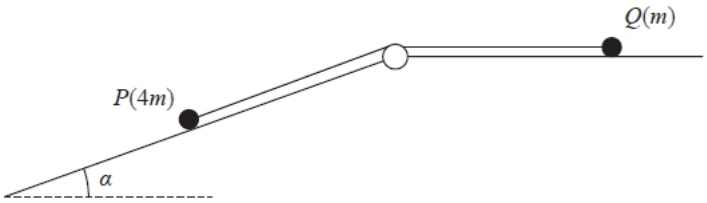


Figure 4

A particle *P* of mass 4*m* 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)

(Total for question = 13 marks)

(**Q07 WME01/01, Jan 2022**)

Extra Space for working:

Q6.

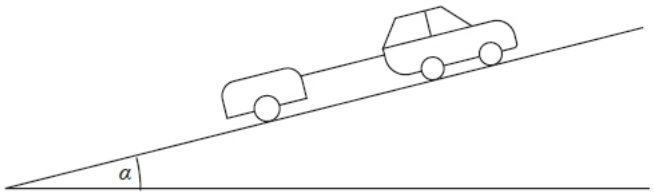


Figure 4

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 m s^{-2}

The non-gravitational resistance to motion of

- the **car** is modelled as a constant force of magnitude 2*R* 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 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)

(Total for question = 11 marks)

(**Q07 WME01/01, June 2023**)

Extra Space for working:

Q7.

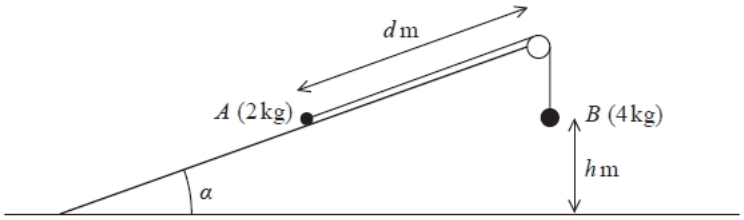


Figure 3

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 for question = 17 marks)

(**Q08 WME01/01, Jan 2021**)

Extra Space for working:

Q8.

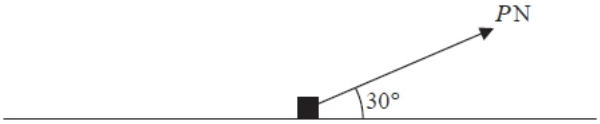


Figure 1

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)

(Total for question = 12 marks)

(**Q04 WME01/01, June 2022**)

Extra Space for working:

Q9.

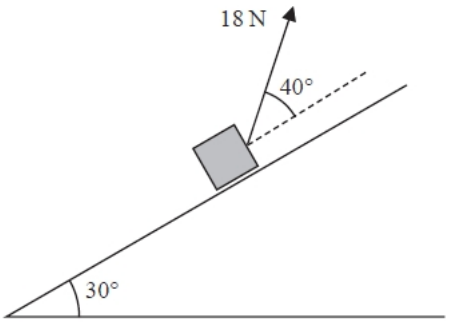


Figure 5

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 m and *B* is above *A*. Particle *P* passes through *A* with speed 2 m 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)

(Total for question = 15 marks)

(**Q08 WME01/01, Jan 2023**)

Extra Space for working:

Q10.

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 ms $^{-1}$ 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 ms $^{-1}$

(c) Find the distance BC.

(5)

(Total for question = 13 marks)

(**Q06 WME01/01, June 2021**)

Extra Space for working:

1.5 Static of A Particle:

Reference Notes:

Q1.

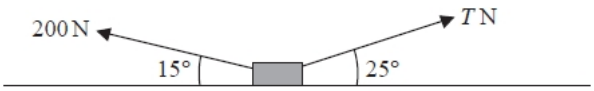


Figure 1

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.

(Total for question = 9 marks)

(**Q03 WME01/01, Jan 2021**)

Q2.

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 **R** = **F** + **G**, find

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

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

(Total for question = 7 marks)

(**Q05 WME01/01, Jan 2021**)

Q3.

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 **i** and **j** are horizontal perpendicular unit vectors.

