Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International Advanced Level

Centre Number	Candidate Number

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.
- Good luck with your examination.

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

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

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

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

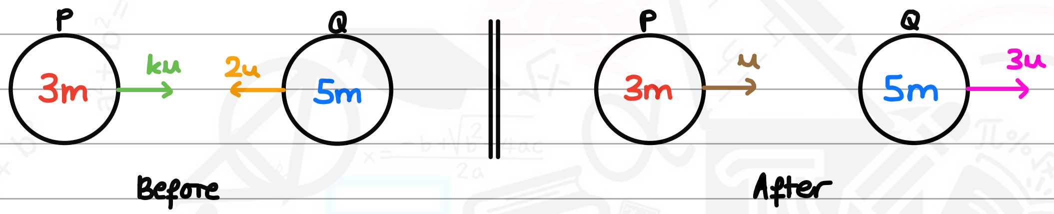
(a) Find, in terms of m and u, the magnitude of the impulse exerted on Q by P in the collision.

(2)

(b) Find the two possible values of k.

(5)

a) Draw a diagram labelling masses and speeds.



The formula for impulse : $\boxed{I = mv - mu}$

$\therefore |I| = |5m(3u) - 5m(-2u)| = |15mu + 10mu| = 25mu$

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

$\therefore 3m(ku) + 5m(-2u) = 3m(u) + 5m(3u)$ OR $3m(ku) + 5m(-2u) = 3m(-u) + 5m(3u)$

$\therefore 3kmu - 10mu = 3mu + 15mu$ $\qquad$ $\therefore 3kmu - 10mu = -3mu + 15mu$

$\therefore 3kmu = 28mu$ $\qquad$ $\therefore 3kmu = 22mu$

$\therefore k = \dfrac{28mu}{3mu} = \dfrac{28}{3}$ $\qquad$ $\therefore k = \dfrac{22mu}{3mu} = \dfrac{22}{3}$

$\therefore k = \dfrac{28}{3}$ OR $\dfrac{22}{3}$

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Question 1 continued

(Total 7 marks)

Q1

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

The car is modelled as a particle.

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

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

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

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

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

(8)

Since acceleration is constant, we can set up a SUVAT for the first three seconds to form and solve equation for u and a.

s : 20
u : u
v :
a : a
t : 3

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

$\therefore 20 = 3u + \frac{1}{2}a(3^2) \quad \therefore 20 = 3u + \frac{9a}{2}$

Setting up another SUVAT between the third and forth second.

s : 10
u : u+3a (speed at t=3)
v :
a : a
t : 4-3

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

$\therefore 10 = (u+3a)(4-3) + \frac{1}{2}a(4-3)^2$

$\therefore 10 = u + 3a + \frac{a}{2}$

$\therefore 20 = 2u + 7a$

Solving these two equations simultaneously : $a = \frac{5}{3}$, $u = \frac{25}{6}$

Now we can set up a SUVAT for the whole journey from A to B.

s :
u : u
v : 20
a : a
t : t

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

$\therefore 20 = \frac{25}{6} + \frac{5}{3}t \quad \therefore \frac{5}{3}t = \frac{95}{6} \quad \therefore t = \frac{19}{2}$ OR 9.5 seconds //

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Question 2 continued

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Question 2 continued

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Question 2 continued

Q2

(Total 8 marks)

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

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

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

where a and b are constants.

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

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

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

(4)

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

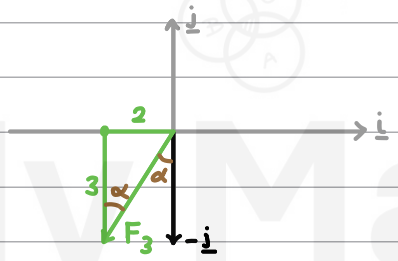
When the three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_4$ act on P, the acceleration of P has magnitude $3.25\,\mathrm{m\,s^{-2}}$

(b) Find the value of λ.

(5)

a) Since P is in equilibrium at rest, the sum of the forces acting on it is zero.

$\therefore\ F_1 + F_2 + F_3 = 0 \qquad \therefore\ F_3 = -(F_1 + F_2) = -(5i + 2j + -3i + j) = -(2i + 3j) = -2i - 3j$



To find the angle between F_3 and $-j$, we can use right-angle trigonometry.

