

Please check the examination details below before entering your candidate information

Candidate surname

Other names

**Pearson Edexcel**  
**Level 3 GCE**

Centre Number

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Candidate Number

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**Thursday 20 June 2019**

Morning (Time: 1 hour 30 minutes)

Paper Reference **9FM0/3C**

**Further Mathematics**

**Advanced**

**Paper 3C: Further Mechanics 1**

**You must have:**

Mathematical Formulae and Statistical Tables (Green), calculator

Total Marks

**Candidates may use any calculator permitted by Pearson regulations. Calculators must not have the facility for algebraic 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.
- Unless otherwise indicated, whenever a numerical value of  $g$  is required, take  $g = 9.8 \text{ m s}^{-2}$  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 7 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.

Turn over ►

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1.

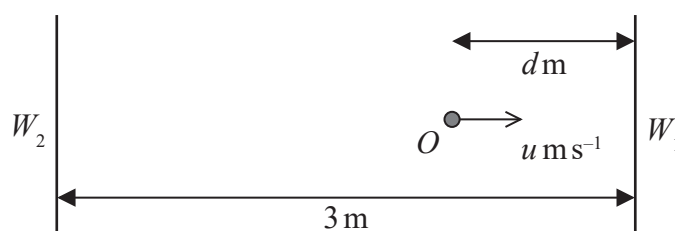


Figure 1

Figure 1 represents the plan of part of a smooth horizontal floor, where  $W_1$  and  $W_2$  are two fixed parallel vertical walls. The walls are 3 metres apart.

A particle lies at rest at a point  $O$  on the floor between the two walls, where the point  $O$  is  $d$  metres,  $0 < d \leq 3$ , from  $W_1$

At time  $t = 0$ , the particle is projected from  $O$  towards  $W_1$  with speed  $u\text{ m s}^{-1}$  in a direction perpendicular to the walls.

The coefficient of restitution between the particle and each wall is  $\frac{2}{3}$

The particle returns to  $O$  at time  $t = T$  seconds, having bounced off each wall once.

(a) Show that  $T = \frac{45 - 5d}{4u}$  (6)

The value of  $u$  is fixed, the particle still hits each wall once but the value of  $d$  can now vary.

(b) Find the least possible value of  $T$ , giving your answer in terms of  $u$ . You must give a reason for your answer. (2)

Question 1 continued

Lined area for writing the answer to Question 1 continued.

Question 1 continued

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Question 1 continued

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(Total for Question 1 is 8 marks)

2.

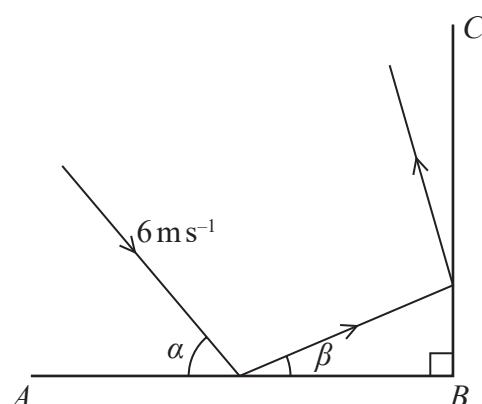


Figure 2

Figure 2 represents the plan view of part of a horizontal floor, where  $AB$  and  $BC$  are fixed vertical walls with  $AB$  perpendicular to  $BC$ .

A small ball is projected along the floor towards  $AB$  with speed  $6 \text{ m s}^{-1}$  on a path that makes an angle  $\alpha$  with  $AB$ , where  $\tan \alpha = \frac{4}{3}$ . The ball hits  $AB$  and then hits  $BC$ .

Immediately after hitting  $AB$ , the ball is moving at an angle  $\beta$  to  $AB$ , where  $\tan \beta = \frac{1}{3}$

The coefficient of restitution between the ball and  $AB$  is  $e$ .

The coefficient of restitution between the ball and  $BC$  is  $\frac{1}{2}$

By modelling the ball as a particle and the floor and walls as being smooth,

- (a) show that the value of  $e = \frac{1}{4}$  (5)
- (b) find the speed of the ball immediately after it hits  $BC$ . (4)
- (c) Suggest two ways in which the model could be refined to make it more realistic. (2)

Question 2 continued

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Question 2 continued

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Question 2 continued

Lined area for writing answers.

(Total for Question 2 is 11 marks)

3. A particle  $P$ , of mass  $0.5 \text{ kg}$ , is moving with velocity  $(4\mathbf{i} + 4\mathbf{j}) \text{ m s}^{-1}$  when it receives an impulse  $\mathbf{I}$  of magnitude  $2.5 \text{ N s}$ .

As a result of the impulse, the direction of motion of  $P$  is deflected through an angle of  $45^\circ$

Given that  $\mathbf{I} = (\lambda\mathbf{i} + \mu\mathbf{j}) \text{ N s}$ , find all the possible pairs of values of  $\lambda$  and  $\mu$ .

