AQA

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level
FURTHER MATHEMATICS

Paper 3 Mechanics

Time allowed: 2 hours

Materials
- You must have the AQA Formulae and statistical tables booklet for A-level Mathematics and A-level Further Mathematics.
- You should have a 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 2 hours 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.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

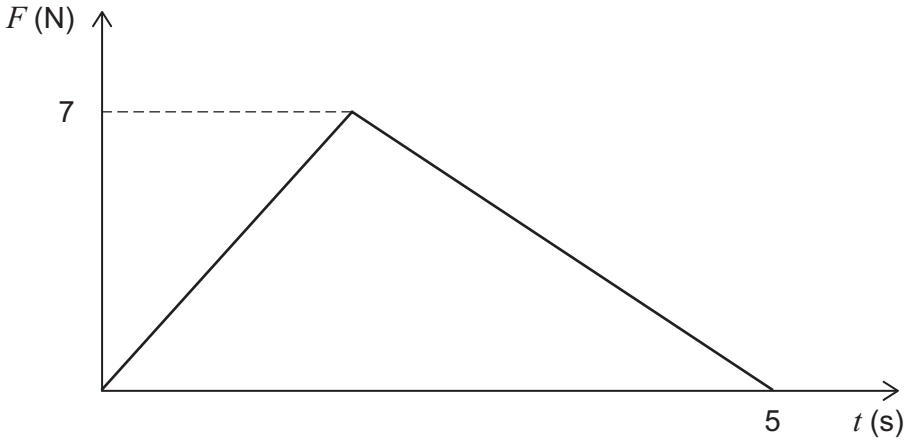
Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 50.

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

Do not write outside the box

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

1 The graph shows how a force, F newtons, varies during a 5 second period of time.



Calculate the magnitude of the impulse of the force.

Circle your answer.

[1 mark]

17.5 N s 25 N s 35 N s 70 N s

2 A car of mass 1200 kg is travelling at a constant speed of 18 m s^{-1} on a straight horizontal road.

The car experiences a total resistive force of 240 newtons.

Calculate the power of the car's engine.

Circle your answer.

[1 mark]

900 W 4320 W 16 000 W 21 600 W

Do not write outside the box

3 Three particles are attached to a light rod, AB, of length 40 cm

The particles are attached at A, B and the midpoint of the rod.

The particle at A has mass 5 kg

The particle at B has mass 1 kg

The particle at the midpoint has mass 4 kg

Find the distance of the centre of mass of this system from the midpoint of the rod.

Circle your answer.

[1 mark]

4 cm 8 cm 12 cm 28 cm

Turn over for the next question

Do not write outside the box

4 (a) State the dimensions of force.

[1 mark]

4 (b) The velocity of an object in a circular orbit can be calculated using the formula

$$v = G^a m^b r^c$$

where:

$G =$ Universal constant of gravitation in $\text{N m}^2\,\text{kg}^{-2}$

$m =$ Mass of the Earth in kg

$r =$ Radius of the orbit in metres

Use dimensional analysis to find the values of a, b and c

[4 marks]

Do not write outside the box

5 A train of mass 10 000 kg is travelling at $0.3\,\text{m}\,\text{s}^{-1}$ when it collides with a buffer. The buffer brings the train to rest.

As the buffer brings the train to rest it compresses by 0.2 metres.

When the buffer is compressed by a distance of x metres it exerts a force of magnitude F newtons, where

$$F = Ax + 9000x^2$$

where A is a constant.

5 (a) Find, in terms of A, the work done in compressing the buffer by 0.2 metres.

[2 marks]

5 (b) Find the value of A

[2 marks]

Turn over for the next question

Do not write outside the box

6 A particle, of mass 5 kg, moves on a circular path so that at time t seconds it has position vector **r** metres, where

$$\mathbf{r} = (2\sin 3t)\mathbf{i} + (2\cos 3t)\mathbf{j}$$

6 (a) Prove that the velocity of the particle is perpendicular to its position vector.

