

**Thursday 21 June 2012 – Afternoon**

**A2 GCE MATHEMATICS**

**4730**      Mechanics 3

**QUESTION PAPER**

Candidates answer on the Printed Answer Book.

**OCR supplied materials:**

- Printed Answer Book 4730
- List of Formulae (MF1)

**Other materials required:**

- Scientific or graphical calculator

**Duration:** 1 hour 30 minutes



**INSTRUCTIONS TO CANDIDATES**

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found in the centre of the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book.** Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Give non-exact numerical answers correct to 3 significant figures unless a different degree of accuracy is specified in the question or is clearly appropriate.
- The acceleration due to gravity is denoted by  $g \text{ m s}^{-2}$ . Unless otherwise instructed, when a numerical value is needed, use  $g = 9.8$ .

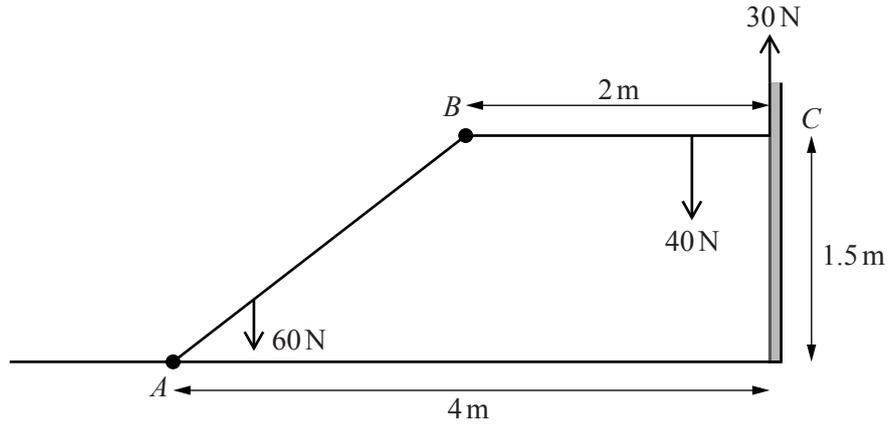
**INFORMATION FOR CANDIDATES**

- This information is the same on the Printed Answer Book and the Question Paper.
- The number of marks is given in brackets [ ] at the end of each question or part question on the Question Paper.
- **You are reminded of the need for clear presentation in your answers.**
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **8** pages. Any blank pages are indicated.

**INSTRUCTION TO EXAMS OFFICER/INVIGILATOR**

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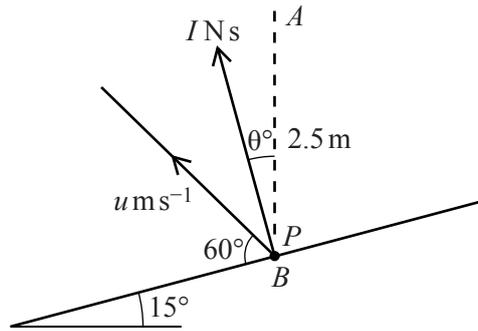
1



Two non-uniform rods  $AB$  and  $BC$  have weights  $60\text{ N}$  and  $40\text{ N}$  respectively. The rods are freely jointed to each other at  $B$ . The rod  $AB$  is freely jointed to a fixed point on horizontal ground at  $A$  and the rod  $BC$  rests against a vertical wall at  $C$ . The rod  $BC$ , whose length is  $2\text{ m}$ , is horizontal at a height of  $1.5\text{ m}$  above the ground. The point  $A$  is  $4\text{ m}$  from the wall. The frictional force exerted on  $BC$  at  $C$  has magnitude  $30\text{ N}$  (see diagram). The coefficient of friction between the rod  $BC$  and the wall is  $0.75$ .

