Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

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 (Yellow), 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 $g = 9.8\,\mathrm{m\,s^{-2}}$, 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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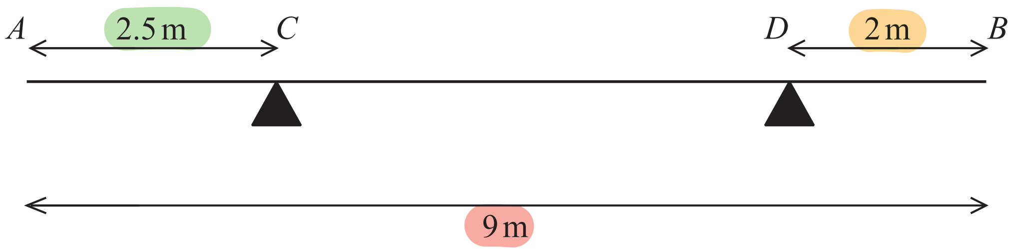


Figure 1

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.

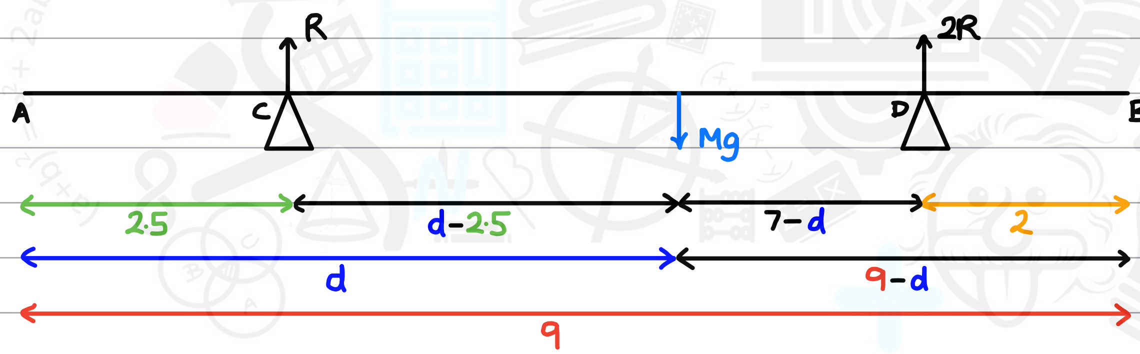
The magnitude of the force acting on the rod at D is twice the magnitude of the force acting on the rod at C.

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

Find the value of d.

(6)

Draw a diagram labelling all the forces.



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

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Question 1 continued

Taking moments about C :

$$\underbrace{Mg(d-2.5)}_{\text{clockwise moments}} = \underbrace{2R(9-2-2.5)}_{\text{anticlockwise moments}}$$

$\therefore Mgd - 2.5Mg = 9R \qquad \therefore Mgd = 9R + 2.5Mg$

Taking moments about D :

$$R(9-2-2.5) = Mg(7-d)$$

$\therefore 4.5R = 7Mg - Mgd \qquad \therefore Mgd = 7Mg - 4.5R$

Equate both expression of Mgd : $9R + 2.5Mg = 7Mg - 4.5R$

$\therefore 13.5R = 4.5Mg \qquad \therefore R = \frac{1}{3}Mg$

Substitute R back into either moment equation.

$\therefore Mgd - 2.5Mg = 9\left(\frac{1}{3}Mg\right)$ OR $4.5\left(\frac{1}{3}Mg\right) = 7Mg - Mgd$

$\therefore Mgd = 3Mg + 2.5Mg \qquad \therefore Mgd = 7Mg - 1.5Mg$

$\therefore d = \frac{5.5Mg}{Mg} = 5.5\,m$ // $\qquad \therefore d = \frac{5.5Mg}{Mg} = 5.5\,m$ //

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Question 1 continued

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Question 1 continued

Q1

(Total 6 marks)

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

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

(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 $\dfrac{6u^2}{g}$ along the plane.

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

(c) Find the value of μ.

(6)

a) Draw a diagram labelling the speeds and masses.

