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Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number	Candidate Number

Friday 16 October 2020

Afternoon (Time: 1 hour 30 minutes)	Paper Reference **WME01/01**

Mathematics

International Advanced Subsidiary/Advanced Level
Mechanics M1

You must have:
Mathematical Formulae and Statistical Tables (Blue), calculator

Total Marks

Candidates may use any calculator permitted by Pearson regulations. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- 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.

Information

- A booklet 'Mathematical Formulae and Statistical Tables' is provided.
- There are 8 questions in this question paper. The total mark for this paper is 75.
- The marks for each question are shown in brackets – *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- If you change your mind about an answer, cross it out and put your new answer and any working underneath.

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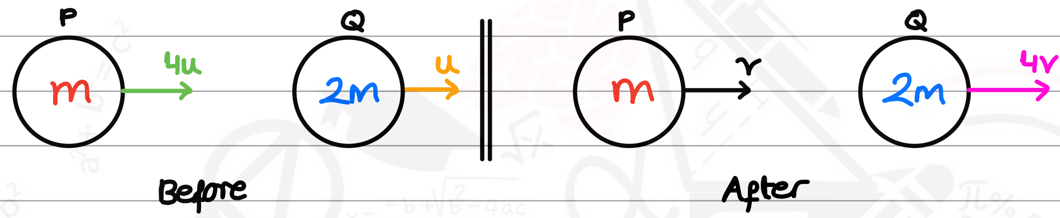
1. Two particles, P and Q, with masses m and $2m$ respectively, are moving in the same direction along the same straight line when they collide directly. Immediately before they collide, P is moving with speed $4u$ and Q is moving with speed u. Immediately after they collide, both particles are moving in the same direction and the speed of Q is four times the speed of P.

(a) Find the speed of Q immediately after the collision. **(3)**

(b) Find the magnitude of the impulse exerted by Q on P in the collision. **(3)**

(c) State clearly the direction of this impulse. **(1)**

a) Draw a diagram labelling the masses and speeds.



Using conservation of linear momentum : $\boxed{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$

$\therefore \quad m(4u) + 2m(u) = m(v) + 2m(4v)$

$\therefore \quad 4mu + 2mu = mv + 8mv$

$\therefore \quad 6mu = 9mv$

$\therefore \quad v = \frac{6mu}{9m} = \frac{2}{3}u \qquad \therefore$ Speed of Q after $= 4v = 4 \times \frac{2}{3}u = \frac{8}{3}u$

b) Formula for impulse : $\boxed{I = mv - mu}$

$\therefore \quad I = mv - m(4u)$

$\quad = m\left(\frac{2}{3}u\right) - m(4u) = \frac{2}{3}mu - 4mu = -\frac{10}{3}mu \qquad \therefore \quad |I| = \frac{10}{3}mu$

c) Opposite to the direction of motion.

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Question 1 continued

Q1

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2. A small ball is thrown vertically upwards with speed $14.7\,\text{m s}^{-1}$ from a point that is $19.6\,\text{m}$ above horizontal ground. The ball is modelled as a particle moving freely under gravity.

Find

(a) the total time from when the ball is thrown to when it first hits the ground,

(4)

(b) the speed of the ball immediately before it first hits the ground,

(3)

(c) the total distance travelled by the ball from when it is thrown to when it first hits the ground.

(4)

(d) Sketch a velocity-time graph for the motion of the ball from when it is thrown to when it first hits the ground.

State the coordinates of the start point and the coordinates of the end point of your graph.

(3)

a) Set up a SUVAT vertically only as the ball won't move horizontally taking upwards as positive from the instant it's released till it hits the ground. SUVAT may be used as the acceleration is constant.

s : -19.6 Equation without v : $\boxed{s = ut + \frac{1}{2}at^2}$

u : 14.7

v : $\therefore -19.6 = 14.7t + \frac{1}{2}(-9.8)t^2$

a : -9.8 $\therefore -4.9t^2 + 14.7t + 19.6 = 0$

t : t $\therefore t = 4$ OR $t = -1$, $t > 0$ $\therefore t = 4$ //

b) We can set up another SUVAT to find the speed of the ball before it hits the ground (v).

s : -19.6 Equation without t : $\boxed{v^2 = u^2 + 2as}$

u : 14.7

v : v $\therefore v^2 = 14.7^2 + 2(-9.8)(-19.6)$

a : -9.8 $\therefore v^2 = 600.25$

t : $\therefore v = \sqrt{600.25} = 24.5\ \text{ms}^{-1}$ //

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Question 2 continued

c) To calculate the total distance travelled we can seperate the journey into three parts.