$\therefore\ \tan\alpha = \dfrac{\text{opposite}}{\text{adjacent}} = \dfrac{2}{3} \qquad \therefore\ \alpha = \tan^{-1}\left(\dfrac{2}{3}\right)$

$\approx 33.7^\circ$ (3sf)

b) Using $\boxed{\Sigma F = ma}$:

$F_1 + F_2 + F_4 = 4(3.25)$

$\therefore\ (5i + 2j) + (-3i + j) + (\lambda i + 3\lambda j) = 13$

$\therefore\ |(2+\lambda)i + (3+3\lambda)j| = 13$

$\therefore\ \sqrt{(2+\lambda)^2 + (3+3\lambda)^2} = 13$

$\therefore\ 4 + 4\lambda + \lambda^2 + 9 + 18\lambda + 9\lambda^2 = 169$

$10\lambda^2 + 22\lambda - 156 = 0$

$\lambda = 3,\ \lambda = -5.2$

It's stated that λ is a positive constant so we must reject the negative value.

$\therefore\ \lambda = 3$

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Question 3 continued

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Question 3 continued

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Question 3 continued

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Q3

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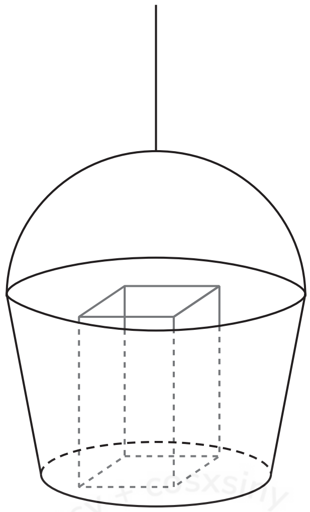


Figure 1

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

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

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

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

(a) Find the tension in the cable.

(3)

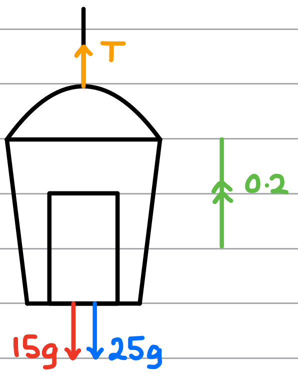
At the top of the building, the bag of cement is removed. A box of tools of mass 12 kg is now placed in the bucket.

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

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

(3)

a) Draw a diagram labelling the forces.



Using $\boxed{\Sigma F = ma}$ ensuring we take positive as the same direction as the acceleration.

$T - 15g - 25g = (15 + 25) \times 0.2$

$T = 40(0.2) + 40(9.8) = 400\text{ N}$ //

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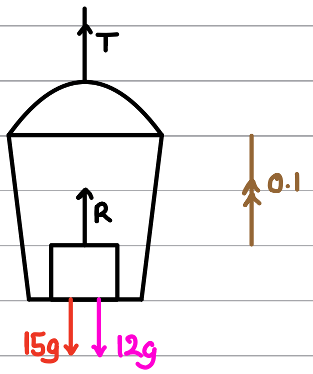
Question 4 continued

b) Redraw the diagram with the new relevant forces.



As we are asked for the normal reaction between bucket and toolbox we must isolate each item and analyse the forces acting on the toolbox alone.

Using $\boxed{\Sigma F = ma}$ on the box of tools:

$R - 12g = 12 \times 0.1$

$R = 1.2 + 12(9.8) = 118.8 \text{ N}$

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Question 4 continued

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Question 4 continued

Q4

(Total 6 marks)

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

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

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

(a) Find the value of T.

(6)

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

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

and μ is a constant.

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

(b) find the value of μ.

(3)

a) The acceleration is constant so SUVAT can be used from 2pm to 2.30pm.

s :

u : $3i+5j$

v : $i+7j$

a : a

t : 0.5 (hours)

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

$\therefore\ a = \dfrac{v-u}{t} = \dfrac{(i+7j)-(3i+5j)}{0.5} = -4i+4j$

$\therefore$ Velocity at time t given by $\boxed{\underline{v} = \underline{v}_0 + at}$ is :

$v_p = (3i+5j) + (-4i+4j)t = (3-4t)i + (5+4t)j$

At time T, the velocity is in the direction $(-i+2j)$ so the velocity is a multiple of this such that : $(3-4t)i + (5+4t)j = k(-i+2j)$

Equate the i and j components and solve.

