



Oxford Cambridge and RSA

**Friday 17 May 2024 – Afternoon**

**AS Level Further Mathematics B (MEI)**

**Y411/01 Mechanics A**

**Time allowed: 1 hour 15 minutes**



**You must have:**

- the Printed Answer Booklet
- the Formulae Booklet for Further Mathematics B (MEI)
- a scientific or graphical calculator

**QP**

**INSTRUCTIONS**

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided in the **Printed Answer Booklet**. If you need extra space use the lined page at the end of the Printed Answer Booklet. The question numbers must be clearly shown.
- Fill in the boxes on the front of the Printed Answer Booklet.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.
- Give your final answers to a degree of accuracy that is appropriate to the context.
- The acceleration due to gravity is denoted by  $g \text{ ms}^{-2}$ . When a numerical value is needed use  $g = 9.8$  unless a different value is specified in the question.
- Do **not** send this Question Paper for marking. Keep it in the centre or recycle it.

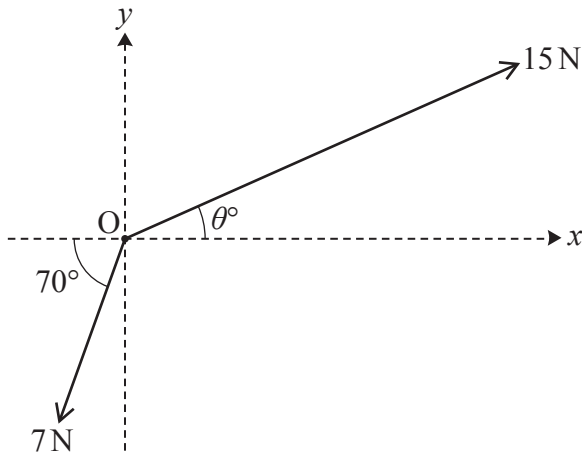
**INFORMATION**

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [ ].
- This document has **8** pages.

**ADVICE**

- Read each question carefully before you start your answer.

- 1** Two horizontal forces of magnitudes 7 N and 15 N act at a point O.  
The 15 N force acts an angle of  $\theta^\circ$  above the positive  $x$ -axis.  
The 7 N force acts at an angle of  $70^\circ$  below the negative  $x$ -axis (see diagram).



The resultant of the two forces acts only in the positive  $x$ -direction.

- (a) Calculate the value of  $\theta$ . [2]
- (b) Calculate the magnitude of the resultant of the two forces. [2]

- 2 (a) Find the dimensions of energy. [1]

The moment of inertia,  $I$ , of a rigid body rotating about a fixed axis is measured in  $\text{kg m}^2$ .

- (b) State the dimensions of  $I$ . [1]

The kinetic energy,  $E$ , of a rigid body rotating about a fixed axis is given by the formula

$$E = \frac{1}{2} I \omega^2,$$

where  $\omega$  is the angular velocity (angle per unit time) of the rigid body.

- (c) Show that the formula for  $E$  is dimensionally consistent. [2]

When a rigid body is pivoted from one of its end points and allowed to swing freely, it forms a pendulum. The period,  $t$ , of the pendulum is the time taken for it to complete one oscillation. A student conjectures the formula

$$t = k(mg)^\alpha r^\beta I^\gamma,$$

where

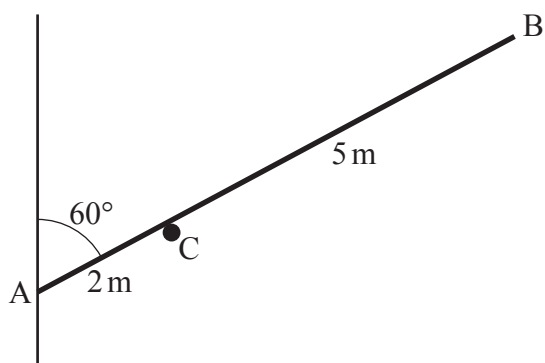
- $k$  is a dimensionless constant,
- $m$  is the mass of the rigid body,
- $g$  is the acceleration due to gravity,
- $r$  is the distance between the pivot point and the rigid body's centre of mass.

