AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level MATHEMATICS

Paper 2

Time allowed: 2 hours

Materials
- You must have the AQA Formulae for A-level Mathematics booklet.
- You should have a graphical or scientific calculator that meets the requirements of the specification.

Instructions
- Use black ink or black ball-point pen. Pencil should only be used for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer each question in the space provided for that question. If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do **not** write outside the box around each page or on blank pages.
- Show all necessary working; otherwise marks for method may be lost.
- Do all rough work in this book. Cross through any work that you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.
- You do not necessarily need to use all the space provided.

For Examiner's Use	
Question	Mark
1	
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TOTAL	

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Section A

Answer **all** questions in the spaces provided.

1 A circle has centre (4, −5) and radius 6

Find the equation of the circle.

Tick (✓) **one** box.

[1 mark]

$(x-4)^2+(y+5)^2=6$ ☐

$(x+4)^2+(y-5)^2=6$ ☐

$(x-4)^2+(y+5)^2=36$ ☑

$(x+4)^2+(y-5)^2=36$ ☐

2 State the value of

$$\lim_{h\to 0}\frac{\sin(\pi+h)-\sin\pi}{h}$$

Circle your answer.

[1 mark]

$\cos h$ $\quad$ (−1) $\quad$ 0 $\quad$ 1

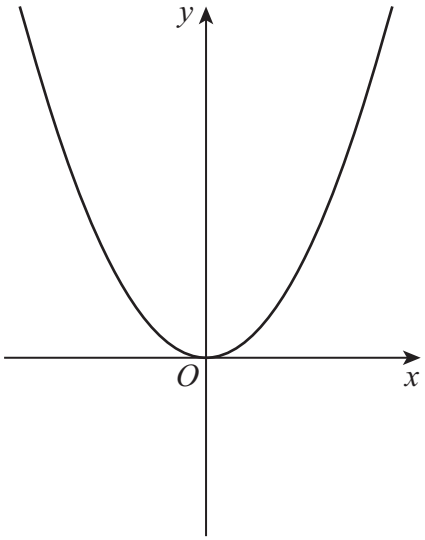
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3 The function f is concave and is represented by one of the graphs below.

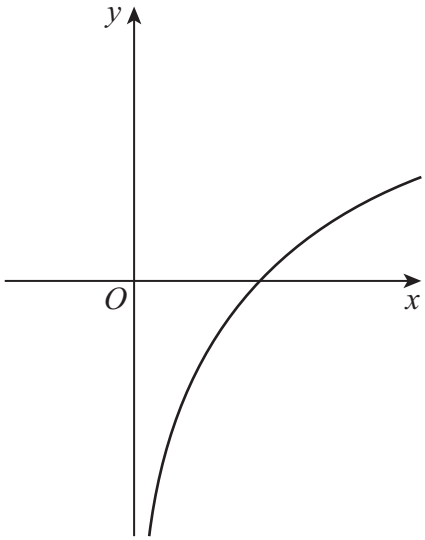
Identify the graph which represents f.

Tick (✓) **one** box.

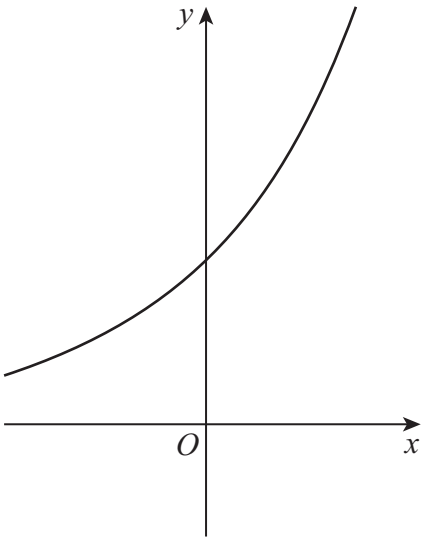
[1 mark]