① Starts at release, ends when changes direction and goes down.
② Starts at change of direction, ends when the ball is level with starting position.
③ Starts when level at the start, ends when the ball hits the floor.

Part ③ is already known as its just the height at the start and parts ① and ② are equal so we can just set up a SUVAT for part ①.

$s: h$ Where 'h' is the height above the starting position

$u: 14.7$

$v: 0$ Equation without t : $\boxed{v^2 = u^2 + 2as}$

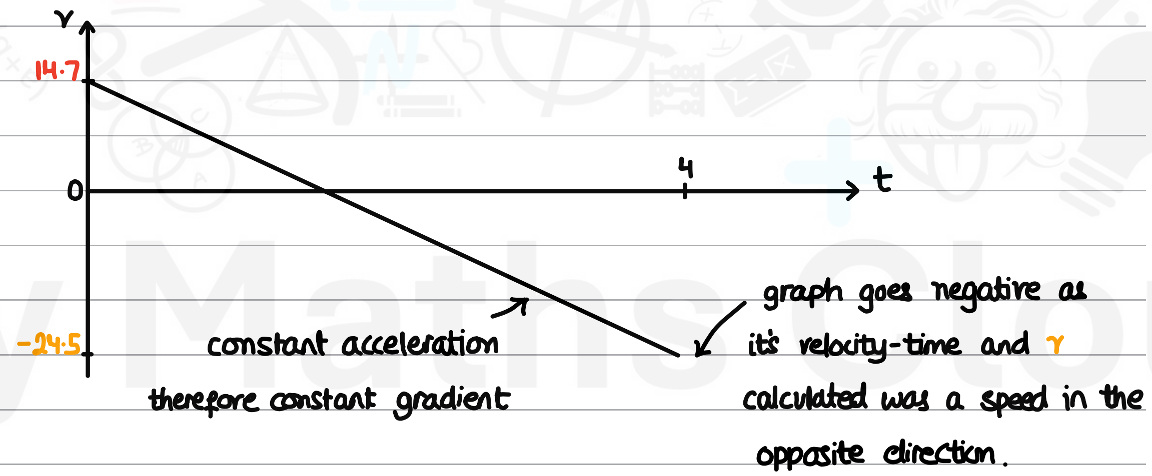
$a: -9.8$

$t:$ $\therefore \; 0^2 = 14.7^2 + 2(-9.8)(h)$

$\therefore \; 19.6h = 14.7^2 \quad \therefore \; h = \dfrac{14.7^2}{19.6} = 11.025 \text{ m}$

$\therefore$ Total distance = ① + ② + ③ = $11.025 + 11.025 + 19.6 = 41.65 \approx 41.7\text{m}$ (3sf)

d)



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Question 2 continued

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Question 2 continued

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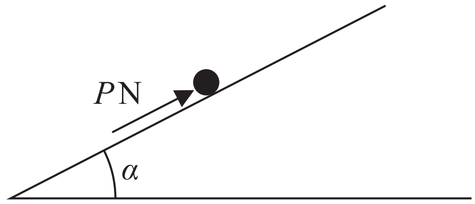