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

Brionie skates with constant velocity $(4\mathbf{i} - 2\mathbf{j})$ 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)

(Total for question = 12 marks)

(**Q06 WME01/01, Jan 2021**)

Extra Space for working:

Q4.

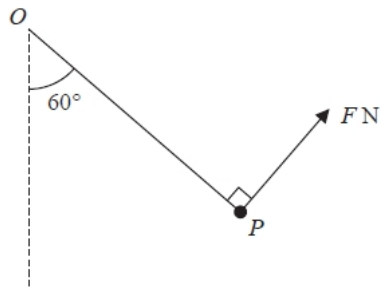


Figure 1

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)

(Total for question = 6 marks)

(**Q01 WME01/01, Jan 2022**)

Q5.

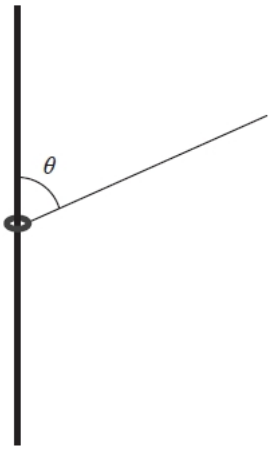


Figure 3

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)

(Total for question = 12 marks)

(**Q05 WME01/01, Oct 2023**)

Extra Space for working:

Q6.

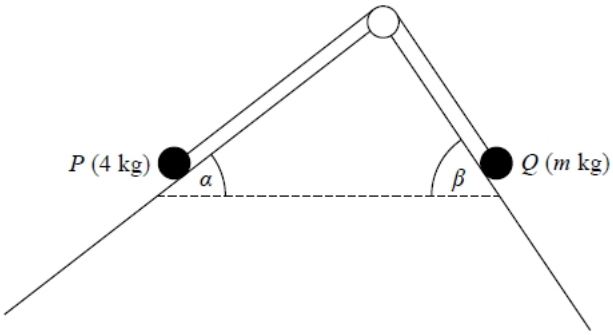


Figure 3

A particle P of mass 4 kg is attached to one end of a light inextensible string. A particle Q of mass m kg is attached to the other end of the string. The string passes over a small smooth pulley which is fixed at a point on the intersection of two fixed inclined planes. The string lies in a vertical plane that contains a line of greatest slope of each of the two inclined planes. The first plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$ and the second plane is inclined to the horizontal at an angle β, where $\tan \beta = \frac{4}{3}$. Particle P is on the first plane and particle Q is on the second plane with the string taut, as shown in Figure 3.

The first plane is rough and the coefficient of friction between P and the plane is $\frac{1}{4}$. The second plane is smooth. The system is in limiting equilibrium.

Given that P is on the point of slipping down the first plane,

(a) find the value of m,

(10)

(b) find the magnitude of the force exerted on the pulley by the string,

(4)

(c) find the direction of the force exerted on the pulley by the string.

(1)

(Total for question = 15 marks)

(**Q07 WME11/01, Specimen papers**)

Extra Space for working:

1.6 Moment:

Reference Notes:

Q1.

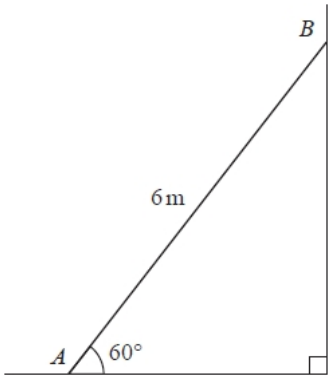


Figure 3

A ladder *AB* has length 6 m and mass 30 kg. The ladder rests in equilibrium at 60° to the horizontal with the end *A* on rough horizontal ground and the end *B* against a smooth vertical wall, as shown in Figure 3.

A man of mass 70 kg stands on the ladder at the point *C*, where *AC* = 2 m, and the ladder remains in equilibrium. The ladder is modelled as a uniform rod in a vertical plane perpendicular to the wall. The man is modelled as a particle.

(a) Find the magnitude of the force exerted on the ladder by the ground.

(6)

The man climbs further up the ladder. When he is at the point *D* on the ladder, the ladder is about to slip.

Given that the coefficient of friction between the ladder and the ground is 0.4

(b) find the distance *AD*.

(4)

(c) State how you have used the modelling assumption that the ladder is a rod.