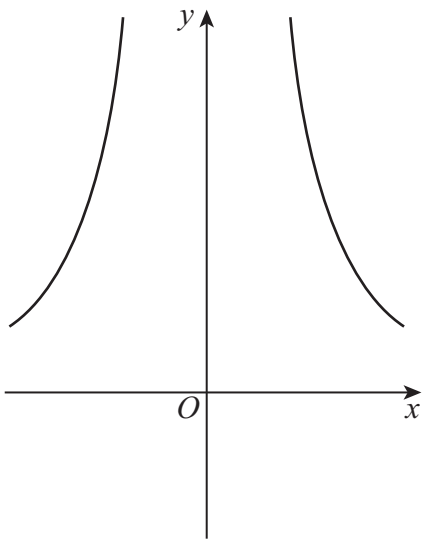
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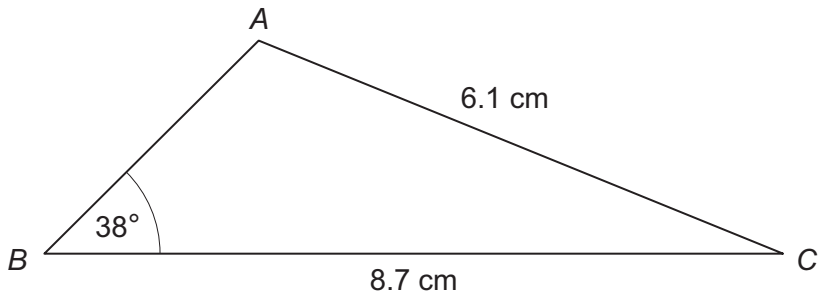
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4



The diagram shows a triangle *ABC*.

AB is the shortest side. The lengths of *AC* and *BC* are 6.1 cm and 8.7 cm respectively.

The size of angle *ABC* is 38°

Find the size of the largest angle.

Give your answer to the nearest degree.

[3 marks]

$\frac{\sin A}{8.7} = \frac{\sin 38°}{6.1}$

$\sin A = \frac{8.7 \sin 38°}{6.1} = 0.87807...$

$A = 61.41...°$ or $A = 180° - 61.41...° = 118.58...°$

AB is the shortest side, so angle C must be the smallest angle.

If $A = 61.4°$ then $C = 180° - 38° - 61.4° = 80.6°$, the largest angle, so AB would be the longest side: not possible.

So $A = 118.58...°$ (then $C = 23.4°$ and AB = 3.94 cm, the shortest)

Largest angle = angle BAC = 119°

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Turn over for the next question

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5 The binomial expansion of $(2+5x)^4$ is given by

$$(2+5x)^4 = A + 160x + Bx^2 + 1000x^3 + 625x^4$$

5 (a) Find the value of A and the value of B.

[2 marks]

Constant term: $A = 2^4 = 16$

x^2 term: ${}^4C_2 \times 2^2 \times (5x)^2 = 6 \times 4 \times 25x^2 = 600x^2$

$A = 16, \quad B = 600$

5 (b) Show that

$$(2+5x)^4 - (2-5x)^4 = Cx + Dx^3$$

where C and D are constants to be found.

[2 marks]

$(2-5x)^4$ is the same expansion with x replaced by $-x$:

$(2-5x)^4 = 16 - 160x + 600x^2 - 1000x^3 + 625x^4$

$(2+5x)^4 - (2-5x)^4$

$= (16 + 160x + 600x^2 + 1000x^3 + 625x^4)$

$\quad - (16 - 160x + 600x^2 - 1000x^3 + 625x^4)$

$= 320x + 2000x^3$

which is of the form $Cx + Dx^3$ with $C = 320$ and $D = 2000$

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5 (c) Hence, or otherwise, find

$$\int \left((2+5x)^4 - (2-5x)^4 \right) \mathrm{d}x$$

[2 marks]

$\int((2+5x)^4 - (2-5x)^4)\,dx = \int(320x + 2000x^3)\,dx$

$= \frac{320}{2}x^2 + \frac{2000}{4}x^4 + c$

$= 160x^2 + 500x^4 + c$

Turn over for the next question

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6 (a) Asif notices that $24^2 = 576$ and $2 + 4 = 6$ gives the last digit of 576

He checks two more examples:

$27^2 = 729$	$29^2 = 841$
$2 + 7 = 9$	$2 + 9 = 11$
Last digit 9	Last digit 1

Asif concludes that he can find the last digit of any square number greater than 100 by adding the digits of the number being squared.