- (d) Use dimensional analysis to find the values of  $\alpha$ ,  $\beta$  and  $\gamma$ . [4]

The moment of inertia of a thin uniform rigid rod of mass 1.5 kg and length 0.8 m, rotating about one of its endpoints, is  $0.32 \text{ kg m}^2$ . The student suspends such a rod from one of its endpoints and allows it to swing freely. The student measures the period of this pendulum and finds that it is 1.47 seconds.

- (e) Using the formula conjectured by the student, determine the value of  $k$ . [3]

- 3 The diagram shows a uniform beam AB, of weight 80 N and length 7 m, resting in equilibrium in a vertical plane. The end A is in contact with a rough vertical wall, and the angle between the beam and the upward vertical is  $60^\circ$ . The beam is supported by a smooth peg at a point C, where  $AC = 2$  m.



- (a) Complete the diagram in the **Printed Answer Booklet** to show all the forces acting on the beam. [2]
- (b) (i) Show that the magnitude of the frictional force exerted on the beam by the wall is 25 N. [3]
- (ii) Hence determine the magnitude of the total contact force exerted on the beam by the wall. [3]
- (c) Determine the direction of the total contact force exerted on the beam by the wall. [2]

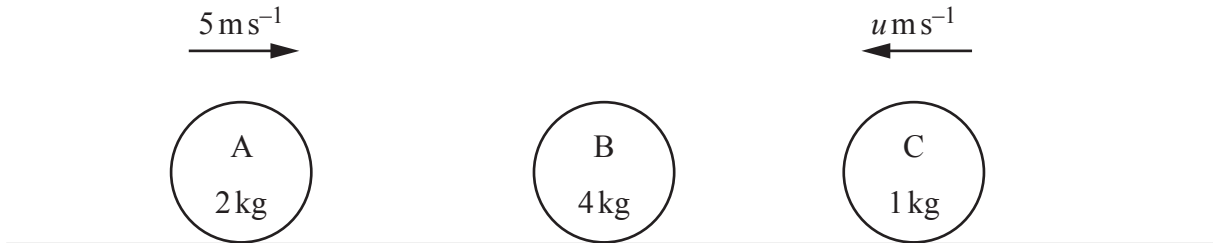
The coefficient of friction between the beam and the wall is  $\mu$ .

- (d) Find the range of possible values for  $\mu$ . [2]
- (e) Explain how your answer to part (b)(ii) would change if the peg were situated closer to A but the angle between the beam and the upward vertical remained at  $60^\circ$ . [1]

- 4 Three spheres A, B, and C, of equal radius are in the same straight line on a smooth horizontal surface. The masses of A, B and C are 2 kg, 4 kg and 1 kg respectively.

Initially the three spheres are at rest.

Spheres A and C are each given impulses so that A moves towards B with speed  $5 \text{ m s}^{-1}$  and C moves towards B with speed  $u \text{ m s}^{-1}$  as shown in the diagram below.



The coefficient of restitution between A and B is  $\frac{4}{5}$ .

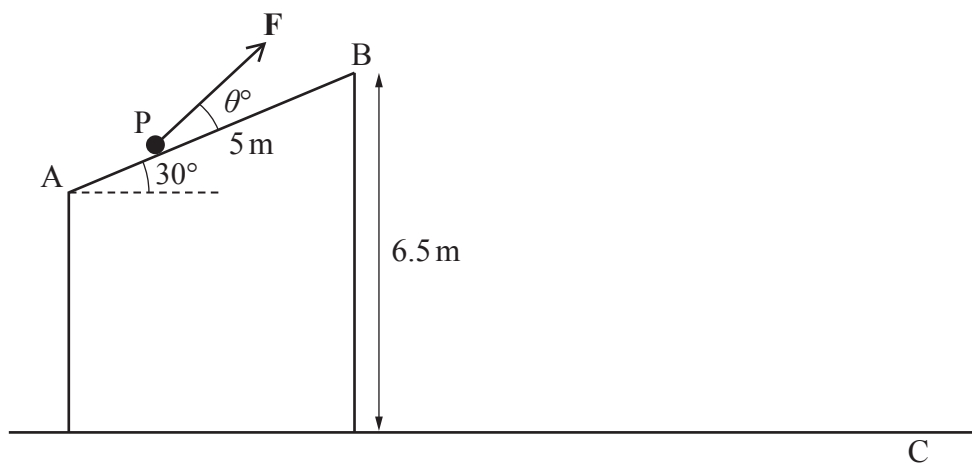
It is given that the first collision occurs between A and B.