Using the conservation of momentum formula :

$$\boxed{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$$

$\therefore\ 2m(3u) + 4m(0) = 2m(x) + 4m(2u)$

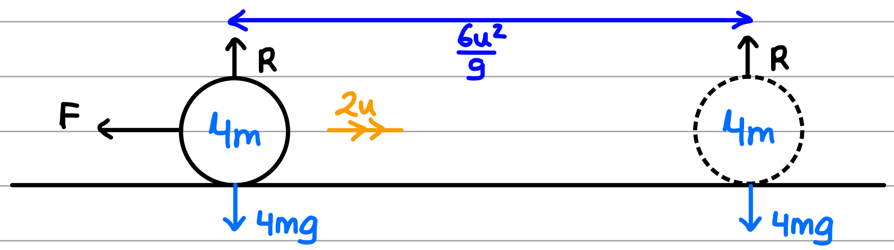
$\therefore\ 6mu = 2mx + 8mu$

$\therefore\ x = \dfrac{6mu - 8mu}{2m} = -u \qquad \therefore$ Speed $= u$ //

b) Since the answer is negative the assumption that particle P continues to the right was wrong meaning after the collision it bounced backwards. This also means the speed is just u.

$\therefore$ Answer : Opposite to original direction.

c) Draw a diagram of Q after the collision.



(Instant after collision) (At rest after travelling distance $\frac{6u^2}{g}$)

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Question 2 continued

Particle Q is in equilibrium vertically so the sum of the vertical forces is zero.

$\therefore$ $\boxed{\Sigma F = 0}$ $\therefore$ $R - 4mg = 0$ $\therefore$ $R = 4mg$

Friction formula : $\boxed{F = \mu R}$ $\therefore$ $F = \mu \times 4mg = 4mg\mu$

For consistency, we will assume right as positive.

Since F is constant the acceleration is constant so we can use SUVAT.

s : $\frac{6u^2}{g}$ Equation without time : $\boxed{v^2 = u^2 + 2as}$

u : $2u$

v : 0 $\therefore$ $0^2 = (2u)^2 + 2a\left(\frac{6u^2}{g}\right)$ $\therefore$ $4u^2 + \frac{12au^2}{g} = 0$

a : a

t : $\therefore$ $u^2\left(4 + \frac{12a}{g}\right) = 0$

$\therefore$ $u^2 = 0$ OR $4 + \frac{12a}{g} = 0$ $\therefore$ $a = \frac{4g}{-12} = -\frac{1}{3}g$

(Not possible as $u > 0$)

Equation of motion : $\boxed{\Sigma F = ma}$, taking right as positive :

$\therefore$ $-F = 4ma$ $\therefore$ $-4mg\mu = 4ma$

$\therefore$ $\mu = \frac{4ma}{-4mg} = -\frac{a}{g} = -\frac{\left(-\frac{1}{3}g\right)}{g} = \frac{1}{3}$ //

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Question 2 continued

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Question 2 continued

Q2

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3. A car is moving at a constant speed of $25\,\text{m}\,\text{s}^{-1}$ 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 $48\,\text{m}$ 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 $6\,\text{m}\,\text{s}^{-2}$ 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 $13\,\text{m}\,\text{s}^{-1}$.

In a **second** model, the car is assumed to decelerate uniformly at $6\,\text{m}\,\text{s}^{-2}$ from A until it reaches a speed of $13\,\text{m}\,\text{s}^{-1}$. 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 $25\,\text{m}\,\text{s}^{-1}$ from A until time $t = 0.2$, the car then decelerates uniformly at $6\,\text{m}\,\text{s}^{-2}$ until it reaches a speed of $13\,\text{m}\,\text{s}^{-1}$. 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)

a) Acceleration is constant throughout so a SUVAT should be set up from t=0 till the car reaches the sign.

s : 48 Equation without time : $\boxed{v^2 = u^2 + 2as}$

u : 25

v : v $\quad v^2 = 25^2 + 2(-6)(48)$

a : −6 $\quad v^2 = 49 \quad \therefore v = 7\text{ms}^{-1}$ //

t :

b) Set up a SUVAT during the deceleration phase.

s : s Equation without s : $\boxed{v = u + at}$

u : 25

v : 13 $\quad \therefore 13 = 25 - 6t \quad \therefore 6t = 12 \quad \therefore t = 2$

a : −6

t : t $\quad \therefore$ Deceleration phase takes 2 seconds.