Give a counter example to show that Asif's conclusion is **not** correct.

[2 marks]

e.g. $12^2 = 144$

$1 + 2 = 3$, but the last digit of 144 is 4

$3 \neq 4$, so Asif's conclusion is not correct.

6 (b) Claire tells Asif that he should look only at the last digit of the number being squared.

$27^2 = 729$	$24^2 = 576$
$7^2 = 49$	$4^2 = 16$
Last digit 9	Last digit 6

Using Claire's method determine the last digit of 23456789^2

[1 mark]

Last digit is 9: $9^2 = 81$

Last digit of 23456789^2 is 1

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6 (c) Given Claire's method is correct, use proof by exhaustion to show that no square number has a last digit of 8

[2 marks]

Only the last digit matters, so check the squares of 0 to 9:

$0^2 = 0$, $1^2 = 1$, $2^2 = 4$, $3^2 = 9$, $4^2 = 16$

$5^2 = 25$, $6^2 = 36$, $7^2 = 49$, $8^2 = 64$, $9^2 = 81$

Last digits: 0, 1, 4, 9, 6, 5, 6, 9, 4, 1

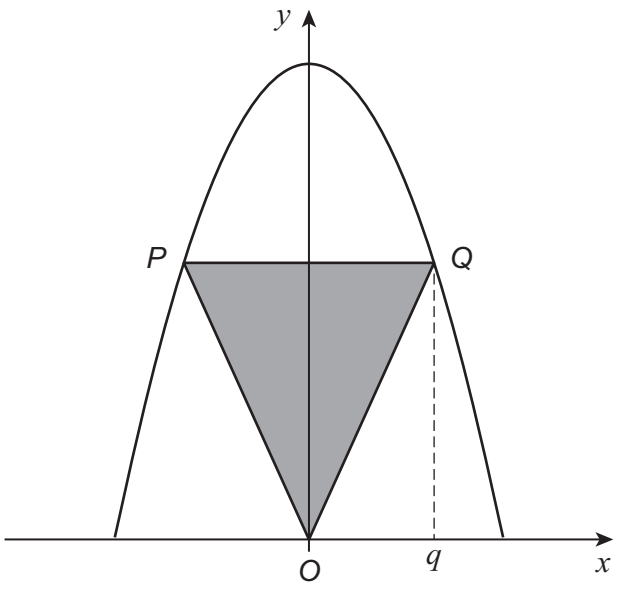
Every whole number ends in one of the digits 0 to 9, and none of these squares ends in 8.

Therefore no square number has a last digit of 8.

Turn over for the next question

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7 The curve $y = 15 - x^2$ and the isosceles triangle OPQ are shown on the diagram below.



Vertices P and Q lie on the curve such that Q lies vertically above some point $(q, 0)$

The line PQ is parallel to the x-axis.

7 (a) Show that the area, A, of the triangle OPQ is given by

$$A = 15q - q^3 \quad \text{for } 0 < q < c$$

where c is a constant to be found.

[3 marks]

Q = (q, 15 − q²) and, by symmetry, P = (−q, 15 − q²)

Base PQ = 2q, height of triangle = 15 − q²

A = ½ × 2q × (15 − q²)

A = 15q − q³

Q lies above the x-axis: 15 − q² > 0 ⇒ q < √15

so 0 < q < √15, c = √15

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7 (b) Find the exact maximum area of triangle *OPQ*.

Fully justify your answer.

[6 marks]

