AQA

Please write clearly in block capitals.

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

Surname StemUp Model Solution

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I declare this is my own work.

AS
FURTHER MATHEMATICS

Paper 2 Mechanics

Friday 16 May 2025 Afternoon Time allowed: 1 hour 30 minutes

Materials
- You must have the AQA Formulae and statistical tables booklet for A-level Mathematics and A-level Further Mathematics.
- You should have a graphical or scientific calculator that meets the requirements of the specification.
- You must ensure you have the other optional Question Paper/Answer Book for which you are entered (**either** Discrete **or** Statistics). You will have 1 hour 30 minutes to complete **both** papers.

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 require 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 40.

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
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TOTAL	

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

1 A particle travels around a horizontal circle of radius r metres with a constant angular speed of ω radians per second.

State an expression for the magnitude of the acceleration, in m s^{-2}, of the particle.

Circle your answer.

[1 mark]

$r^2\omega$ $\quad$ $\frac{\omega}{r^2}$ $\quad$ $r\omega^2$ $\quad$ $\frac{\omega^2}{r}$

2 State the dimensions of power.

Circle your answer.

[1 mark]

ML^2T $\quad$ ML^2T^{-1} $\quad$ ML^2T^{-2} $\quad$ ML^2T^{-3}

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3 A light elastic string has a modulus of elasticity of 20 newtons and a natural length of 0.5 metres.

One end of the string is attached to a fixed point.

A particle of weight 25 newtons is attached to the other end of the string.

The particle hangs in equilibrium with the string vertical.

Find the extension of the string.

[2 marks]

Hooke's law: $T = \lambda x/l = 20x/0.5 = 40x$

Equilibrium: $T = 25$

$40x = 25$

$x = 25 \div 40 = 0.625$

Extension = 0.625 m

Turn over for the next question

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4 Two particles, P and Q, are moving on a smooth horizontal surface.

Particle P has mass 4 kg and is moving with velocity $\begin{bmatrix} -1 \\ 2 \end{bmatrix}$ m s^{-1}

Particle Q has mass 6 kg and is moving with velocity $\begin{bmatrix} 4 \\ -3 \end{bmatrix}$ m s^{-1}

The particles collide and coalesce to form a single particle.

Find the velocity of the single particle immediately after the collision.

[2 marks]

Conservation of momentum (combined mass 4 + 6 = 10 kg):

$4\begin{bmatrix} -1 \\ 2 \end{bmatrix} + 6\begin{bmatrix} 4 \\ -3 \end{bmatrix} = 10\mathbf{v}$

$\begin{bmatrix} -4 \\ 8 \end{bmatrix} + \begin{bmatrix} 24 \\ -18 \end{bmatrix} = 10\mathbf{v}$

$\begin{bmatrix} 20 \\ -10 \end{bmatrix} = 10\mathbf{v}$

$\mathbf{v} = \begin{bmatrix} 2 \\ -1 \end{bmatrix}$ m s^{-1}

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5 The path of a person on a theme park ride can be modelled as a circle of radius 15 metres.

The person has a constant angular speed about the centre of the circle.

The person completes one revolution every 40 seconds.

Find the speed of the person on the ride in metres per second.

Give your answer to two significant figures.

[3 marks]

One revolution (2π rad) every 40 s:

$\omega = 2\pi/40 = \pi/20$ rad s^{-1} (= 0.15707...)

$v = r\omega = 15 \times \pi/20 = 3\pi/4$

$v = 2.3561...$

Speed = 2.4 m s^{-1} (2 s.f.)

Turn over for the next question

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6 A ball of mass m is thrown vertically upwards with initial speed u

The ball travels a vertical distance h before instantaneously coming to rest.

It is thought that

$$h = km^a u^b g^c$$

where

- $[k] = 1$
- g is the acceleration due to gravity
- a, b and c are constants.

6 (a) Explain what is meant by $[k] = 1$

[1 mark]

k is dimensionless: it has no dimensions (k is just a number).

6 (b) Use dimensional analysis to find the value of a, the value of b and the value of c

[3 marks]

$[h] = L$, $[m] = M$, $[u] = LT^{-1}$, $[g] = LT^{-2}$, $[k] = 1$

$[h] = [k][m]^a[u]^b[g]^c$

$L = M^a(LT^{-1})^b(LT^{-2})^c$

$L = M^a L^{b+c} T^{-b-2c}$

M: $a = 0$

L: $b + c = 1$

T: $-b - 2c = 0 \Rightarrow b = -2c$

$-2c + c = 1 \Rightarrow c = -1, \quad b = 2$

$\therefore a = 0, \quad b = 2, \quad c = -1$

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7 A car of mass 900 kg is travelling along a straight horizontal road.

The car experiences a constant resistance force of 500 newtons.

7 (a) At a particular time, the car has speed 10 m s^{-1} and is accelerating at 0.6 m s^{-2}

7 (a) (i) Show that the driving force has magnitude 1040 newtons at this time.

[2 marks]

Newton's second law (D = driving force):

D − 500 = 900 × 0.6

D − 500 = 540

D = 500 + 540 = 1040 N as required

7 (a) (ii) Find the power of the car at this time.

Give your answer in kW

[2 marks]

P = Fv = 1040 × 10

P = 10 400 W

Power = 10.4 kW

7 (b) It is given that the maximum speed of the car is 30 m s^{-1} on this horizontal road.

Find the maximum power of the engine.

[1 mark]

At maximum speed a = 0, so driving force = resistance = 500 N

Max power = Fv = 500 × 30 = 15 000 W = 15 kW

Turn over ▶

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8 A horizontal force, F newtons, is acting on a particle moving in a straight line on a smooth horizontal surface.