$\therefore\ 3-4T = -k$

$5+4T = 2k$

$\therefore\ k = 8$ and $T = \frac{11}{4}$ OR 2.75 hours //

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Question 5 continued

b) If the velocity of P and Q are equal, we can equate them and solve for t and μ.

$\therefore \ v_P = v_Q \qquad (3-4t)\mathbf{i} + (5+4t)\mathbf{j} = (-4-2t)\mathbf{i} + (\mu+3t)\mathbf{j}$

Equate $\mathbf{i}$ and $\mathbf{j}$ components:

$3-4t = -4-2t \qquad\qquad 5+4t = \mu+3t$

$\therefore \ 2t = 7 \qquad\qquad \therefore \ \mu = 5+t = 5+3.5 = 8.5$ //

$t = 3.5$

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Question 5 continued

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Question 5 continued

Q5

(Total 9 marks)

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

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

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

(a) Find the magnitude of the frictional force acting on the particle as it moves up the plane.
(3)

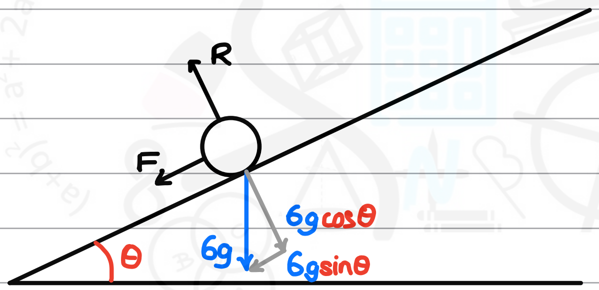
The particle comes to instantaneous rest at the point B.

(b) Find the distance AB.
(5)

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

(c) Find the distance BC.
(5)

a) Draw a diagram labelling the forces. $\tan\theta = \frac{5}{12}$, $\sin\theta = \frac{5}{13}$ $\cos\theta = \frac{12}{13}$



Since there's no movement perpendicular to the plane, the sum of the forces in this direction is zero.

$\boxed{\Sigma F = 0}$ $\therefore R - 6g\cos\theta = 0$

$\therefore R = 6g\cos\theta$

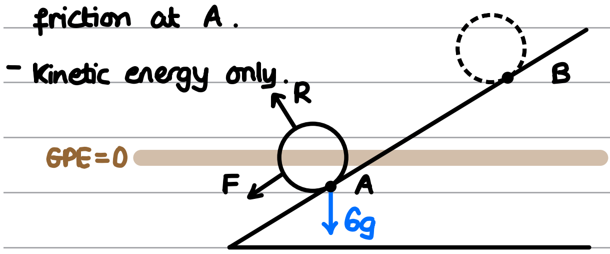
Using the friction formula: $\boxed{F = \mu R}$ $\therefore F = \frac{1}{4} \times 6g\cos\theta = \frac{18g}{13}$ N //

b) To calculate the distance travelled we need to conserve energy and use diagrams, tables or SUVAT.

WAY 1

- No relative GPE and no work done to friction at A.
- Kinetic energy only.

- An increase of relative GPE and work done by friction at B.
- No kinetic energy (at rest).



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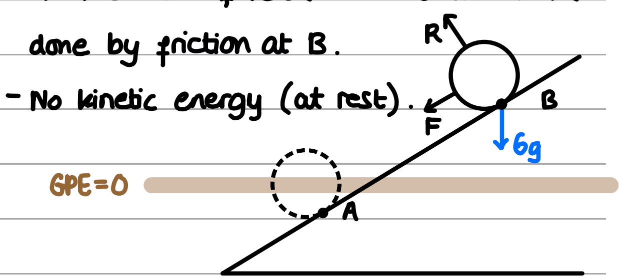

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Question 6 continued

The formula for kinetic energy : $\boxed{KE = \frac{1}{2}mv^2}$

$\therefore$ KE at A $= \frac{1}{2} \times 6 \times 5^2 = 75$

The formula for GPE : $\boxed{GPE = mg\Delta h}$

$\therefore$ GPE at B $= 6 \times g \times x\sin\theta = \frac{30}{13}gx$ where x is the distance AB.