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Question 3 continued

SUVAT formula to find distance travelled during deceleration :

$\therefore$ $\boxed{s = ut + \frac{1}{2}at^2}$ $\therefore$ $s = 25(2) + \frac{1}{2}(-6)(2)^2 = 50 - 12 = 38m$

$\therefore$ Distance remaining while travelling at $13ms^{-1}$: $48 - 38 = 10m$

Using $\boxed{s = vt}$: $t = \frac{s}{v} = \frac{10}{13} \approx 0.769s$ (3sf)

$\therefore$ Total time during deceleration and constant speed :

$t = 2 + \frac{10}{13} = \frac{36}{13} \approx 2.77s$ // (3sf)

c) Distance travelled in constant speed phase :

$\boxed{s = vt}$ $\therefore$ $d = 25 \times 0.2 = 5m$

We already calculated the distance travelled during deceleration from $25ms^{-1}$ to $13ms^{-1}$ at $6ms^{-2}$ which was 38m and the time taken to decelerate which was 2s in part b.

$\therefore$ Total distance travelled before travelling at $13ms^{-1}$ = $5 + 38 = 43m$

$\therefore$ Remaining distance to travel = $48 - 43 = 5m$

$\therefore$ Time taken travelling at $13ms^{-1}$:

$\boxed{s = vt}$ $t = \frac{48-43}{13} = \frac{5}{13} \approx 0.384615...s$

$\therefore$ Total time to reach sign = $0.2 + 2 + \frac{5}{13} \approx 2.58s$ // (3sf)

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Question 3 continued

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Question 3 continued

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

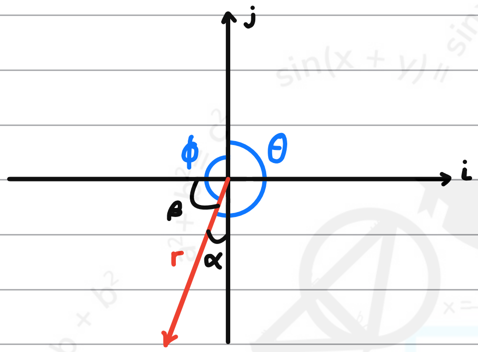
$$\mathbf{r} = (t - 3)\mathbf{i} + (1 - 2t)\mathbf{j}$$

(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)

a) When $t=2$, $r = -i-3j$

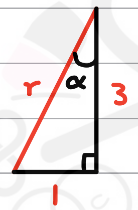
Draw a diagram to visualise the vectors.



There are two possible angles : θ or ϕ

To find θ we can find α then add on $180°$ and for ϕ we can find β and add on $90°$.

For α :

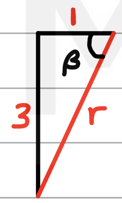


Using $\boxed{\tan x = \frac{\text{opposite}}{\text{adjacent}}}$

$\therefore \tan\alpha = \frac{1}{3}$ $\quad\therefore \alpha = \tan^{-1}\left(\frac{1}{3}\right) \approx 18°$ (nearest degree)

$\therefore \theta = \alpha + 180 = 198°$ // (nearest degree)

For β :



Using $\boxed{\tan x = \frac{\text{opposite}}{\text{adjacent}}}$

$\therefore \tan\beta = \frac{3}{1}$ $\quad\therefore \beta = \tan^{-1}(3) = 72°$ (nearest degree)

$\therefore \phi = 90 + 72 = 162°$ // (nearest degree)

$\therefore$ Size of angle between r and j when $t=2$: $162°$ OR $198°$ //

Note : In the exam only one angle is sufficient for all 3 marks as both answers are correct.

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Question 4 continued

b) To find the values of t for when P is 2.5m from O, we take the modulus of r and equate it to 2.5.

$\therefore \sqrt{(t-3)^2+(1-2t)^2} = 2.5$

$\therefore (t-3)^2+(1-2t)^2 = 6.25$

$\therefore t^2-6t+9 + 1-4t+4t^2 = 6.25$

$\therefore 5t^2 - 10t + 3.75 = 0$

$\therefore t^2 - 2t + 0.75 = 0$

$\therefore (t-0.5)(t-1.5) = 0$

$\therefore t = 0.5$ OR $t = 1.5$ //

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Question 4 continued

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Question 4 continued

Q4

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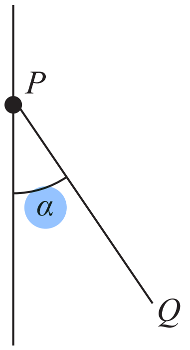