(1)

(Total for question = 11 marks)

(**Q06 WME02/01, Jan 2021**)

Extra Space for working:

Q2.

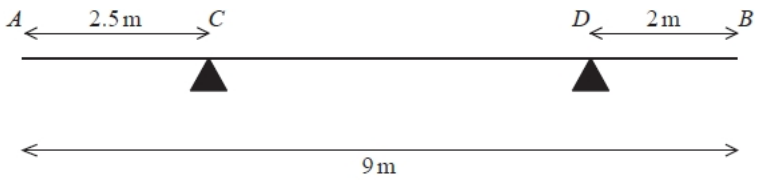


Figure 1

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)

(Total for question = 6 marks)

(**Q01 WME01/01, Oct 2021**)

Q3.

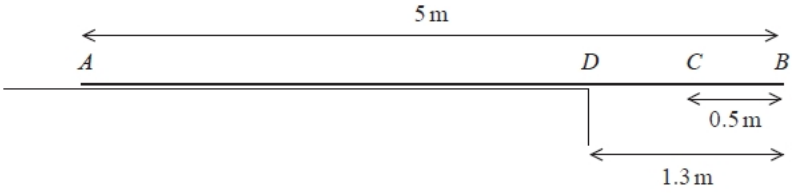


Figure 2

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)

(Total for question = 7 marks)

(**Q03 WME01/01, Jan 2022**)

Extra Space for working:

Q4.

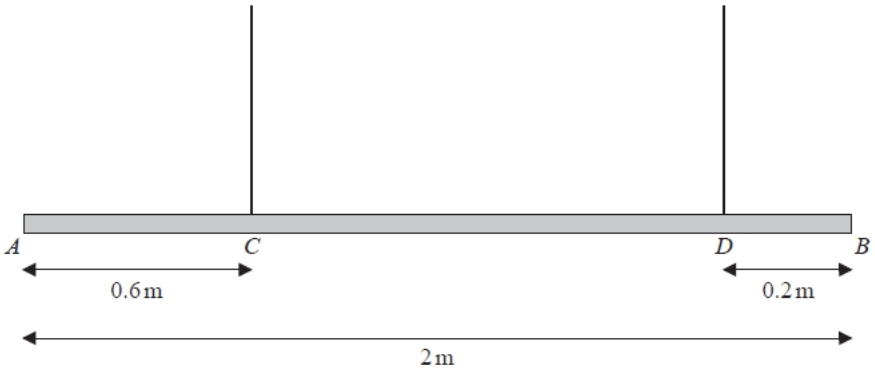


Figure 1

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)

(Total for question = 12 marks)

(**Q04 WME01/01, June 2023**)

Extra Space for working:

Q5.

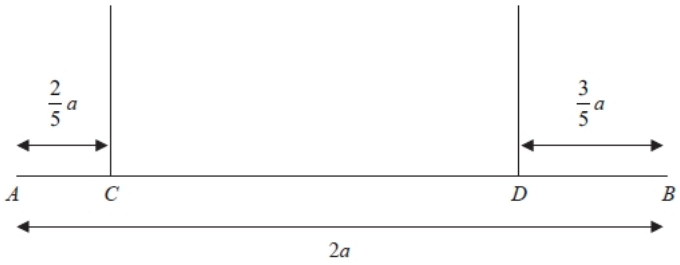


Figure 1

A uniform rod *AB* has length 2*a* 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 $\frac{3}{5}M$

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

(3)

(Total for question = 6 marks)

(**Q02 WME01/01, Oct 2022**)

Extra Space for working:

Q6.

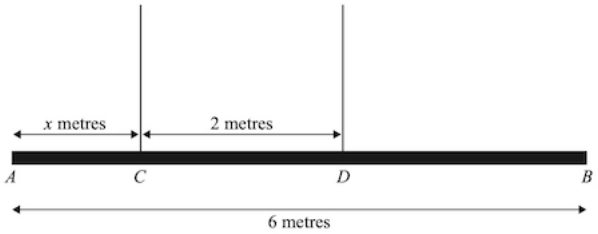


Figure 1

Figure 1 shows a beam *AB* with weight 24N 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)

(Total for question = 5 marks)

(**Q01 WME01/01, Oct 2023**)

Q7.