The formula for work done : $\boxed{W = Fd}$

$\therefore$ Work done by friction from A to B $= \frac{18g}{13} \times x = \frac{18}{13}gx$

Using conservation of energy where the energy at the start equals energy at the end :

$\therefore$ $75 = \frac{30}{13}gx + \frac{18}{13}gx$

$\therefore$ $75 = \frac{48}{13}gx$ $x = 75 \times \frac{13}{48g} = \frac{75 \times 13}{48 \times 9.8} = 2.0727... \approx 2.07\text{ m}$ (3sf)

WAY 2

We can put the calculated energies in a table and compare them.

	KE	GPE	Work by friction
Start	$\frac{1}{2} \times 6 \times 5^2$	$6 \times g \times x\sin\theta$	0
End	0	0	$\frac{18g}{13} \times x$

Now we equate the total energy at the start to end to conserve energy.

$\therefore$ $\frac{1}{2} \times 6 \times 5^2 + 6 \times g \times x\sin\theta = \frac{18g}{13} \times x$ $\therefore$ $75 = \frac{30}{13}gx + \frac{18}{13}gx$

$\therefore$ $75 = \frac{48}{13}gx$ $x = 75 \times \frac{13}{48g} = \frac{75 \times 13}{48 \times 9.8} = 2.0727... \approx 2.07\text{ m}$ (3sf)

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Question 6 continued

WAY 3

Use the equation of motion to calculate the acceleration of the particle.

$\boxed{\Sigma F = ma}$ $\therefore$ $-F - 6g\sin\theta = 6a$ taking up the slope as positive.

$\therefore$ $a = \dfrac{-F - 6g\sin\theta}{6} = \dfrac{-\frac{18g}{13} - 6(9.8)\left(\frac{5}{13}\right)}{6} = -\dfrac{8}{13}g$

Now we can set up a SUVAT from A to B.

S : x Formula without time : $\boxed{v^2 = u^2 + 2as}$

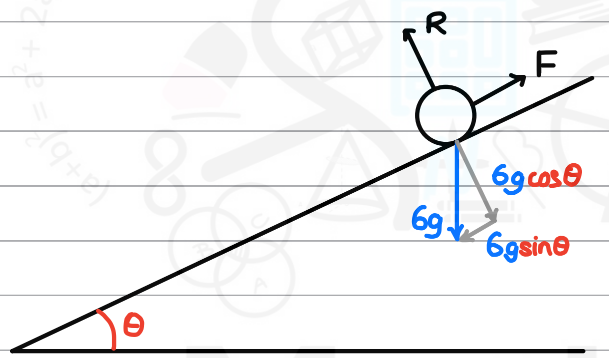
u : 5

v : 0 $\therefore$ $0^2 = 5^2 + 2\left(-\frac{8}{13}g\right)x$ $\therefore$ $\frac{16g}{13}x = 25$

a : $-\frac{8}{13}g$

t : $\therefore$ $x = \dfrac{25\times 13}{16\times 9.8} = 2.07... \approx 2.07\,m$ (3sf)

c) Redraw the diagram labelling the forces.



The direction of friction has been reversed as the particle is now moving down the slope.

Equation of motion parallel to the plane : $\boxed{\Sigma F = ma}$

$\therefore$ $-F + 6g\sin\theta = 6a$ $\therefore$ $a = \dfrac{-F + 6g\sin\theta}{6} = \dfrac{-\frac{18}{13}g + 6(9.8)\left(\frac{5}{13}\right)}{6} = \dfrac{2g}{13}$

Now we can set up a SUVAT from B to C.

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

u : 0

v : 5 $\therefore$ $5^2 = 0^2 + 2\times\frac{2g}{13}\times s$ $\therefore$ $s = 25 - 2\times\frac{2g}{13}$

a : $\frac{2g}{13}$

t : $\therefore$ $s = 25 - \dfrac{4\times 9.8}{13} = 8.29... \approx 8.30\,m$ (3sf)

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Question 6 continued

Q6

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7.