The maximum occurs when $\frac{dA}{dq} = 0$

$\frac{dA}{dq} = 15 - 3q^2$

$15 - 3q^2 = 0 \Rightarrow q^2 = 5 \Rightarrow q = \sqrt{5} \quad (q > 0)$

$\frac{d^2A}{dq^2} = -6q$

At $q = \sqrt{5}$: $\frac{d^2A}{dq^2} = -6\sqrt{5} = -13.4... < 0$, so a maximum

Maximum area $= 15\sqrt{5} - (\sqrt{5})^3$

$= 15\sqrt{5} - 5\sqrt{5}$

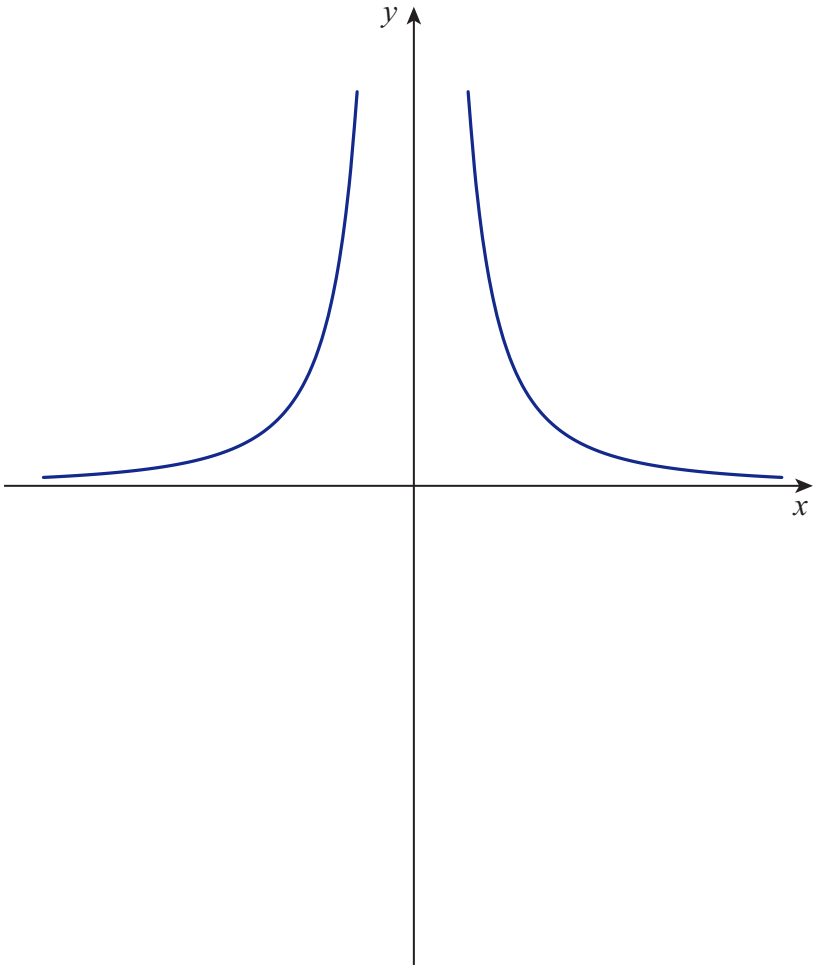
$= 10\sqrt{5}$

Turn over for the next question

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8 (a) Sketch the graph of $y = \frac{1}{x^2}$

[2 marks]



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8 (b) The graph of $y = \frac{1}{x^2}$ can be transformed onto the graph of $y = \frac{9}{x^2}$ using a stretch in one direction.

Beth thinks the stretch should be in the y-direction.

Paul thinks the stretch should be in the x-direction.

State, giving reasons for your answer, whether Beth is correct, Paul is correct, both are correct or neither is correct.

[3 marks]

Stretch in the y-direction, scale factor 9: $y = 9 \times \frac{1}{x^2} = \frac{9}{x^2}$

Stretch in the x-direction, scale factor 3: replace x by $\frac{x}{3}$

$y = \frac{1}{(x/3)^2} = \frac{1}{x^2/9} = \frac{9}{x^2}$

Both stretches map $y = \frac{1}{x^2}$ onto $y = \frac{9}{x^2}$,

so Beth and Paul are both correct.

Turn over for the next question

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9 Given that

$$\log_2 x^3 - \log_2 y^2 = 9$$

show that

$$x = Ay^p$$

where A is an integer and p is a rational number.

[4 marks]

$\log_2 x^3 - \log_2 y^2 = 9$

$\log_2 \frac{x^3}{y^2} = 9$

$\frac{x^3}{y^2} = 2^9 = 512$

$x^3 = 512y^2$

$x = (512y^2)^{1/3} = 8y^{2/3}$

so $x = Ay^p$ with $A = 8$ (an integer) and $p = \frac{2}{3}$ (rational)

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10 A gardener has a greenhouse containing 900 tomato plants.