Figure 1

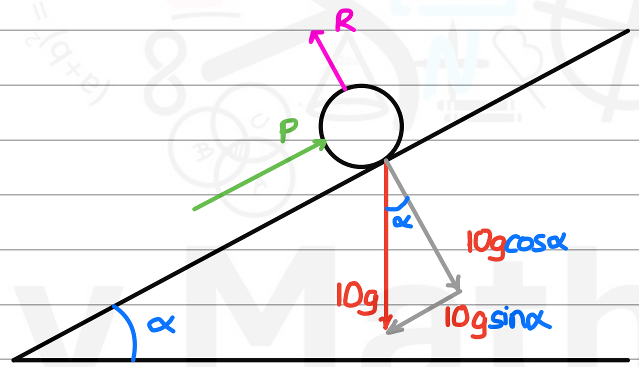
A particle of mass 10 kg is placed on a fixed rough inclined plane. The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$. The particle is held in equilibrium by a force of magnitude P newtons, which acts up the plane, as shown in Figure 1. The line of action of the force lies in a vertical plane that contains a line of greatest slope of the plane. The coefficient of friction between the particle and the plane is $\frac{1}{2}$.

(a) Find the normal reaction between the particle and the plane. **(2)**

(b) Find the greatest possible value of P. **(4)**

(c) Find the least possible value of P. **(2)**

a) Draw a diagram labelling the forces.



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

$\therefore \sin\alpha = \frac{3}{5}$ $\quad \cos\alpha = \frac{4}{5}$

As there's no movement perpendicular to the plane, the sum of the perpendicular forces is zero.

$\therefore \boxed{\Sigma F = 0}$ $\quad \therefore R - 10g\cos\alpha = 0 \quad \therefore R = 10g\cos\alpha = 10 \times 9.8 \times \frac{4}{5} = 78.4\text{ N}$ //

b) The greatest value of P occurs when the particle is on the point of slipping up the plane meaning friction is acting down the slope to oppose motion as shown below.

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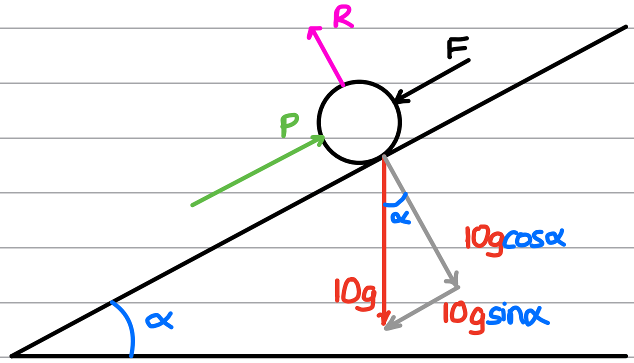
Question 3 continued



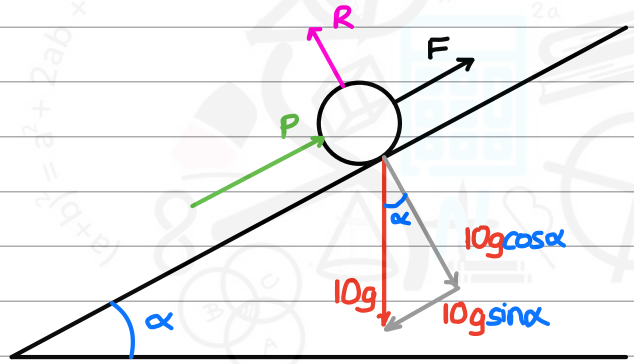
As there's no movement perpendicular to the plane, the sum of the perpendicular forces is zero.

Friction formula : $\boxed{F = \mu R}$

$\therefore$ $\boxed{\Sigma F = 0}$ $\therefore$ $P_{max} - 10g\sin\alpha - F = 0$ $\therefore$ $P_{max} = 10g\sin\alpha + F$

$\therefore$ $P_{max} = 10g\sin\alpha + \frac{1}{2}R = 10(9.8)\left(\frac{3}{5}\right) + \frac{1}{2}(78.4) = 98\text{ N}$ //

c) To find the least value of P we simply do the opposite of finding the largest value meaning friction is now acting up the slope.



As there's no movement perpendicular to the plane, the sum of the perpendicular forces is zero.