[4 marks]

Do not write outside the box

6 (b) Prove that the magnitude of the resultant force on the particle is constant.

[3 marks]

Turn over for the next question

Do not write outside the box

7 Two snooker balls, one white and one red, have equal mass.

The balls are on a horizontal table *ABCD*

The white ball is struck so that it moves at a speed of $2\,m\,s^{-1}$ parallel to *AB*

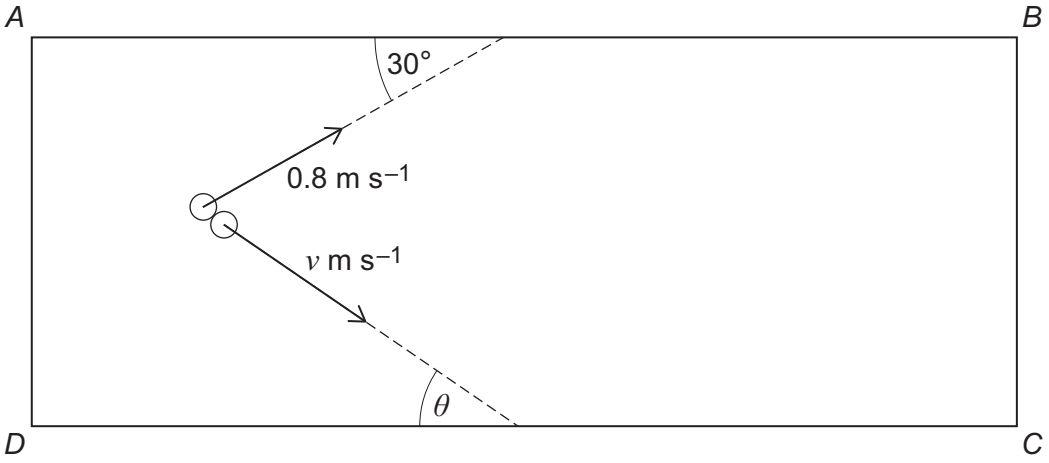
The white ball hits a stationary red ball.

After the collision, the white ball moves at a speed of $0.8\,m\,s^{-1}$ and at an angle of 30° to *AB*

After the collision, the red ball moves at a speed $v\,m\,s^{-1}$ and at an angle θ to *CD*

When the collision takes place, the white ball is the same distance from *AB* as the distance the red ball is from *CD*

The diagram below shows the table and the velocities of the balls after the collision.



Not to scale

After the collision, the white ball hits *AB* and the red ball hits *CD*

Model the balls as particles that do not experience any air resistance.

7 (a) Explain why the two balls hit the sides of the table at the same time.

[2 marks]

Do not write outside the box

7 (b) Show that $\theta = 17.0°$ correct to one decimal place.

[4 marks]

7 (c) Find v

[2 marks]

7 (d) Determine which ball travels the greater distance after the collision and before hitting the side of the table.

Fully justify your answer.

[2 marks]

7 (e) State **one** possible refinement to the model that you have used.

[1 mark]

Do not write outside the box

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

A rope is used to pull a crate, of mass 60 kg, along a rough horizontal surface.

The coefficient of friction between the crate and the surface is 0.4

The crate is at rest when the rope starts to pull on it.

The tension in the rope is 240 N and the rope makes an angle of 30° to the horizontal.

When the crate has moved 5 metres, the rope becomes detached from the crate.

8 (a) Use an energy method to find the maximum speed of the crate.

[4 marks]

Do not write outside the box

8 (b) Use an energy method to find the total distance travelled by the crate.

[2 marks]

8 (c) A student claims that in reality the crate is unlikely to travel more than 5.3 metres in total. Comment on the validity of this claim.