The gardener notices that some of the tomato plants are damaged by insects.

Initially there are 25 damaged tomato plants.

The number of tomato plants damaged by insects is increasing by 32% each day.

10 (a) The total number of plants damaged by insects, x, is modelled by

$$x = A \times B^t$$

where A and B are constants and t is the number of days after the gardener first noticed the damaged plants.

10 (a) (i) Use this model to find the total number of plants damaged by insects 5 days after the gardener noticed the damaged plants.

[3 marks]

$A = 25$ (initial number), $B = 1.32$ (32% increase each day)

$x = 25 \times 1.32^t$

$t = 5$: $x = 25 \times 1.32^5 = 100.18...$

Total number of damaged plants = 101

10 (a) (ii) Explain why this model is not realistic in the long term.

[2 marks]

The model is exponential, so the number of damaged plants it predicts grows without limit as t increases. This can't be true as there are only 900 tomato plants in the greenhouse, so x can never exceed 900.

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10 (b) A refined model assumes the rate of increase of the number of plants damaged by insects is given by

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \frac{x(900 - x)}{2700}$$

10 (b) (i) Show that

$$\int \left(\frac{A}{x} + \frac{B}{900 - x} \right) \mathrm{d}x = \int \mathrm{d}t$$

where A and B are positive integers to be found.

[3 marks]

$\frac{dx}{dt} = \frac{x(900 - x)}{2700}$

$\frac{2700}{x(900 - x)} \frac{dx}{dt} = 1 \quad \Rightarrow \quad \int \frac{2700}{x(900 - x)} dx = \int dt$

$\frac{2700}{x(900 - x)} \equiv \frac{A}{x} + \frac{B}{900 - x}$

$2700 \equiv A(900 - x) + Bx$

$x = 0: \quad 2700 = 900A \Rightarrow A = 3$

$x = 900: \quad 2700 = 900B \Rightarrow B = 3$

$\therefore \int \left(\frac{3}{x} + \frac{3}{900 - x} \right) dx = \int dt, \quad A = 3, \; B = 3$

Question 10 continues on the next page

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10 (b) (ii) Hence, find t in terms of x.

[5 marks]

$3 \ln x - 3 \ln(900 - x) = t + c$

$t = 0, x = 25$: $3 \ln 25 - 3 \ln 875 = c$

$c = 3 \ln\left(\frac{25}{875}\right) = 3 \ln\left(\frac{1}{35}\right) = -3 \ln 35 \quad (= -10.67)$

$t = 3 \ln x - 3 \ln(900 - x) + 3 \ln 35$

$t = 3 \ln\left(\frac{35x}{900 - x}\right)$

10 (b) (iii) Hence, find the number of days it takes from when the damage is first noticed until half of the plants are damaged by the insects.

[2 marks]

Half of the plants: $x = 450$

$t = 3 \ln\left(\frac{35 \times 450}{900 - 450}\right) = 3 \ln 35 = 10.66...$

It takes 11 days until half the plants are damaged.

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Section B

Answer **all** questions in the spaces provided.

11 A moon vehicle has a mass of 212 kg and a length of 3 metres.

On the moon the vehicle has a weight of 345 N

Calculate a value for acceleration due to gravity on the moon.

Circle your answer.

[1 mark]

$0.614\,\text{m s}^{-2}$ $\quad$ (1.63 m s^{-2}) $\quad$ $1.84\,\text{m s}^{-2}$ $\quad$ $4.89\,\text{m s}^{-2}$

12 A car is travelling along a straight horizontal road with initial velocity $u\,\text{m s}^{-1}$

The car begins to accelerate at a constant rate $a\,\text{m s}^{-2}$ for 5 seconds, to reach a final velocity of $4u\,\text{m s}^{-1}$

Express a in terms of u.

Circle your answer.

[1 mark]

$a = 0.2u$ $\quad$ $a = 0.4u$ $\quad$ ($a = 0.6u$) $\quad$ $a = 0.8u$

Turn over for the next question

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13 **In this question use $g = 9.8\,\text{m s}^{-2}$**

A ball is projected from a point on horizontal ground with an initial velocity of $7\,\text{m s}^{-1}$ at an angle θ above the horizontal.