- (a) State how you can tell from the information given above that kinetic energy is lost when A collides with B. [1]
- (b) Show that the combined kinetic energy of A and B decreases by 24% during their collision. [5]

Sphere B next collides with C. The coefficient of restitution between B and C is  $\frac{2}{3}$ .

- (c) Given that a third collision occurs, determine the range of possible values for  $u$ . [6]
- (d) State **one** limitation of the model used in this question. [1]

- 5 In the diagram below, points A, B and C lie in the same vertical plane. The slope AB is inclined at an angle of  $30^\circ$  to the horizontal and  $AB = 5$  m. The point B is a vertical distance of 6.5 m above horizontal ground. The point C lies on the horizontal ground.



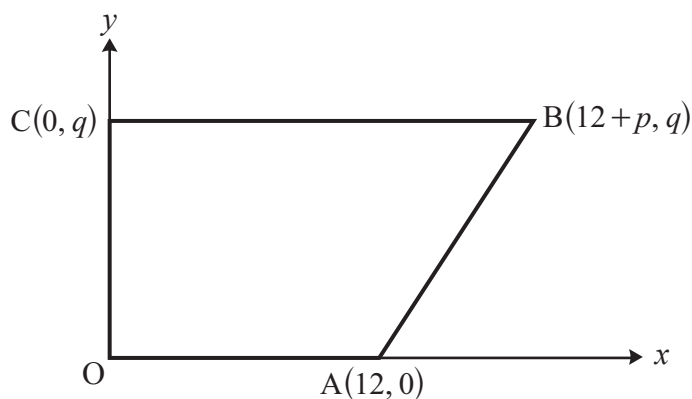
Starting at A, a particle P, of mass  $m$  kg, moves along the slope towards B, under the action of a constant force  $\mathbf{F}$ . The force  $\mathbf{F}$  has a magnitude of 50 N and acts at an angle of  $\theta^\circ$  to AB in the same vertical plane as A and B. When P reaches B,  $\mathbf{F}$  is removed, and P moves under gravity landing at C.

It is given that

- the speed of P at A is  $3 \text{ m s}^{-1}$ ,
- the speed of P at B is  $6 \text{ m s}^{-1}$ ,
- the speed of P at C is  $12 \text{ m s}^{-1}$ ,
- 58 J of work is done against non-gravitational resistances as P moves from A to B,
- 42 J of work is done against non-gravitational resistances as P moves from B to C.

- (a) By considering the motion from B to C, show that  $m = 4.33$  correct to 3 significant figures. [3]
- (b) By considering the motion from A to B, determine the value of  $\theta$ . [4]
- (c) Calculate the power of  $\mathbf{F}$  at the instant that P reaches B. [2]

- 6 A uniform lamina OABC is in the shape of a trapezium where O is the origin of the coordinate system in which the points A, B and C have coordinates  $(12, 0)$ ,  $(12 + p, q)$  and  $(0, q)$  respectively.



- (a) Determine, in terms of  $p$  and  $q$ , the coordinates of the centre of mass of OABC. [4]

The point D has coordinates  $(7.6, q)$ . When OABC is suspended from D, the lamina hangs in equilibrium with BC horizontal.

- (b) Determine the value of  $p$ . [3]

When OABC is suspended from C, the lamina hangs in equilibrium with BC at an angle of  $35^\circ$  to the downward vertical.

- (c) Determine the value of  $q$ , giving your answer correct to 3 significant figures. [3]

**END OF QUESTION PAPER**



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