Friction formula : $\boxed{F = \mu R}$

$\therefore$ $\boxed{\Sigma F = 0}$ $\therefore$ $P_{min} - 10g\sin\alpha + F = 0$ $\therefore$ $P_{min} = 10g\sin\alpha - F$

$\therefore$ $P_{min} = 10g\sin\alpha - \frac{1}{2}R = 10(9.8)\left(\frac{3}{5}\right) - \frac{1}{2}(78.4) = 19.6\text{ N}$ //

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Question 3 continued

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Question 3 continued

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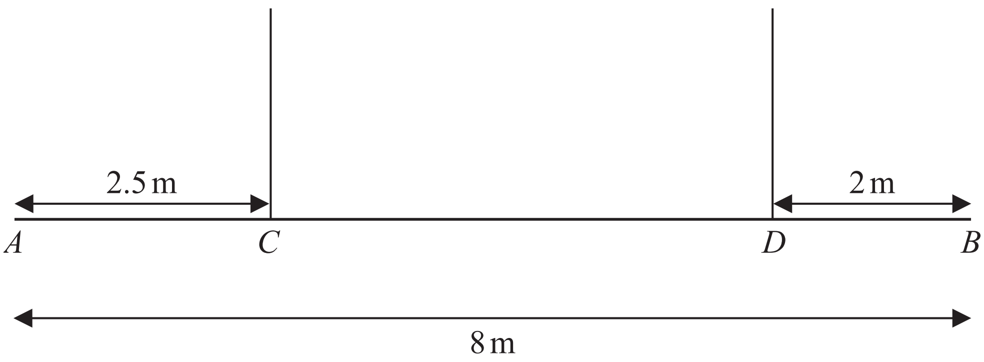


Figure 2

A non-uniform beam AB has length 8 m and mass M kg.

The centre of mass of the beam is d metres from A.

The beam is supported in equilibrium in a horizontal position by two vertical light ropes. One rope is attached to the beam at C, where $AC = 2.5$ m and the other rope is attached to the beam at D, where $DB = 2$ m, as shown in Figure 2.

A gymnast, of mass 64 kg, stands on the beam at the point X, where $AX = 1.875$ m, and the beam remains in equilibrium in a horizontal position but is now on the point of tilting about C.

The gymnast then dismounts from the beam.

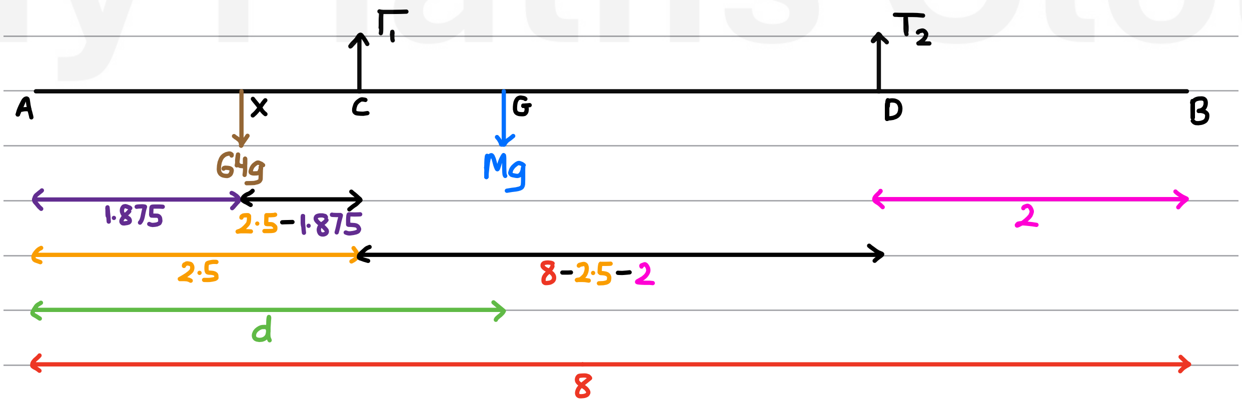
A second gymnast, of mass 48 kg, now stands on the beam at the point Y, where $YB = 0.5$ m, and the beam remains in equilibrium in a horizontal position but is now on the point of tilting about D.

The beam is modelled as a non-uniform rod and the gymnasts are modelled as particles.

Find the value of M.

(8)

Draw a diagram labelling all relevant forces in the first senario.



It's stated that the beam is horizontal and on the point of tilting about C meaning the tension in the rope at D is zero.