Figure 2

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 $\tan\alpha = \dfrac{4}{3}$, 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)

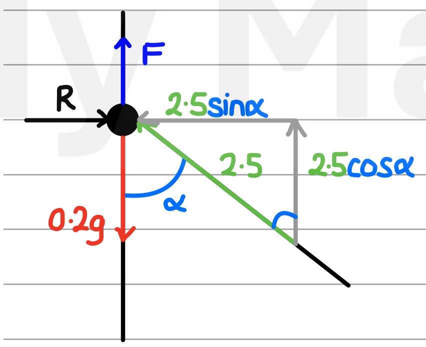
The coefficient of friction between the bead and the wire is μ.

Given that the greatest possible value of T is 6.125

(b) find the value of μ.

(7)

a) Draw a diagram labelling relevant forces.



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

Friction acts in the opposite direction of desired motion and since the bead is in equilibrium, the upwards forces must be equal to the downwards forces.

Since $0.2g > 2.5\cos\alpha$, the bead would tend to move down so friction acts upwards. The bead is in vertical equilibrium $\therefore$

$\boxed{\Sigma F = 0}$ $\therefore$ $F + 2.5\cos\alpha - 0.2g = 0$ $\therefore$ $F = 0.2(9.8) - 2.5\left(\frac{3}{5}\right) = 0.46\text{N}$ //

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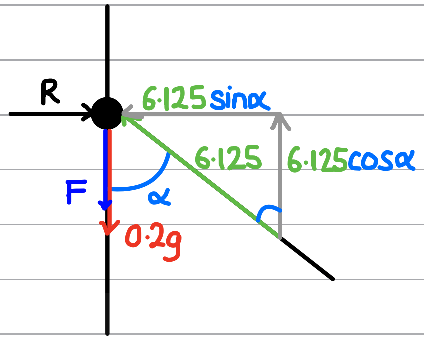
Question 5 continued

b) As there is no horizontal motion, the sum of the horizontal forces is zero.



$\boxed{\Sigma F = 0}$ $\therefore R - 6.125\sin\alpha = 0$

$\therefore R = 6.125 \times \frac{4}{5} = 4.9\,N$

When T is at a maximum the bead tends to move upwards so friction acts downwards. The bead is still in vertical equilibrium $\therefore$

$\boxed{\Sigma F = 0}$ $\therefore F + 0.2g - 6.125\cos\alpha = 0$ $\therefore F = 6.125\cos\alpha - 0.2g$

$\boxed{F = \mu R}$ $\therefore \mu R = 6.125\cos\alpha - 0.2g$

$\therefore \mu = \frac{6.125\cos\alpha - 0.2g}{R} = \frac{6.125\left(\frac{3}{5}\right) - 0.2(9.8)}{4.9} = 0.35$ //

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Question 5 continued

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Question 5 continued

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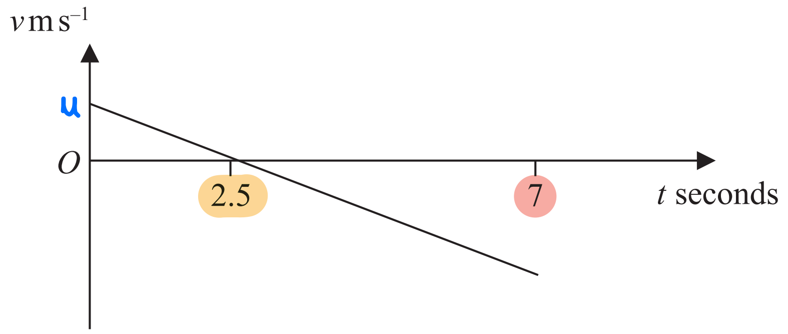

Figure 3

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

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

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

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

(2)

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

(3)

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

SUVAT from $t=0$ to $t=2.5$:

s :

u : u

v : 0

a : -9.8

t : 2.5

Equation without s : $\boxed{v = u + at}$

$\therefore\ 0 = u + (-9.8)(2.5)$ $\quad\therefore\ u = 9.8 \times 2.5 = 24.5\ \mathrm{ms^{-1}}$ //

b) Setting up a SUVAT from $t=0$ to $t=7$:

s : $-h$ (Negative as s is displacement and positive is up)

u : 24.5 (Initial velocity of ball)

v :

a : -9.8 (Negative as acceleration is down and positive is taken as up)

t : 7 (Time interval of SUVAT)