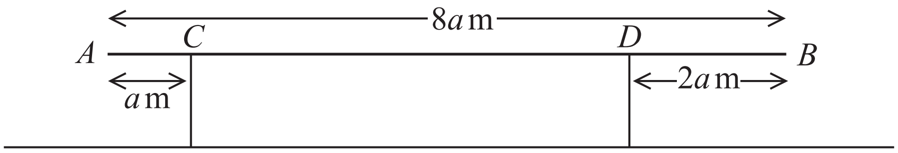


Figure 2

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

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

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

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

(5)

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

The beam remains in equilibrium in a horizontal position.

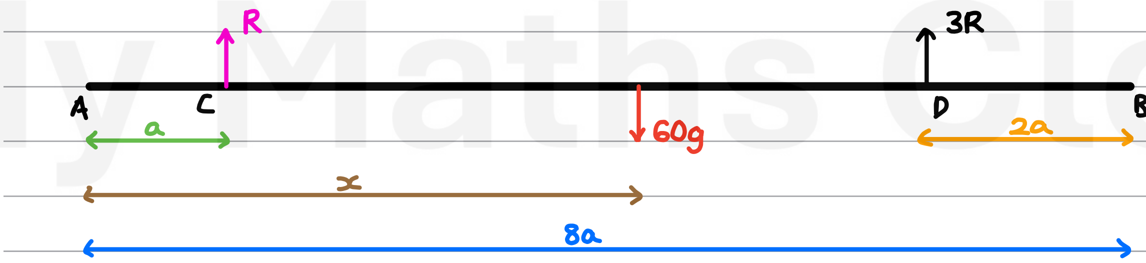
The magnitude of the normal reaction between the beam and the support at C is now equal to the magnitude of the normal reaction between the beam and the support at D.

By modelling the box as a particle,

(b) find the value of M.

(5)

a) Draw a diagram labelling all the relevant 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 $\boxed{\text{moment} = \text{force} \times \text{perpendicular distance}}$

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Question 7 continued

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.

$\therefore$ Taking moments about A :

$$\underbrace{60g(x)}_{\text{clockwise moments}} = \underbrace{R(a) + 3R(8a-2a)}_{\text{anticlockwise moments}}$$

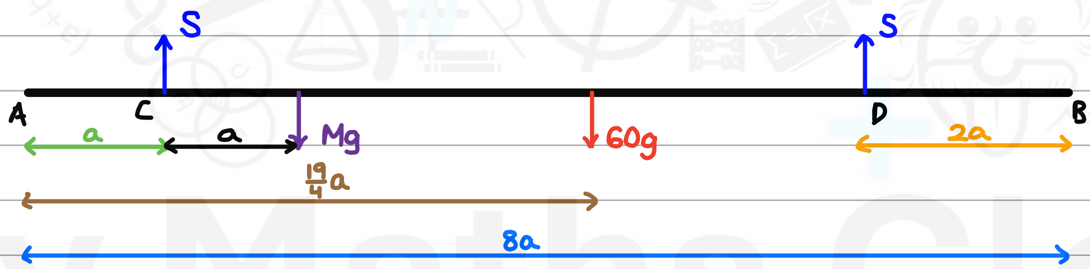
$\therefore \; 60gx = Ra + 18Ra \qquad \therefore \; 60gx = 19Ra$

Since there's no vertical motion, the sum of the vertical forces is zero.

$\therefore \; \boxed{\Sigma F = 0} \qquad \therefore \; R + 3R - 60g = 0 \qquad \therefore \; 4R = 60g \qquad \therefore \; R = 15g$

$\therefore \; 60gx = 19(15g)a \qquad \therefore \; x = \dfrac{19 \times 15g \times a}{60g} = \dfrac{19}{4}a$

b) Redraw new diagram with the added forces.



Taking moments about A :

$$\underbrace{Mg(2a) + 60g\left(\tfrac{19a}{4}\right)}_{\text{clockwise moments}} = \underbrace{S(a) + S(8a-2a)}_{\text{anticlockwise moments}}$$

$\therefore \; 2aMg + 285ag = Sa + 6Sa = 7Sa$

Since there's no vertical motion, the sum of the vertical forces is zero.

