Paper Reference 9FM0/3C
Pearson Edexcel
Level 3 GCE

Further Mathematics

Advanced

PAPER 3C: Further Mechanics 1

Time: 1 hour 30 minutes

YOU MUST HAVE
Mathematical Formulae and Statistical Tables (Green), calculator

YOU WILL BE GIVEN
Diagram Booklet
Answer Booklet

V72092RA

Pearson

Candidates may use any calculator permitted by Pearson regulations. Calculators must not have the facility for symbolic algebraic manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

INSTRUCTIONS

In the boxes on the Answer Booklet and on the Diagram Booklet, write your name, centre number and candidate number.

Answer ALL questions and ensure that your answers to parts of questions are clearly labelled.

(continued on the next page)

Instructions continued.

Answer the questions in the Answer Booklet – there may be more space than you need.

Do NOT write on the Question Paper.

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 $g = 9{\cdot}8\ \mathrm{m\,s^{-2}}$, 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.

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1. A particle A of mass 3m and a particle B of mass m are moving along the same straight line on a smooth horizontal surface.

The particles are moving in opposite directions towards each other when they collide directly.

Immediately before the collision, the speed of A is ku and the speed of B is u

Immediately after the collision, the speed of A is v and the speed of B is 2v

(continued on the next page)

1. continued.

The magnitude of the impulse received by B in the collision is $\frac{3}{2}mu$

(a) Find v in terms of u only.

(3 marks)

(b) Find the two possible values of k

(5 marks)

(Total for Question 1 is 8 marks)

2. Refer to the diagram for Question 2 in the Diagram Booklet.

A van of mass 600 kg is moving up a straight road which is inclined at an angle α to the horizontal, where

$$\sin\alpha = \frac{1}{15}$$

The van is towing a trailer of mass 150 kg

The van is attached to the trailer by a towbar which is parallel to the direction of motion of the van and the trailer, as shown on the diagram in the Diagram Booklet.

(continued on the next page)

2. continued.

The resistance to the motion of the van from non–gravitational forces is modelled as a constant force of magnitude 200 newtons.

The resistance to the motion of the trailer from non–gravitational forces is modelled as a constant force of magnitude 100 newtons.

The towbar is modelled as a light rod.

The engine of the van is working at a constant rate of 12 kW

(continued on the next page)

2. continued.

Find the tension in the towbar at the instant when the speed of the van is $9\ \mathrm{m\,s^{-1}}$

(Total for Question 2 is 8 marks)

3. Refer to the diagram for Question 3 in the Diagram Booklet.

A particle P of mass $0 \cdot 5$ kg is moving in a straight line with speed $2 \cdot 8$ m s^{-1} when it receives an impulse of magnitude 3 N s

The angle between the direction of motion of P immediately before receiving the impulse and the line of action of the impulse is α, where $\tan \alpha = \frac{4}{3}$, as shown on the diagram in the Diagram Booklet.

(continued on the next page)

3. continued.

Find the speed of **P** immediately after receiving the impulse.

(Total for Question 3 is 5 marks)

4. Refer to the diagram for Question 4 in the Diagram Booklet.

Two smooth uniform spheres, A and B, have equal radii.

The mass of A is 3m and the mass of B is 4m

The spheres are moving on a smooth horizontal plane when they collide obliquely.

Immediately before they collide, A is moving with speed 3u at 30° to the line of centres of the spheres and B is moving with speed 2u at 30° to the line of centres of the spheres.

(continued on the next page)

4. continued.

The direction of motion of **B** is turned through an angle of 90° by the collision, as shown on the diagram in the Diagram Booklet.

(i) Find the size of the angle through which the direction of motion of **A** is turned as a result of the collision.

(ii) Find, in terms of **m** and **u**, the magnitude of the impulse received by **B** in the collision.

(Total for Question 4 is 9 marks)

5. Two particles, P and Q, are moving in opposite directions along the same straight line on a smooth horizontal surface when they collide directly.

The mass of P is 3m and the mass of Q is 4m

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

(continued on the next page)

5. continued.