[2 marks]

Turn over for the next question

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

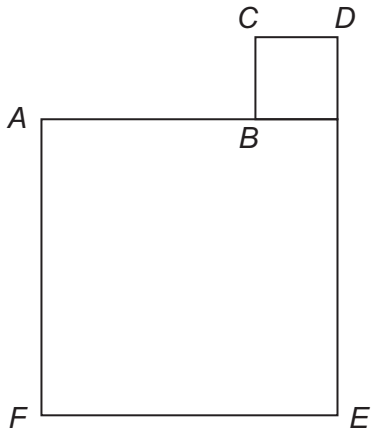
9 Two blocks have square cross sections.

One block has mass 9 kg and its cross section has sides of length 20 cm

The other block has mass 1 kg and its cross section has sides of length 4 cm

The blocks are fixed together to form the composite body shown in **Figure 1**.

Figure 1



9 (a) Find the distance of the centre of mass of the composite body from *AF*

[2 marks]

Question 9 continues on the next page

Do not write outside the box

9 (b) A uniform rod has mass 12 kg and length 1 metre.

One end of the rod rests against a smooth vertical wall.

The other end of the rod rests on the composite body at point *B*

The composite body is on a horizontal surface.

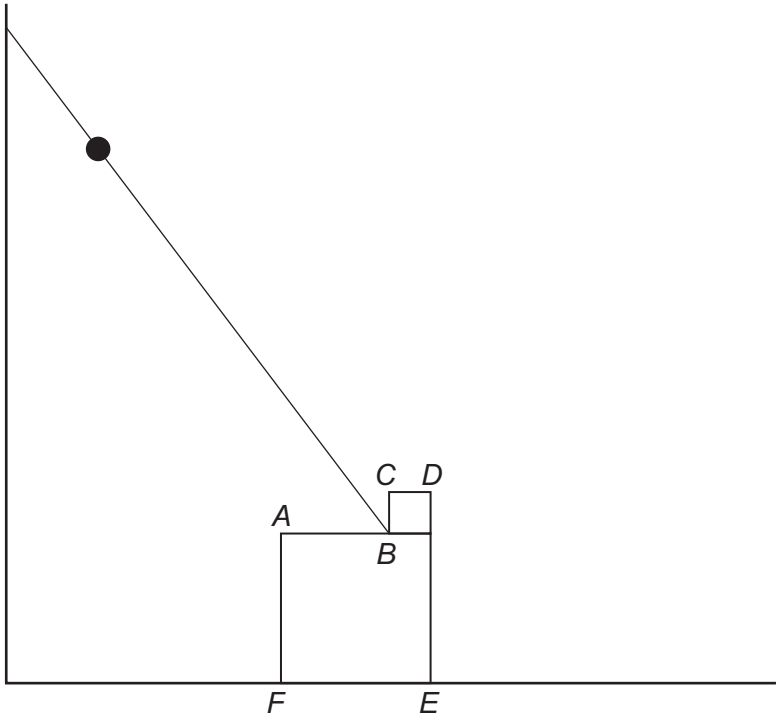
The coefficient of friction between the composite body and the horizontal surface is 0.3

The angle between the rod and *AB* is 60°

A particle of mass m kg is fixed to the rod at a distance of 75 cm from *B*

The rod, particle and composite body are shown in **Figure 2**.

Figure 2



9 (b) (i) Write down the magnitude of the vertical reaction force acting on the rod at *B* in terms of m and g

[1 mark]

Do not write outside the box

9 (b) (ii) Show that the magnitude of the horizontal reaction force acting on the rod at B is

$$\frac{g(6 + 0.75m)}{\sqrt{3}}$$

[3 marks]

Question 9 continues on the next page

Do not write outside the box

9 (b) (iii) Find the maximum value of m for which the composite body does not slide or topple.

Fully justify your answer.

[6 marks]

Do not write outside the box

END OF QUESTIONS

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2022 AQA and its licensors. All rights reserved.