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Question 4 continued

Since it's stated in the question that the beam is in equilibrium, the sum of the clockwise moments is equal to the sum of the anticlockwise moments, therefore :

$$\boxed{\sum \text{moments clockwise} = \sum \text{moments anticlockwise}}$$

where $\boxed{\text{moment} = \text{force} \times \text{perpendicular distance}}$

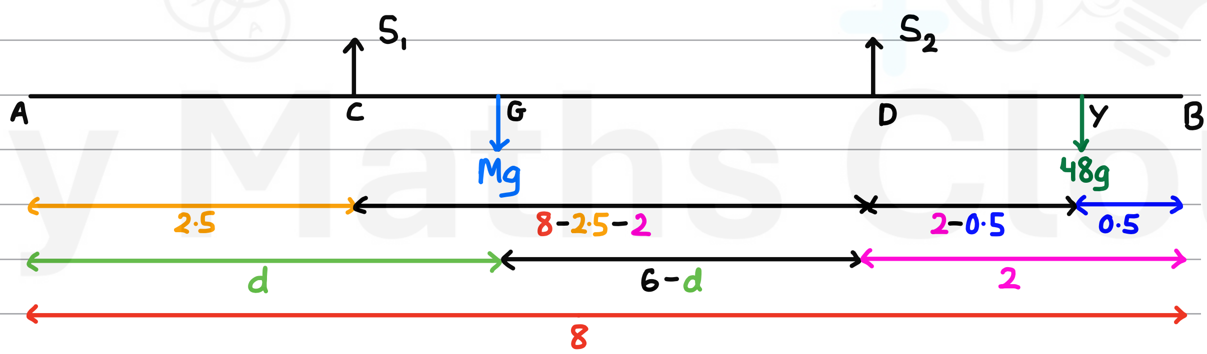
The clockwise forces are ones that go upwards from the left or downwards from the right of where moments taken and anticlockwise forces are ones that go upwards from the right or downwards from the left of where moments are taken.

Taking moments around C :

$$\underbrace{Mg(d-2.5)}_{\text{clockwise moments}} = \underbrace{64g(2.5-1.875)}_{\text{anticlockwise moments}}$$

$$\therefore \quad Mg = \frac{64g(0.625)}{d-2.5} = \frac{40g}{d-2.5} \qquad \therefore \quad M = \frac{40}{d-2.5}$$

Draw another diagram for the second senario.



It's stated that the beam is horizontal and on the point of tilting about D meaning the tension in the rope at C is zero.

Taking moments around D :

$$\underbrace{Mg(6-d)}_{\text{clockwise moments}} = \underbrace{48g(2-0.5)}_{\text{anticlockwise moments}}$$

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Question 4 continued

$\therefore \; Mg = \dfrac{48g(1.5)}{6-d} = \dfrac{72g}{6-d} \quad \therefore \; M = \dfrac{72}{6-d}$

Equating both expressions of M together allow us to calculate d.

$\therefore \; \dfrac{72}{6-d} = \dfrac{40}{d-2.5}$

$\therefore \; 72d - 72(2.5) = 40(6) - 40d$

$\therefore \; 112d = 240 + 180 \qquad d = \dfrac{420}{112} = 3.75$

We can now substitute this back to find M.

$M = \dfrac{72}{6-3.75} = 32\text{ kg}$ // OR $M = \dfrac{40}{3.75-2.5} = 32\text{ kg}$ //

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Question 4 continued

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5. A particle P is moving in a plane with constant acceleration.
The velocity, $\mathbf{v}\,\mathrm{m\,s^{-1}}$, of P at time t seconds is given by

$$\mathbf{v} = (7 - 5t)\mathbf{i} + (12t - 20)\mathbf{j}$$

(a) Find the speed of P when $t = 2$ **(3)**

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

The constant acceleration of P is $\mathbf{a}\,\mathrm{m\,s^{-2}}$

(c) Find $\mathbf{a}$ in terms of $\mathbf{i}$ and $\mathbf{j}$ **(3)**

(d) Find the value of t when P is moving in the direction of the vector $(-5\mathbf{i} + 8\mathbf{j})$ **(4)**