(9)

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Question 3 continued

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Question 3 continued

Lined area for writing the answer to Question 3.

(Total for Question 3 is 9 marks)

4. A car of mass 600 kg pulls a trailer of mass 150 kg along a straight horizontal road. The trailer is connected to the car by a light inextensible towbar, which is parallel to the direction of motion of the car. The resistance to the motion of the trailer is modelled as a constant force of magnitude 200 N. At the instant when the speed of the car is  $v \text{ m s}^{-1}$ , the resistance to the motion of the car is modelled as a force of magnitude  $(200 + \lambda v) \text{ N}$ , where  $\lambda$  is a constant.

When the engine of the car is working at a constant rate of 15 kW, the car is moving at a constant speed of  $25 \text{ m s}^{-1}$

- (a) Show that  $\lambda = 8$

(4)

Later on, the car is pulling the trailer up a straight road inclined at an angle  $\theta$  to the horizontal, where  $\sin \theta = \frac{1}{15}$

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 200 N at all times. At the instant when the speed of the car is  $v \text{ m s}^{-1}$ , the resistance to the motion of the car from non-gravitational forces is modelled as a force of magnitude  $(200 + 8v) \text{ N}$ .

The engine of the car is again working at a constant rate of 15kW.

When  $v = 10$ , the towbar breaks. The trailer comes to instantaneous rest after moving a distance  $d$  metres up the road from the point where the towbar broke.

- (b) Find the acceleration of the car immediately after the towbar breaks.

(4)

- (c) Use the work-energy principle to find the value of  $d$ .

(4)

Question 4 continued

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Question 4 continued

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(Total for Question 4 is 12 marks)

5. A particle  $P$  of mass  $3m$  and a particle  $Q$  of mass  $2m$  are moving along the same straight line on a smooth horizontal plane. The particles are moving in opposite directions towards each other and collide directly.

Immediately before the collision the speed of  $P$  is  $u$  and the speed of  $Q$  is  $2u$ .

Immediately after the collision  $P$  and  $Q$  are moving in opposite directions.

The coefficient of restitution between  $P$  and  $Q$  is  $e$ .

- (a) Find the range of possible values of  $e$ , justifying your answer.

(8)

Given that  $Q$  loses 75% of its kinetic energy as a result of the collision,

- (b) find the value of  $e$ .

(3)

Question 5 continued

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Question 5 continued

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Question 5 continued

Handwriting practice area with 20 horizontal lines.

(Total for Question 5 is 11 marks)

6. [In this question  $\mathbf{i}$  and  $\mathbf{j}$  are perpendicular unit vectors in a horizontal plane.]

A smooth uniform sphere  $A$  has mass  $0.2\text{ kg}$  and another smooth uniform sphere  $B$ , with the same radius as  $A$ , has mass  $0.4\text{ kg}$ .

The spheres are moving on a smooth horizontal surface when they collide obliquely. Immediately before the collision, the velocity of  $A$  is  $(3\mathbf{i} + 2\mathbf{j})\text{ m s}^{-1}$  and the velocity of  $B$  is  $(-4\mathbf{i} - \mathbf{j})\text{ m s}^{-1}$

At the instant of collision, the line joining the centres of the spheres is parallel to  $\mathbf{i}$

The coefficient of restitution between the spheres is  $\frac{3}{7}$

- (a) Find the velocity of  $A$  immediately after the collision. (7)
- (b) Find the magnitude of the impulse received by  $A$  in the collision. (2)
- (c) Find, to the nearest degree, the size of the angle through which the direction of motion of  $A$  is deflected as a result of the collision. (3)

Question 6 continued

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Question 6 continued

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Question 6 continued

Lined area for writing the answer to Question 6.

(Total for Question 6 is 12 marks)

7. A particle  $P$ , of mass  $m$ , is attached to one end of a light elastic spring of natural length  $a$  and modulus of elasticity  $kmg$ .

The other end of the spring is attached to a fixed point  $O$  on a ceiling.

The point  $A$  is vertically below  $O$  such that  $OA = 3a$

The point  $B$  is vertically below  $O$  such that  $OB = \frac{1}{2}a$

The particle is held at rest at  $A$ , then released and first comes to instantaneous rest at the point  $B$ .

- (a) Show that  $k = \frac{4}{3}$  (3)
- (b) Find, in terms of  $g$ , the acceleration of  $P$  immediately after it is released from rest at  $A$ . (3)
- (c) Find, in terms of  $g$  and  $a$ , the maximum speed attained by  $P$  as it moves from  $A$  to  $B$ . (6)

Question 7 continued

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**Question 7 continued**

Lined area for writing answers.

(Total for Question 7 is 12 marks)

**TOTAL FOR PAPER IS 75 MARKS**

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