The coefficient of restitution between P and Q is e

(a) Show that the speed of Q immediately after the collision is $\frac{u}{7}(9e + 2)$

(6 marks)

(continued on the next page)

5. continued.

After the collision with P, particle Q collides directly with a fixed vertical wall and rebounds. The wall is perpendicular to the direction of motion of Q

The coefficient of restitution between Q and the wall is $\frac{1}{2}$

(b) Find the complete range of possible values of e for which there is a second collision between P and Q

(4 marks)

(Total for Question 5 is 10 marks)

6. Refer to the diagram for Question 6 in the Diagram Booklet.

Two blocks, **A** and **B**, of masses **2 kg** and **4 kg** respectively are attached to the ends of a light inextensible string.

Initially **A** is held on a fixed rough plane.
The plane is inclined to horizontal ground at an angle θ, where $\tan\theta = \frac{3}{4}$

(continued on the next page)

6. continued.

The string passes over a small smooth light pulley P that is fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane.

Block A is held on the plane with the distance AP greater than 3 metres.

(continued on the next page)

6. continued.

Block B hangs freely below P at a distance of 3 metres above the ground, as shown on the diagram in the Diagram Booklet.

The coefficient of friction between A and the plane is μ

Block A is released from rest with the string taut.

(continued on the next page)

6. continued.

By modelling the blocks as particles,

(a) find the potential energy lost by the whole system as a result of B falling 3 metres.

(3 marks)

Given that the speed of B at the instant it hits the ground is $4 \cdot 5 \text{ m s}^{-1}$ and ignoring air resistance,

(b) use the work–energy principle to find the value of μ

(6 marks)

(continued on the next page)

6. continued.

After B hits the ground, A continues to move up the plane but does not reach the pulley in the subsequent motion.

Block A comes to instantaneous rest after moving a total distance of $(3 + d)$ metres from its point of release.

Ignoring air resistance,

(c) use the work–energy principle to find the value of d

(4 marks)

(Total for Question 6 is 13 marks)

7. A spring of natural length a has one end attached to a fixed point A The other end of the spring is attached to a package P of mass m

The package P is held at rest at the point B, which is vertically below A such that $AB = 3a$

After being released from rest at B, the package P first comes to instantaneous rest at A

(continued on the next page)

7. continued.

Air resistance is modelled as being negligible.

By modelling the spring as being light and modelling P as a particle,

(a) show that the modulus of elasticity of the spring is $2mg$

(5 marks)

(continued on the next page)

7. continued.

(b) (i) Show that P attains its maximum speed when the extension of the spring is $\frac{1}{2}a$

(ii) Use the principle of conservation of mechanical energy to find the maximum speed, giving your answer in terms of a and g

(6 marks)

(continued on the next page)

7. continued.

In reality, the spring is not light.

(c) State one way in which this would affect your energy equation in part (b)

(1 mark)

(Total for Question 7 is 12 marks)

8. Refer to the diagram for Question 8 in the Diagram Booklet.

It represents the plan view of part of a smooth horizontal floor, where RS and ST are smooth fixed vertical walls.

The vector $\overrightarrow{RS}$ is in the direction of $\underline{i}$ and the vector $\overrightarrow{ST}$ is in the direction of $(2\underline{i} + \underline{j})$

(continued on the next page)

8. continued.

A small ball **B** is projected across the floor towards **RS**

Immediately before the impact with **RS**, the velocity of **B** is $(6\underline{i} - 8\underline{j})\ \mathrm{m\,s^{-1}}$

The ball bounces off **RS** and then hits **ST**

The ball is modelled as a particle.

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8. continued.

Given that the coefficient of restitution between **B** and **RS** is **e**,

(a) find the full range of possible values of **e**

(3 marks)

(continued on the next page)

8. continued.

It is now given that $e = \frac{1}{4}$ and that the coefficient of restitution between **B** and **ST** is $\frac{1}{2}$

(b) Find, in terms of $\underline{\mathbf{i}}$ and $\underline{\mathbf{j}}$, the velocity of **B** immediately after its impact with **ST**

(7 marks)

(Total for Question 8 is 10 marks)

TOTAL FOR PAPER IS 75 MARKS

END OF PAPER