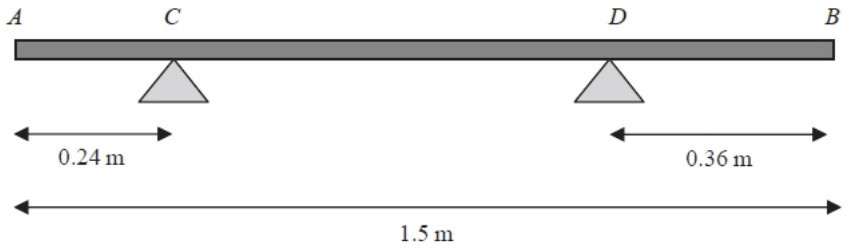


Figure 1

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* = 0.24m and *DB* = 0.36m, 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*

(Total for question = 8 marks)

(**Q04 WME01/01, Jan 2023**)

Q8.

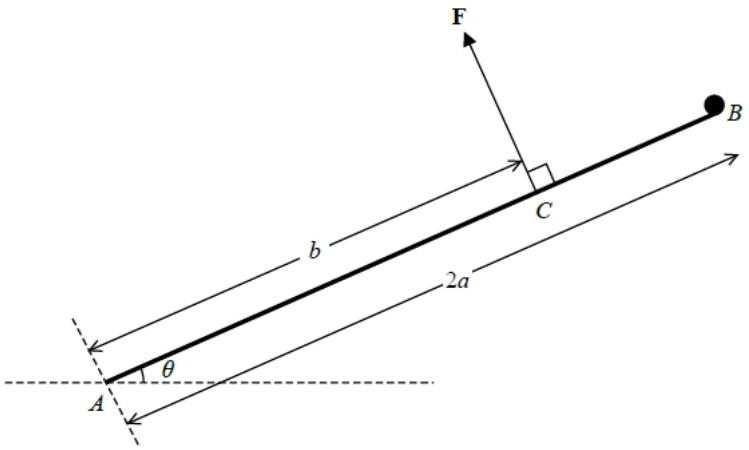


Figure 3

A uniform rod AB, of mass $3m$ and length $2a$, is freely hinged at A to a fixed point on horizontal ground. A particle of mass m is attached to the rod at the end B. The system is held in equilibrium by a force **F** acting at the point C, where $AC = b$. The rod makes an acute angle θ with the ground, as shown in Figure 3. The line of action of **F** is perpendicular to the rod and in the same vertical plane as the rod.

(a) Show that the magnitude of **F** is $\frac{5mga}{b}\cos\theta$

(4)

The force exerted on the rod by the hinge at A is **R**, which acts upwards at an angle ϕ above the horizontal, where $\phi > \theta$.

(b) Find

(i) the component of **R** parallel to the rod, in terms of m, g and θ,
(ii) the component of **R** perpendicular to the rod, in terms of a, b, m, g and θ.

(5)

(c) Hence, or otherwise, find the range of possible values of b, giving your answer in terms of a.

(2)

(Total for question = 11 marks)

(**Q06 WME12/01, Specimen papers**)

Extra Space for working:

1.7 Equilibrium:

Reference Notes:

Q1.

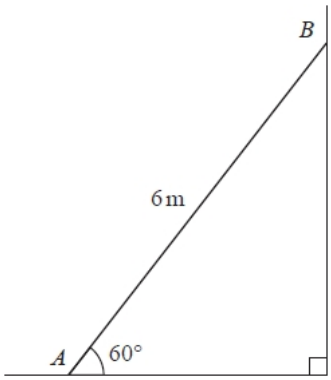


Figure 3

A ladder *AB* has length 6 m and mass 30 kg. The ladder rests in equilibrium at 60° to the horizontal with the end *A* on rough horizontal ground and the end *B* against a smooth vertical wall, as shown in Figure 3.

A man of mass 70 kg stands on the ladder at the point *C*, where *AC* = 2 m, and the ladder remains in equilibrium. The ladder is modelled as a uniform rod in a vertical plane perpendicular to the wall. The man is modelled as a particle.

(a) Find the magnitude of the force exerted on the ladder by the ground.