The ball reaches a maximum vertical height of h metres above the ground.

13 (a) Show that

$$h = 2.5\sin^2\theta$$

[3 marks]

Vertically: $u = 7\sin\theta$, $v = 0$ at maximum height, $a = -9.8$, $s = h$

$v^2 = u^2 + 2as$

$0 = (7\sin\theta)^2 + 2(-9.8)h$

$0 = 49\sin^2\theta - 19.6h$

$h = \frac{49\sin^2\theta}{19.6}$

$h = 2.5\sin^2\theta$

13 (b) Hence, given that $0° \leq \theta \leq 60°$, find the maximum value of h.

[2 marks]

$\sin^2\theta$ increases for $0° \leq \theta \leq 60°$, so h is greatest at $\theta = 60°$

$h = 2.5\sin^2 60° = 2.5 \times \frac{3}{4} = 1.875$

Maximum value of $h = 1.875$ m $\left(= \frac{15}{8}\text{ m}\right)$

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13 (c) Nisha claims that the larger the size of the ball, the greater the maximum vertical height will be.

State whether Nisha is correct, giving a reason for your answer.

[1 mark]

Nisha is incorrect: the model treats the ball as a particle and ignores air resistance, which would be greater for a larger ball.

Turn over for the next question

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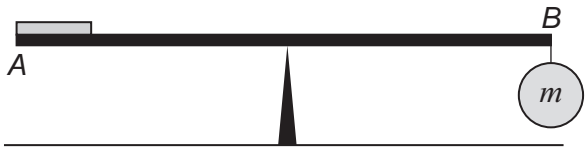
14 A £2 coin has a diameter of 28 mm and a mass of 12 grams.

A uniform rod AB of length 160 mm and a fixed load of mass m grams are used to check that a £2 coin has the correct mass.

The rod rests with its midpoint on a support.

A £2 coin is placed face down on the rod with part of its curved edge directly above A.

The fixed load is hung by a light inextensible string from a point directly below the other end of the rod at B, as shown in the diagram.



14 (a) Given that the rod is horizontal and rests in equilibrium, find m.

[3 marks]

Coin's centre is 14 mm from A, so 80 − 14 = 66 mm from the support

Moments about the support (midpoint of AB):

$12g \times 66 = mg \times 80$

$m = \frac{12 \times 66}{80} = 9.9$

$m = 9.9$ grams

14 (b) State an assumption you have made about the £2 coin to answer **part (a)**.

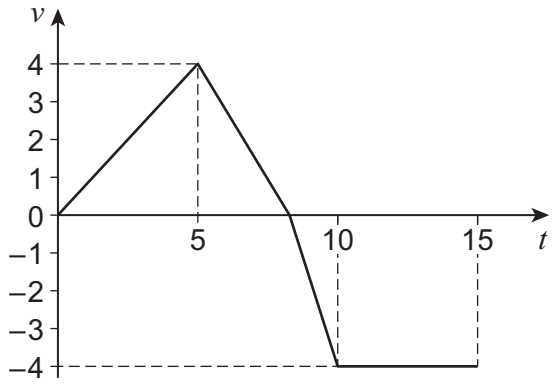
[1 mark]

The coin is uniform, so its weight acts at its centre.

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15 A car is moving in a straight line along a horizontal road.

The graph below shows how the car's velocity $v\,\text{m}\,\text{s}^{-1}$ changes with time, t seconds.



Over the period $0 \leq t \leq 15$ the car has a total displacement of -7 metres.

Initially the car has velocity $0\,\text{m}\,\text{s}^{-1}$

Find the next time when the velocity of the car is $0\,\text{m}\,\text{s}^{-1}$

[4 marks]

Let T be the next time when v = 0

Area above the axis $(0 \leq t \leq T) = \frac{1}{2} \times T \times 4 = 2T$

Area below the axis $(T \leq t \leq 15) = \frac{1}{2} \times (10 - T) \times 4 + 5 \times 4$

$= 2(10 - T) + 20$

Total displacement: $2T - [2(10 - T) + 20] = -7$

$2T - 20 + 2T - 20 = -7$

$4T = 33$

$T = 8.25$

The velocity is next 0 m s^{-1} at t = 8.25 seconds

Turn over ▶

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16 Two particles, P and Q, move in the same horizontal plane.