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

$\therefore\ -h = 24.5(7) + \frac{1}{2}(-9.8)(7^2) = -68.6$ $\quad\therefore\ h = 68.6\ \mathrm{m}$ //

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Question 6 continued

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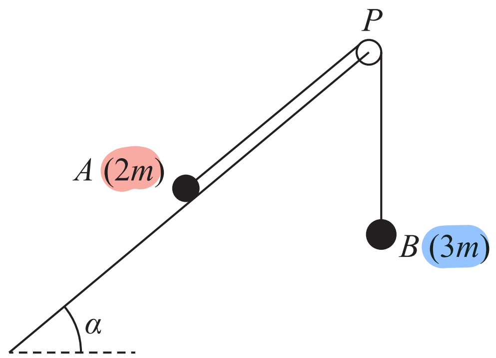


Figure 4

One end of a light inextensible string is attached to a particle A of mass $2m$. 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)

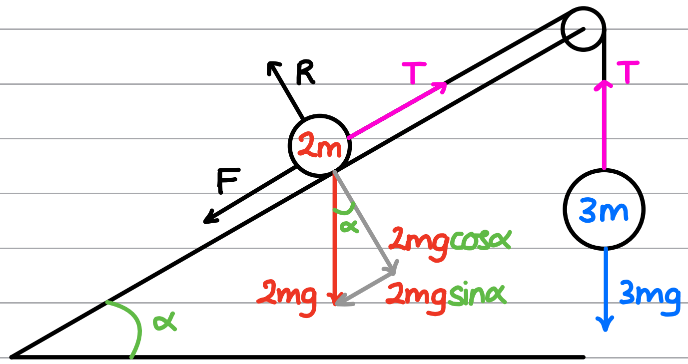
(c) find the magnitude of the force exerted on the pulley by the string.

(4)

(d) State how you have used the information that P is a smooth pulley.

(1)

a) Draw a diagram labelling all the forces.



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

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

Question 7 continued

Equation of motion formula : $\boxed{\Sigma F = ma}$

(i) For particle A : $T - 2mg\sin\alpha - F = 2ma$

(ii) For particle B : $3mg - T = 3ma$

b) Use the equation of motion formula for the entire system.

$\therefore$ $\boxed{\Sigma F = ma}$ $\therefore$ $3mg - T + T - 2mg\sin\alpha - F = (2m + 3m)a$

$\therefore$ $3mg - 2mg\sin\alpha - F = 5ma$

No movement of particle A perpendicular to the plane so the sum of the perpendicular forces is zero.

$\therefore$ $\boxed{\Sigma F = 0}$ $\therefore$ $R - 2mg\cos\alpha = 0$ $\therefore$ $R = 2mg\left(\frac{4}{5}\right) = \frac{8}{5}mg$

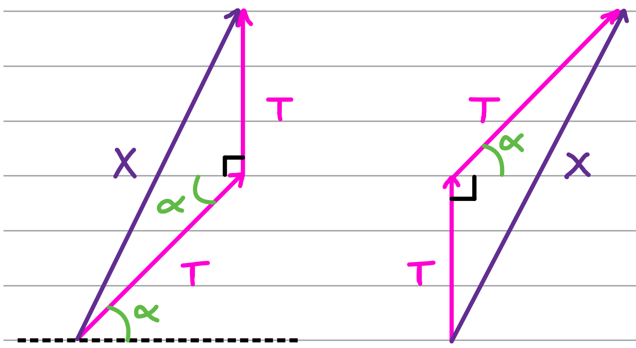
Friction formula to calculate F : $\boxed{F = \mu R}$ $\therefore$ $F = \frac{1}{2}\left(\frac{8}{5}mg\right) = \frac{4}{5}mg$

Substitute F back into original equation and solve for a.

$\therefore$ $3mg - 2mg\sin\alpha - \frac{4}{5}mg = 5ma$

$\therefore$ $a = \dfrac{3mg - 2mg\left(\frac{3}{5}\right) - \frac{4}{5}mg}{5m} = \dfrac{3mg - \frac{6}{5}mg - \frac{4}{5}mg}{5m} = \dfrac{mg}{5m} = \frac{1}{5}g$ //

c) The force exerted on the pulley by the string is the resultant of the two tensions which can be drawn in a diagram where X is the resutant/magnitude of the tensions.