(6)

The man climbs further up the ladder. When he is at the point *D* on the ladder, the ladder is about to slip.

Given that the coefficient of friction between the ladder and the ground is 0.4

(b) find the distance *AD*.

(4)

(c) State how you have used the modelling assumption that the ladder is a rod.

(1)

(Total for question = 11 marks)

(**Q06 WME02/01, Jan 2021**)

Extra Space for working:

Q2.

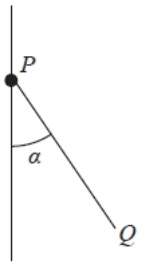


Figure 2

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)

(Total for question = 10 marks)

(**Q05 WME01/01, Oct 2021**)

Extra Space for working:

Q3.

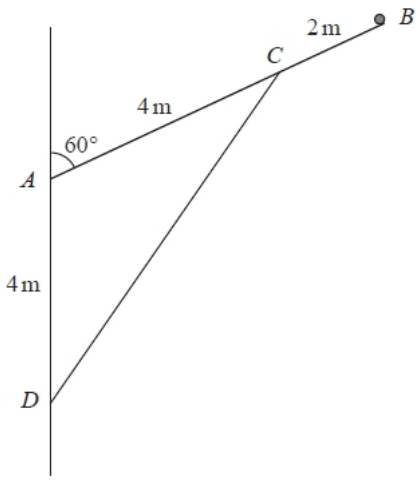


Figure 3

A uniform pole *AB*, of weight 50 N and length 6 m, has a particle of weight *W* newtons attached at its end *B*. The pole has its end *A* freely hinged to a vertical wall.
A light rod holds the particle and pole in equilibrium with the pole at 60° to the wall.
One end of the light rod is attached to the pole at *C*, where *AC* = 4 m.
The other end of the light rod is attached to the wall at the point *D*.
The point *D* is vertically below *A* with *AD* = 4 m, as shown in Figure 3.

The pole and the light rod lie in a vertical plane which is perpendicular to the wall.

The pole is modelled as a rod.

Given that the thrust in the light rod is $60\sqrt{3}$ N,

(a) show that *W* = 15

(4)

(b) find the magnitude of the resultant force acting on the pole at *A*.

(6)

(Total for question = 10 marks)

(**Q06 WME02/01, Jan 2023**)

Extra Space for working:

Q4.

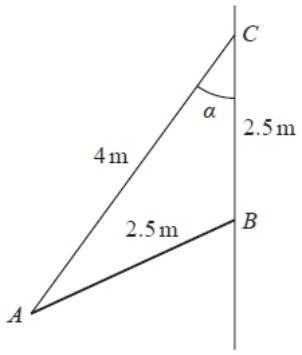


Figure 2

A pole *AB* has length 2.5 m and weight 70 N.
The pole rests with end *B* against a rough vertical wall. One end of a cable of length 4 m is attached to the pole at *A*. The other end of the cable is attached to the wall at the point *C*.
The point *C* is vertically above *B* and *BC* = 2.5 m.
The angle between the cable and the wall is α, as shown in Figure 2.
The pole is in a vertical plane perpendicular to the wall.
The cable is modelled as a light inextensible string and the pole is modelled as a uniform rod.

Given that $\tan \alpha = \frac{3}{4}$

(a) show that the tension in the cable is 56 N.

(4)

Given also that the pole is in limiting equilibrium,

(b) find the coefficient of friction between the pole and the wall.

(6)

(Total for question = 10 marks)

(**Q05 WME02/01, Oct 2021**)

Extra Space for working:

Q5.

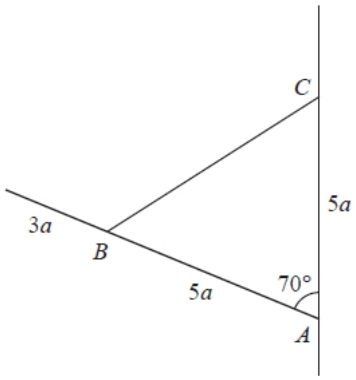


Figure 3

A uniform rod, of length 8*a* and mass *M*, has one end freely hinged to a fixed point *A* on a vertical wall. One end of a light inextensible string is attached to the rod at the point *B*, where *AB* = 5*a*. The other end of the string is attached to the wall at the point *C*, where *AC* = 5*a* and *C* is vertically above *A*. The rod rests in equilibrium in a vertical plane perpendicular to the wall with angle *BAC* = 70°, as shown in Figure 3.