Particle P is initially at rest at the point with position vector $(-4\mathbf{i} + 5\mathbf{j})$ metres and moves with constant acceleration $(3\mathbf{i} - 4\mathbf{j})\,\text{m s}^{-2}$

Particle Q moves in a straight line, passing through the points with position vectors $(\mathbf{i} - \mathbf{j})$ metres and $(10\mathbf{i} + c\mathbf{j})$ metres.

P and Q are moving along parallel paths.

16 (a) Show that $c = -13$

[4 marks]

P starts from rest, so it moves in the direction of its acceleration $\begin{bmatrix} 3 \\ -4 \end{bmatrix}$

Direction of Q's path: $\begin{bmatrix} 10 \\ c \end{bmatrix} - \begin{bmatrix} 1 \\ -1 \end{bmatrix} = \begin{bmatrix} 9 \\ c+1 \end{bmatrix}$

Paths are parallel: $\begin{bmatrix} 9 \\ c+1 \end{bmatrix} = k\begin{bmatrix} 3 \\ -4 \end{bmatrix}$

$9 = 3k \Rightarrow k = 3$

$c + 1 = -4k = -12$

$c = -13$

16 (b) (i) Find an expression for the position vector of P at time t seconds.

[1 mark]

$u = 0$: $r = r_0 + \frac{1}{2}at^2$

$r = \begin{bmatrix} -4 \\ 5 \end{bmatrix} + \frac{1}{2}\begin{bmatrix} 3 \\ -4 \end{bmatrix} t^2$

$r = (-4 + 1.5t^2)i + (5 - 2t^2)j$

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16 (b) (ii) Hence, prove that the paths of P and Q are not collinear.

[3 marks]

If the paths were collinear, P would pass through $(i - j)$ on Q's path:

$$\begin{bmatrix} 1 \\ -1 \end{bmatrix} = \begin{bmatrix} -4 \\ 5 \end{bmatrix} + \tfrac{1}{2}t^2 \begin{bmatrix} 3 \\ -4 \end{bmatrix}$$

i: $1 = -4 + 1.5t^2 \Rightarrow t^2 = \frac{10}{3}$

j: $-1 = 5 - 2t^2 \Rightarrow t^2 = 3$

The values of t^2 are different, so no single value of t satisfies both components: P never passes through the point $(i - j)$ on the path of Q.

The paths are parallel but do not share a point, so the paths of P and Q are not collinear.

Turn over for the next question

Do not write outside the box

17 A particle is moving such that its position vector, **r** metres, at time t seconds, is given by

$$\mathbf{r} = \mathrm{e}^t \cos t\ \mathbf{i} + \mathrm{e}^t \sin t\ \mathbf{j}$$

Show that the **magnitude** of the acceleration of the particle, $a\,\mathrm{m\,s^{-2}}$, is given by

$$a = 2\mathrm{e}^t$$

Fully justify your answer.

[7 marks]

$r = e^t \cos t\, i + e^t \sin t\, j$

Product rule:

$v = \frac{dr}{dt} = (e^t \cos t - e^t \sin t)i + (e^t \sin t + e^t \cos t)j$

$a = \frac{dv}{dt} = (e^t \cos t - e^t \sin t - e^t \sin t - e^t \cos t)i$

$\quad + (e^t \sin t + e^t \cos t + e^t \cos t - e^t \sin t)j$

$a = -2e^t \sin t\, i + 2e^t \cos t\, j$

$|a| = \sqrt{((-2e^t \sin t)^2 + (2e^t \cos t)^2)}$

$= \sqrt{(4e^{2t} \sin^2 t + 4e^{2t} \cos^2 t)}$

$= \sqrt{(4e^{2t}(\sin^2 t + \cos^2 t))}$

$= \sqrt{(4e^{2t})}$ since $\sin^2 t + \cos^2 t = 1$

$= 2e^t$ $(e^t > 0)$

Hence the magnitude of the acceleration is $a = 2e^t$

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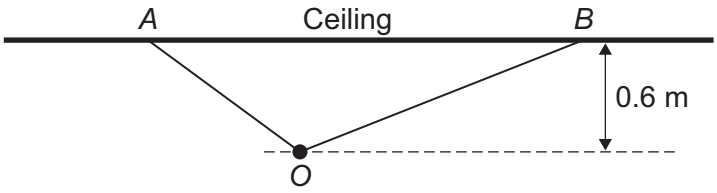
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18 An object, O, of mass m kilograms is hanging from a ceiling by two light, inelastic strings of different lengths.