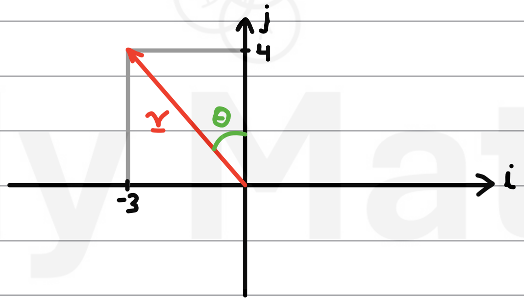
a) We can first find the velocity at $t=2$.

$v = (7-5(2))i + (12(2)-20)j$

$v = -3i+4j \quad \therefore$ speed $= |v| = \sqrt{(-3)^2+(4)^2} = 5\ \mathrm{ms^{-1}}$

We ignore the negative value after rooting as speed is always positive.

b) Draw the direction of motion of P at $t=2$ on an i-j graph.



Using SOHCAHTOA:

$\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}} = \dfrac{3}{4}$

$\therefore \theta = \tan^{-1}\left(\dfrac{3}{4}\right) = 36.86989... \approx 37^\circ$

c) $a = \dfrac{dv}{dt} = \dfrac{d}{dt}(v) = \dfrac{d}{dt}\left[(7-5t)i + (12t-20)j\right] = \dfrac{d}{dt}\left[(7i-20j) + t(-5i+12j)\right]$

$a = (-5i+12j)$

d) P moves in the direction of $(-5i+8j)$ when the velocity is a positive scalar multiple (k) of $(-5i+8j)$.

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Question 5 continued

$\therefore \ v = k(-5i + 8j)$

$\therefore \ (7-5t) = -5k$ AND $(12t-20) = 8k$

$\therefore \ k = \frac{7-5t}{-5}$ AND $k = \frac{12t-20}{8}$

Equating both expressions for k :

$\frac{7-5t}{-5} = \frac{12t-20}{8}$

$\therefore \ 56 - 40t = -60t + 100$

$\therefore \ 20t = 44$

$\therefore \ t = 2.2$ //

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Question 5 continued

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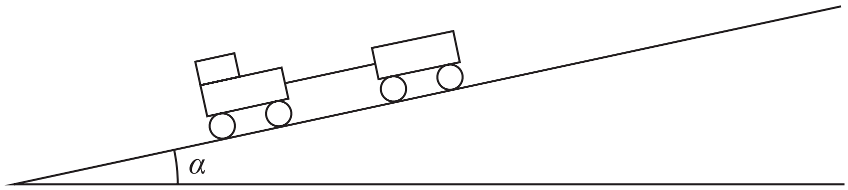


Figure 3

A railway engine of mass 1500 kg is attached to a railway truck of mass 500 kg by a straight rigid coupling. The engine pushes the truck up a straight track, which is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{7}{25}$. The coupling is parallel to the track and parallel to the direction of motion, as shown in Figure 3.

The engine produces a constant driving force of magnitude D newtons. The engine and the truck experience constant resistances to motion, from non-gravitational forces, of magnitude 1200 N and 500 N respectively.

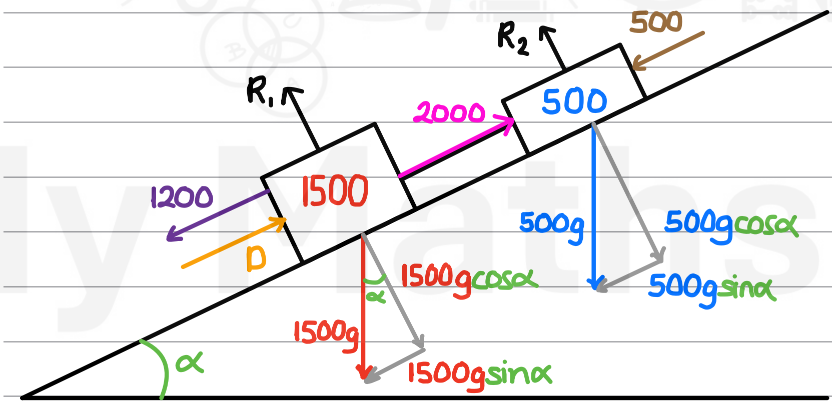
The thrust in the coupling is 2000 N.