(a) Find, in terms of *M* and *g*, the tension in the string.

(3)

The magnitude of the force acting on the rod at *A* is λMg, where λ is a constant.

(b) Find, to 2 significant figures, the value of λ.

(6)

(Total for question = 9 marks)

(**Q05 WME02/01, June 2021**)

Extra Space for working:

Q6.

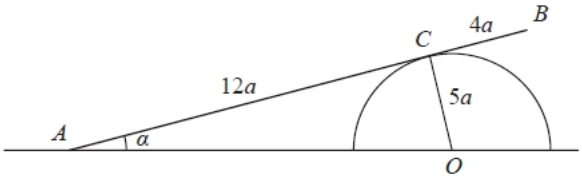


Figure 1

A smooth solid hemisphere is fixed with its flat surface in contact with rough horizontal ground. The hemisphere has centre O and radius $5a$.
A uniform rod AB, of length $16a$ and weight W, rests in equilibrium on the hemisphere with end A on the ground. The rod rests on the hemisphere at the point C, where $AC = 12a$ and angle $CAO = \alpha$, as shown in Figure 1.

Points A, C, B and O all lie in the same vertical plane.

(a) Explain why $AO = 13a$

(1)

The normal reaction on the rod at C has magnitude kW

(b) Show that $k = \frac{8}{13}$

(3)

The resultant force acting on the rod at A has magnitude R and acts upwards at $\theta°$ to the horizontal.

(c) Find

(i) an expression for R in terms of W
(ii) the value of θ

(8)

(Total for question = 12 marks)

(**Q05 WME02/01, Jan 2022**)

Extra Space for working:

Q7.

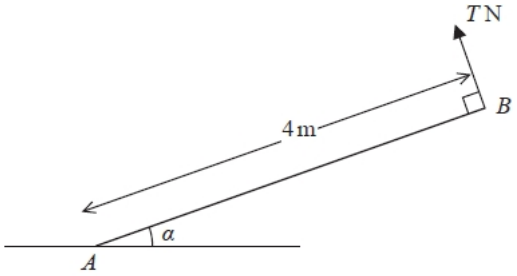


Figure 2

A uniform rod AB has length 4 m and weight 50 N.
The rod has its end A on rough horizontal ground. The rod is held in equilibrium at an angle α to the ground by a light inextensible cable attached to the rod at B, as shown in Figure 2. The cable and the rod lie in the same vertical plane and the cable is perpendicular to the rod. The tension in the cable is T newtons.

Given that $\sin \alpha = \frac{3}{5}$

(a) show that $T = 20$

(3)

Given also that the rod is in limiting equilibrium,

(b) find the value of the coefficient of friction between the rod and the ground.

(6)

(Total for question = 9 marks)

(**Q05 WME02/01, June 2022**)

Extra Space for working:

Q8.

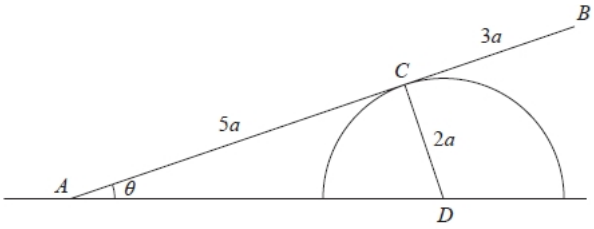


Figure 1

A uniform rod AB has length $8a$ and weight W.

The end A of the rod is freely hinged to horizontal ground.

The rod rests in equilibrium against a block which is also fixed to the ground.

The block is modelled as a smooth solid hemisphere with radius $2a$ and centre D.

The point of contact between the rod and the block is C, where $AC = 5a$

The rod is at an angle θ to the ground, as shown in Figure 1.

Points A, B, C and D all lie in the same vertical plane.

(a) Show that $AD = \sqrt{29}a$

(1)

(b) Show that the magnitude of the normal reaction at C between the rod and the block is $\frac{4}{\sqrt{29}}W$

(3)

The resultant force acting on the rod at A has magnitude kW and acts at an angle α to the ground.