Whether the vertical or diagonal tension is drawn first is irrelevant as this doesn't affect X as seen in the diagram.

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Question 7 continued

Calculate T using the equation of motion of B :

$3mg - T = 3ma$ $\quad \therefore \quad T = 3mg - 3m\left(\frac{1}{5}g\right) = \frac{12}{5}mg$

Using Cosine Rule : $\boxed{a^2 = b^2 + c^2 - 2bc(\cos A)}$

$\therefore \; X^2 = T^2 + T^2 - 2(T)(T)\cos(90+\alpha)$

$\therefore \; X^2 = 2T^2 - 2T^2\cos(90+\alpha)$

Using Cosine Angle Addition Identity : $\boxed{\cos(A+B) = \cos(A)\cos(B) - \sin(A)\sin(B)}$

$\therefore \; \cos(90+\alpha) = \cos(90)\cos\alpha - \sin(90)\sin\alpha = -\sin\alpha$

$$\therefore \; X^2 = 2T^2 - 2T^2(-\sin\alpha)$$
$$= 2T^2(1+\sin\alpha)$$
$$= 2T^2\left(1+\frac{3}{5}\right) = \frac{16}{5}T^2$$

$$\therefore \; X = T\sqrt{\frac{16}{5}} = \frac{4T}{\sqrt{5}} = \frac{4}{\sqrt{5}}\left(\frac{12}{5}mg\right) = \frac{48}{5\sqrt{5}}mg = \frac{48\sqrt{5}}{25}mg \; //$$

d) Tension is the same on either side of the pulley.

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Question 7 continued

(Total 14 marks)

Q7

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

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

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

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

(2)

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

(2)

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

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

(c) Find the position vector of the lighthouse.

(4)

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

(4)

a) First calculate the displacement and time taken in hours :

Displacement $= (4i+6j) - (-2i+9j) = 6i-3j$ Time $= 36\text{ min} = 0{\cdot}6\text{ hrs}$

Velocity formula : $\boxed{s = vt}$

$\therefore\ v = \dfrac{s}{t} = \dfrac{(6i-3j)}{0{\cdot}6} = 10i-5j$ //

b) Position vector formula : $\boxed{\underline{r} = \underline{r}_0 + vt}$

$\therefore\ \underline{r} = (-2i+9j) + (10i-5j)t$ // OR $\underline{r} = (-2+10t)i + (9-5t)j$ //

c) <u>At 8:48 am</u> : Time after 7:00 = 1hr 48min = 1·8h

Position of ship $= (-2i+9j) + 1{\cdot}8(10i-5j) = (-2i+9j) + (18i-9j) = 16i$

$\therefore$ Position = (16, 0)

The lighthouse is due east so it will have the same y-coordinate but larger x-coordinate

$\therefore$ Lighthouse coordinate $= (L, 0)$ where $L > 16$.

P 6 6 6 4 9 A 0 2 8 3 2

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Question 8 continued

At 9:00am : Time after 7:00 = 2 hrs

Position of ship $= (-2i+9j) + 2(10i-5j) = (-2i+9j) + (20i-10j) = 18i-j$

The lighthouse is north-east so we must add an equal amount to the x and y-coordinate to go in the north-east direction. The amount added should be enough so the y-coordinate is zero which is just 1 as the ship is at $(18,-1)$ meaning the lighthouse is at $(19,0)$.

$\therefore$ Position vector of lighthouse $= 19i$

d) Due south means the ship has the same x-coordinate as the lighthouse $(19i)$.

Position vector of ship : $\underline{r} = (-2+10t)i + (9-5t)j$

Equate i component of position vector of ship to 19 to find t :

$-2+10t = 19 \quad \therefore \quad 10t = 21 \quad \therefore \quad t = 2.1$ when ship is due south.

Substitute the value of t to find the y-coordinate of the ship.

y-coordinate : $9-5t \quad \therefore \quad 9-5(2.1) = -1.5$

$\therefore$ Position of ship when due south of lighthouse : $(19i-1.5j)$

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Question 8 continued

Leave blank

Question 8 continued

Turn over

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Question 8 continued

Q8

(Total 12 marks)

TOTAL FOR PAPER: 75 MARKS

END