At time t seconds, $F = 20t + 2$ where $0 \leq t \leq T$

The magnitude of the impulse exerted on the particle by the horizontal force over the interval $0 \leq t \leq T$ is 168 N s

8 (a) (i) Show that

$$5T^2 + T - 84 = 0$$

[3 marks]

Impulse $= \int_0^T F\,dt = \int_0^T (20t + 2)\,dt$

$= [10t^2 + 2t]_0^T$

$= (10T^2 + 2T) - 0$

$10T^2 + 2T = 168$

$10T^2 + 2T - 168 = 0$

$\div 2$: $5T^2 + T - 84 = 0$ as required

8 (a) (ii) Find the value of T

[1 mark]

$(5T + 21)(T - 4) = 0 \Rightarrow T = 4$ or $T = -4.2$ (reject, $T > 0$)

$T = 4$

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8 (b) It is given that the velocity of the particle increases from 10 m s^{-1} to 30 m s^{-1} over the interval $0 \leq t \leq T$

Find the mass of the particle.

[2 marks]

Impulse = change in momentum: $I = mv - mu$

$168 = m(30) - m(10)$

$20m = 168$

$m = 8.4$ kg

Turn over for the next question

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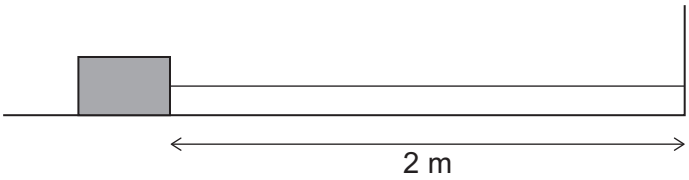
9 A block of mass 4 kg rests on a horizontal surface.

The block is attached to one end of a light elastic string.

The other end of the string is attached to a vertical wall.

The string has natural length 1.5 metres and a stiffness of 120 N m^{-1}

The block is released from rest at a distance of 2 metres from the wall as shown in the diagram.



Assume that no air resistance acts on the block.

9 (a) Find the elastic potential energy of the string when the block is 2 metres from the wall.

[2 marks]

Extension $x = 2 - 1.5 = 0.5$ m

$EPE = \frac{1}{2}kx^2 = \frac{1}{2} \times 120 \times 0.5^2$

$EPE = 15$ J

9 (b) Assuming that the horizontal surface is modelled as smooth, use an energy method to find the speed of the block when it hits the wall.

Give your answer to three significant figures.

[2 marks]

Smooth surface: EPE at start = KE when string goes slack,

then speed is constant until the block hits the wall.

$\frac{1}{2}mv^2 = 15 \Rightarrow \frac{1}{2} \times 4 \times v^2 = 15$

$v^2 = 7.5 \Rightarrow v = \sqrt{7.5} = 2.7386...$

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Speed = 2.74 m s^{-1} (3 s.f.)

9 (c) In an improved model the horizontal surface is modelled as rough, with a constant friction force of magnitude F newtons.

Given that the block just reaches the wall, find the value of F

[2 marks]

Work done against friction over 2 m = EPE lost

F × 2 = 15

F = 7.5

9 (d) State how your answer to part **(c)** would change if air resistance was considered.

[1 mark]

F would be smaller: F < 7.5 (air resistance also removes energy).

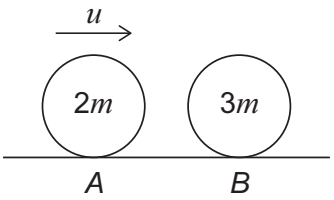
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10 Two smooth spheres, A and B, of equal size, initially lie at rest on a smooth horizontal surface.

Sphere A has mass $2m$ and sphere B has mass $3m$

Sphere A is projected with speed u directly towards sphere B as shown in the diagram.



Subsequently A collides directly with B

The coefficient of restitution between A and B is $\frac{3}{4}$

10 (a) Find, in terms of u, the speed of A and the speed of B immediately after the collision.

[5 marks]

Let v_A, v_B be the velocities of A and B after the collision

(positive in the direction of u).

Conservation of momentum:

$2mu = 2mv_A + 3mv_B \Rightarrow 2v_A + 3v_B = 2u$ (1)

Newton's law of restitution:

$v_B - v_A = \frac{3}{4}u \Rightarrow 2v_B - 2v_A = \frac{3}{2}u$ (2)

(1) + (2): $5v_B = 2u + \frac{3}{2}u = \frac{7}{2}u$

$v_B = \frac{7}{10}u$

$v_A = v_B - \frac{3}{4}u = \frac{7}{10}u - \frac{3}{4}u = \frac{14-15}{20}u$

$v_A = -\frac{u}{20}$ (A moves back, away from B)

Speed of A $= \frac{u}{20}$, speed of B $= \frac{7u}{10}$

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10 (b) Subsequently B hits a vertical wall and rebounds, travelling directly towards A

The coefficient of restitution between B and the wall is e

It is given that B **does not** collide again with A

Find the range of possible values of e

[4 marks]

Speed of B after hitting the wall: $w_B = e \times \frac{7u}{10} = \frac{7ue}{10}$

A moves away from B with speed $\frac{u}{20}$, B moves towards A with w_B

No further collision if B cannot catch A: $w_B \leq$ speed of A

$\frac{7ue}{10} \leq \frac{u}{20}$

$e \leq \frac{10}{140} = \frac{1}{14}$ $(= 0.0714...)$

B rebounds from the wall, so $e > 0$

$\therefore \quad 0 < e \leq \frac{1}{14}$

END OF QUESTIONS

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