(c) Find (i) the exact value of k

(ii) the exact value of $\tan \alpha$

(8)

(Total for question = 12 marks)

(Q05 WME02/01, Oct 2022)

Extra Space for working:

Q9.

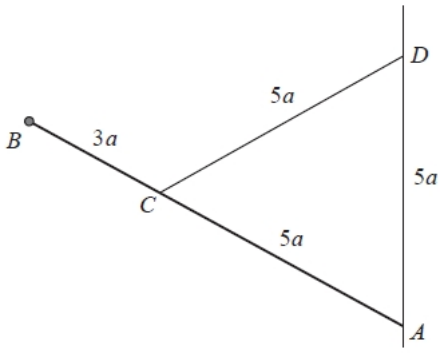


Figure 4

A uniform rod AB has length $8a$ and weight W.

The end A of the rod is freely hinged to a fixed point on a vertical wall.

A particle of weight $\frac{1}{4}W$ is attached to the rod at B.

A light inelastic string of length $5a$ has one end attached to the rod at the point C, where $AC = 5a$.

The other end of the string is attached to the wall at the point D, where D is above A and $AD = 5a$, as shown in Figure 4.

The rod rests in equilibrium.

The tension in the string is T.

(a) Show that $T = \frac{6}{5}W$

(3)

(b) Find, in terms of W, the magnitude of the force exerted on the rod by the hinge at A.

(6)

(Total for question = 9 marks)

(Q06 WME02/01, Oct 2023)

Extra Space for working:

1.8 Momentum:

Reference Notes:

Q1.

Two particles P and Q are moving in opposite directions along the same horizontal straight line. Particle P has mass m and particle Q has mass km. The particles collide directly. Immediately before the collision, the speed of P is u and the speed of Q is $2u$. 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 only, the magnitude of the impulse exerted on Q by P in the collision.

(2)

(Total for question = 6 marks)

(**Q02 WME11/01, Specimen papers**)

Q2.

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)

(Total for question = 6 marks)

(**Q02 WME01/01, Jan 2021**)

Q3.

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)

(Total for question = 7 marks)

(**Q01 WME01/01, June 2021**)

Q4.

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)

(Total for question = 7 marks)

(**Q02 WME01/01, Jan 2022**)

Q5.

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 2*u*. The mass of *Q* is 3*m* and the magnitude of the impulse exerted by *P* on *Q* in the collision is 4*mu*.

Find

(a) the speed of *Q* immediately after the collision,

(3)

(b) the direction of motion of *Q* immediately after the collision.

(1)

(Total for question = 4 marks)

(**Q01 WME01/01, June 2022**)

Q6.

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 $2u$ m s^{-1} and the speed of *B* is $3u$ m s^{-1}

Immediately after the collision, the speed of *B* is $2u$ 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)

(Total for question = 7 marks)

(**Q01 WME01/01, June 2023**)

Extra Space for working:

Q7.

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 m s^{-1}

Immediately after the impact, the hammer and tent peg move together, vertically downwards, with the **same** speed v 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)

(Total for question = 10 marks)

(**Q03 WME01/01, Oct 2023**)

Extra Space for working:

Q8.

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)

(Total for question = 10 marks)

(**Q02 WME01/01, Oct 2021**)

Extra Space for working:

Q9.

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 m 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)

(Total for question = 5 marks)

(**Q01 WME01/01, Oct 2022**)

Q10.

A block *A* of mass 9 kg is released from rest from a point *P* which is a height *h* metres above horizontal soft ground. The block falls and strikes another block *B* of mass 1.5 kg which is on the ground vertically below *P*. The speed of *A* immediately before it strikes *B* is 7 m s^{-1}. The blocks are modelled as particles.

(a) Find the value of *h*.

(2)

Immediately after the impact the blocks move downwards together with the same speed and both come to rest after sinking a vertical distance of 12 cm into the ground. Assuming that the resistance offered by the ground has constant magnitude *R* newtons,

(b) find the value of *R*.

(8)

(Total for question = 10 marks)

(**Q03 WME11/01, Specimen papers**)