$\therefore \; \boxed{\Sigma F = 0} \qquad \therefore \; S + S - 60g - Mg = 0 \qquad \therefore \; 2S = 60g + Mg \qquad \therefore \; S = \dfrac{60g + Mg}{2}$

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Question 7 continued

Substituting the value of S into the moment equation :

$$2aMg + 285ag = 7\left(\frac{60g + Mg}{2}\right)a$$

$$\therefore 2aMg + 285ag = \frac{420ag + 7Mg}{2}$$

$$\therefore 4aMg + 570ag = 420ag + 7aMg$$

$$\therefore 3aMg = 150ag \qquad M = \frac{150ag}{3ag} = 50 \,//$$

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Question 7 continued

Q7

(Total 10 marks)

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

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

At time $t = 20$ seconds, tram B starts from rest and moves in the same direction as tram A. Tram B moves with constant acceleration $3\,\text{m s}^{-2}$ for 4 seconds and then continues to move along the track at constant speed.
$(t = 24)$

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.

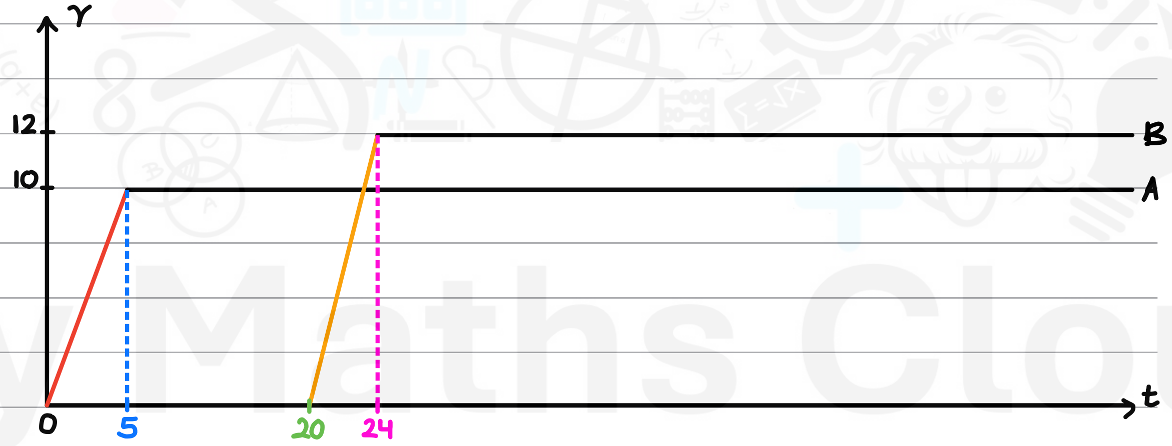
(b) Find the value of d.

(5)

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

(5)

a)



As the acceleration for B (3ms^{-2}) is greater than A's (2ms^{-2}) the gradient needs to be steeper for B.

b) We first need the time they're travelling at the same speed.

Using $\boxed{v = u + at}$ for B : $v = 0 + 3t$ $\therefore v_B = 3t$

which is only applicable between $t = 20$ and $t = 24$ as it's only accelerating during these times.

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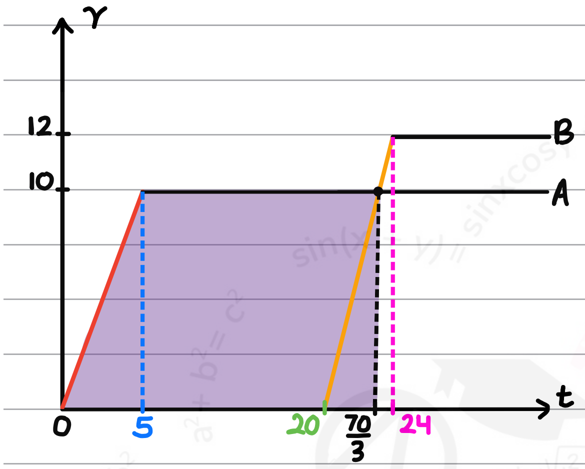
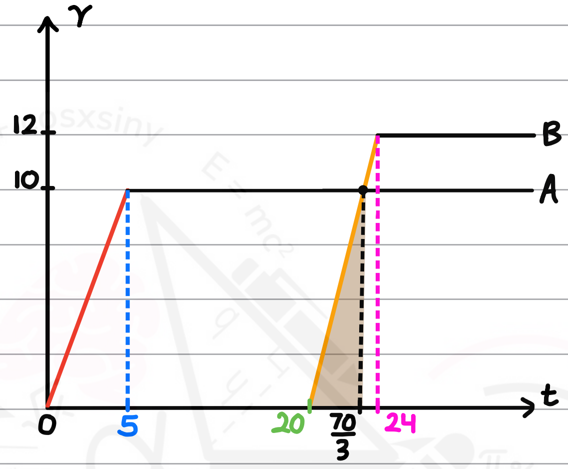
Question 8 continued