The coupling is modelled as a light rod.

(a) Find the acceleration of the engine and the truck. **(4)**

(b) Find the value of D. **(4)**

a) Draw a diagram labelling all relevant forces.



We can only consider forces on the truck only as D is unknown. The coupling is also rigid so the acceleration of the truck and engine are the same which can be calculated using the equation of motion.

$\boxed{\Sigma F = ma}$ $\quad \therefore 2000 - 500 - 500g\sin\alpha = 500a$

$\therefore a = \dfrac{1500 - 500(9.8)(7/25)}{500} = 0.256\,\text{ms}^{-2}$ //

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Question 6 continued

b) To find D we consider forces on the engine only to simplify the equation.

$\boxed{\Sigma F = ma}$ $\therefore$ $D - 1200 - 1500g\sin\alpha - 2000 = 1500a$

$\therefore D = 1500(0.256) + 1200 + 1500g\left(\frac{7}{25}\right) + 2000 = 7700\text{ N}$ //

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Question 6 continued

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Question 6 continued

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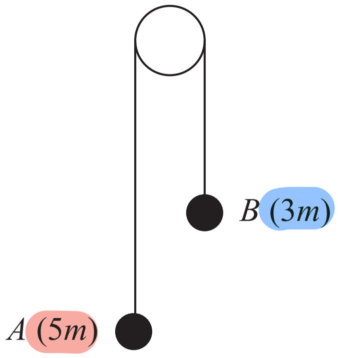


Figure 4

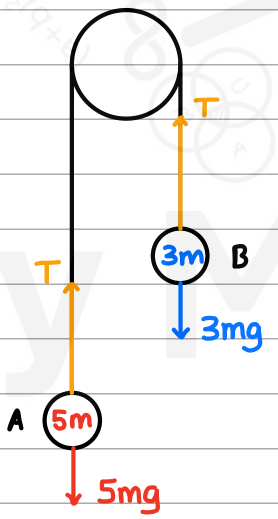
One end of a light inextensible string is attached to a particle A of mass $5m$. The other end of the string is attached to a particle B of mass $3m$. The string passes over a small, smooth, light fixed pulley. Particle A is held at rest with the string taut and the hanging parts of the string vertical,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

a) Draw a diagram labelling all relevant forces.



Using the equation of motion on each particle taking downwards as positive : $\boxed{\Sigma F = ma}$

Particle A : $5mg - T = 5ma \quad \therefore T = 5mg - 5ma$

Particle B : $3mg - T = 3m(-a) \quad \therefore T = 3mg + 3ma$

$\therefore 5mg - 5ma = 3mg + 3ma$

$\therefore 8ma = 2mg$

$\therefore a = \frac{2mg}{8m} = \frac{1}{4}g$

$\therefore T = 5mg - 5m\left(\frac{g}{4}\right) = \frac{15mg}{4}$ OR $T = 3mg + 3m\left(\frac{g}{4}\right) = \frac{15mg}{4}$

The total force acting on the pulley during descent is $2T$.

$\therefore |F| = 2 \times \frac{15mg}{4} = \frac{30mg}{4} = \frac{15mg}{2}$ N //

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Question 7 continued

b) Tension on both sides of the pulley are equal.