The shorter string, of length 0.8 metres, is fixed to the ceiling at A.

The longer string, of length 1.2 metres, is fixed to the ceiling at B.

This object hangs 0.6 metres directly below the ceiling as shown in the diagram.



18 (a) Show that the tension in the shorter string is over 30% more than the tension in the longer string.

[4 marks]

Let α and β be the angles OA and OB make with the ceiling.

$\sin\alpha = \frac{0.6}{0.8} \Rightarrow \alpha = 48.59°$

$\sin\beta = \frac{0.6}{1.2} \Rightarrow \beta = 30°$

Resolving horizontally: $T_A \cos\alpha = T_B \cos\beta$

$T_A = T_B \times \frac{\cos 30°}{\cos 48.59°}$

$T_A = 1.309... T_B$

$1.309 > 1.3$, so $T_A > 1.3T_B$

So the tension in the shorter string is over 30% more than the tension in the longer string.

Do not write outside the box

18 (b) The tension in the longer string is known to be $2g$ newtons.

Find the value of m.

[4 marks]

$T_B = 2g \Rightarrow T_A = 1.309... \times 2g = 2.618...g$

Resolving vertically: $T_A \sin\alpha + T_B \sin\beta = mg$

$2.618...g \times \sin 48.59° + 2g \times \sin 30° = mg$

$m = 2.618... \times 0.75 + 2 \times 0.5$

$m = 1.963... + 1 = 2.963...$

$m = 2.96 \ (\approx 3)$

Turn over for the next question

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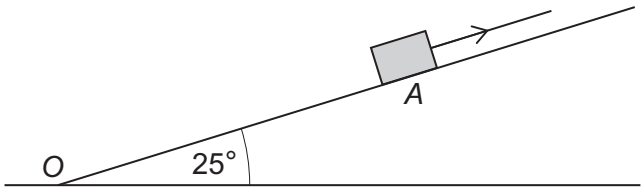
19 **In this question use $g = 9.8\,\text{m s}^{-2}$**

A rough wooden ramp is 10 metres long and is inclined at an angle of 25° above the horizontal. The bottom of the ramp is at the point *O*.

A crate of mass 20 kg is at rest at the point *A* on the ramp.

The crate is pulled up the ramp using a rope attached to the crate.

Once in motion, the rope remains taut and parallel to the line of greatest slope of the ramp.



19 (a) The tension in the rope is 230 N

The crate accelerates up the ramp at $1.2\,\text{m s}^{-2}$

Find the coefficient of friction between the crate and the ramp.

[7 marks]

Perpendicular to slope: $R = 20g \cos 25° = 196 \cos 25° = 177.63...$ N

Friction: $F = \mu R = 177.63...\mu$

Weight down the slope $= 20g \sin 25° = 196 \sin 25° = 82.83...$ N

$F = ma$ up the slope:

$T - 20g \sin 25° - F = 20 \times 1.2$

$230 - 196 \sin 25° - 196 \cos 25° \mu = 24$

$177.63...\mu = 230 - 24 - 82.83... = 123.16...$

$\mu = \frac{123.16...}{177.63...} = 0.6933...$

$\mu = 0.69$

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19 (b) (i) The crate takes 3.8 seconds to reach the top of the ramp.

Find the distance *OA*.

[3 marks]

From rest: $u = 0$, $a = 1.2$, $t = 3.8$

$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 1.2 \times 3.8^2 = 8.664$ m

$OA = 10 - 8.664 = 1.336$

$OA = 1.3$ m

19 (b) (ii) Other than air resistance, state **one** assumption you have made about the crate in answering part **(b)(i)**.

[1 mark]

The crate is modelled as a particle.

END OF QUESTIONS

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