Equate the velocity of A ($10ms^{-1}$) and B for $20 \leq t \leq 24$:

$10 = 3t \quad \therefore t = \frac{10}{3} \quad \therefore$ Time at same speed $= \frac{10}{3} + 20 = \frac{70}{3}$

Now we find the distance travelled by each tram at $t = \frac{70}{3}$ which can be found by calculating the area under the graph.



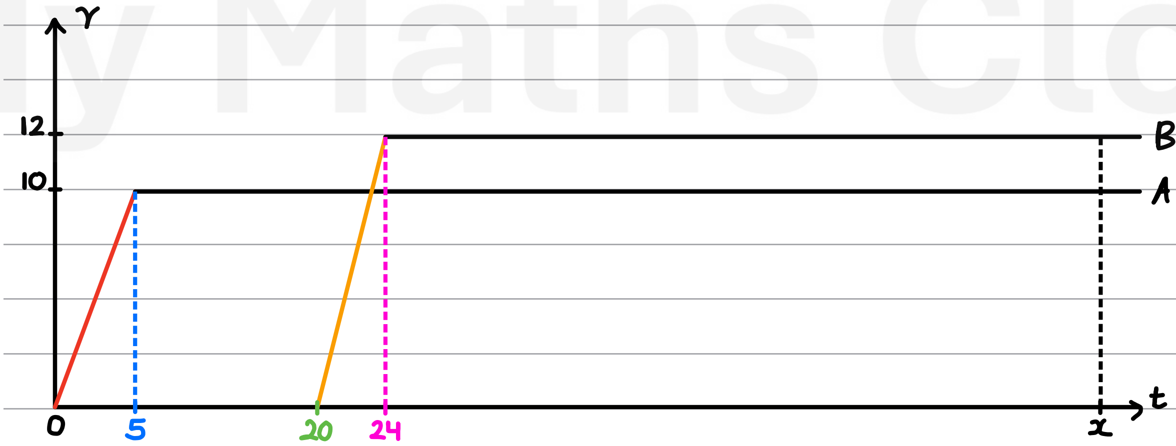


= Distance travelled by A   = Distance travelled by B

$\therefore$ ● $= \frac{5 \times 10}{2} + \frac{55}{3} \times 10 = \frac{625}{3}$ m $\therefore$ ● $= \frac{\frac{10}{3} \times 10}{2} = \frac{50}{3}$ m

$\therefore$ Difference in distance travelled $(d) = \frac{625}{3} - \frac{50}{3} = \frac{575}{3}$ m

c) We first must calculate the time $(t = x)$ at which B overtakes A which occurs when the distance travelled by each tram is the same.



We can create expressions for the distance travelled by each tram using a similar concept in part b) using the area under the graph.

P 6 5 2 6 6 A 0 2 9 3 2

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Question 8 continued

d_A : $\frac{5\times10}{2} + (x-5)\times10 = 25 + 10(x-5)$

d_B : $\frac{4\times12}{2} + (x-24)\times12 = 24 + 12(x-24)$

We can now equate the expressions for the distance travelled.

$\therefore\ 25+10(x-5) = 24+12(x-24)$

$\therefore\ 10x-25 = 12x-264$

$\therefore\ 2x = 239 \qquad x = 119.5$ seconds

$\therefore$ Distance of trams at $t=x$ $(t=119.5)$:

$d_A = 25+10(119.5-5) = 1170$

$d_B = 24+12(119.5-24) = 1170$

$\therefore$ Distance of trams at the overtake from the depot $= 1170\text{ m}$ //

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Question 8 continued

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Question 8 continued

Q8

(Total 13 marks)

TOTAL FOR PAPER: 75 MARKS

END

P 6 5 2 6 6 A 0 3 2 3 2