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Question 7 continued

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Question 7 continued

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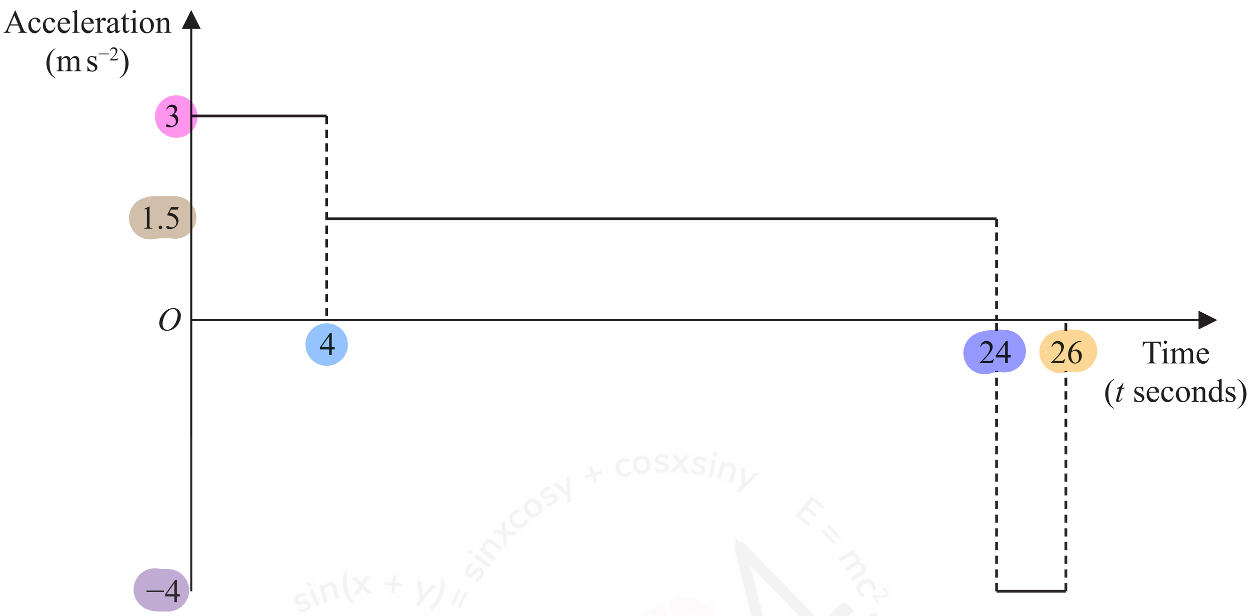

Figure 5

The acceleration-time graph shown in Figure 5 represents part of a journey made by a car along a straight horizontal road. The car accelerated from rest at time $t = 0$

(a) Find the distance travelled by the car during the first 4 s of its journey.
(2)

(b) Find the total distance travelled by the car during the first 26 s of its journey.
(6)

a) The acceleration of the car is constant so SUVAT can be used.

s : s (Distance travelled in first 4 seconds)
u : 0 (The car accelerated from rest)
v :
a : 3 (Acceleration from $t=0$ to $t=4$)
t : 4 (Time interval of SUVAT)

SUVAT formula without v : $\boxed{s = ut + \frac{1}{2}at^2}$

$\therefore s = (0)(4) + \frac{1}{2}(3)(4)^2 = 24\text{m}$

b) We can just repeat the above steps to find the remaining distances using SUVAT.

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Question 8 continued

For $t=4$ to $t=24$:

s: d (Distance travelled from $t=4$ to $t=24$)
u: 3×4 (Velocity at $t=4$ using $\boxed{v=u+at}$)
v:
a: 1.5 (Acceleration from $t=4$ to $t=24$)
t: $24-4$ (Time interval for SUVAT)

SUVAT formula without v : $\boxed{s=ut+\frac{1}{2}at^2}$

$\therefore\ d=(3\times4)(24-4)+\frac{1}{2}(1.5)(24-4)^2=240+300=540\text{ m}$

For $t=24$ to $t=26$

s: p (Distance travelled from $t=24$ to $t=26$)
u: $12+1.5(24-4)$ (Velocity at $t=4$ using $\boxed{v=u+at}$)
v:
a: -4 (Acceleration from $t=24$ to $t=26$)
t: $26-24$ (Time interval for SUVAT)

SUVAT formula without v : $\boxed{s=ut+\frac{1}{2}at^2}$

$\therefore\ p=[12+1.5(24-4)](26-24)+\frac{1}{2}(-4)(26-24)^2=84-8=76\text{ m}$

$\therefore$ Total distance travelled : $d_T=24+540+76=640\text{m}$ //

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Q8

(Total 8 marks)

TOTAL FOR PAPER = 75 MARKS

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