- (i) Find the distance of the centre of mass of  $BC$  from  $B$ . [2]
- (ii) Given that the rod  $BC$  is on the point of slipping downwards at  $C$ , find the magnitude and direction of both the vertical component and the horizontal component of the force exerted on  $AB$  at  $B$ . [4]
- (iii) Find the distance of the centre of mass of  $AB$  from  $A$ . [3]

2



$B$  is a point on a smooth plane surface inclined at an angle of  $15^\circ$  to the horizontal. A particle  $P$  of mass  $0.45\text{ kg}$  is released from rest at the point  $A$  which is  $2.5\text{ m}$  vertically above  $B$ . The particle  $P$  rebounds from the surface at an angle of  $60^\circ$  to the line of greatest slope through  $B$ , with a speed of  $u\text{ m s}^{-1}$ . The impulse exerted on  $P$  by the surface has magnitude  $I\text{ N s}$  and is in a direction making an angle of  $\theta^\circ$  with the upward vertical through  $B$  (see diagram).

(i) Explain why  $\theta = 15$ . [1]

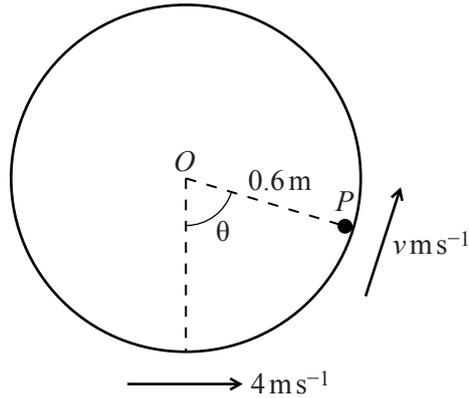
(ii) Find the values of  $u$  and  $I$ . [7]

3 A particle  $P$  of mass  $m\text{ kg}$  is released from rest and falls vertically. When  $P$  has fallen a distance of  $x\text{ m}$  it has a speed of  $v\text{ m s}^{-1}$ . The only forces acting on  $P$  are its weight and air resistance of magnitude  $\frac{1}{400}mv^2\text{ N}$ .

(i) Find  $v^2$  in terms of  $x$  and show that  $v^2$  must be less than  $3920$ . [8]

(ii) Find the speed of  $P$  when it has fallen  $100\text{ m}$ . [2]

4



A hollow cylinder is fixed with its axis horizontal. The inner surface of the cylinder is smooth and has radius  $0.6\text{ m}$ . A particle  $P$  of mass  $0.45\text{ kg}$  is projected horizontally with speed  $4\text{ m s}^{-1}$  from the lowest point of a vertical cross-section of the cylinder and moves in the plane of the cross-section, which is perpendicular to the axis of the cylinder. While  $P$  remains in contact with the surface, its speed is  $v\text{ m s}^{-1}$  when  $OP$  makes an angle  $\theta$  with the downward vertical at  $O$ , where  $O$  is the centre of the cross-section (see diagram). The force exerted on  $P$  by the surface is  $RN$ .

(i) Show that  $v^2 = 4.24 + 11.76 \cos \theta$  and find an expression for  $R$  in terms of  $\theta$ . [6]

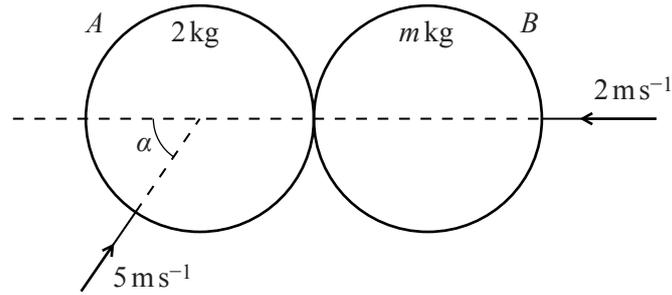
(ii) Find the speed of  $P$  at the instant when it leaves the surface. [4]

5 One end of a light elastic string, of natural length  $0.78\text{ m}$  and modulus of elasticity  $0.8\text{ mg N}$ , is attached to a fixed point  $O$  on a smooth plane inclined at angle  $\alpha$  to the horizontal, where  $\sin \alpha = \frac{5}{13}$ . A particle  $P$  of mass  $m\text{ kg}$  is attached to the other end of the string.  $P$  is released from rest at  $O$  and moves down the plane without reaching the bottom. Find

(i) the maximum speed of  $P$  in the subsequent motion, [6]

(ii) the distance of  $P$  from  $O$  when it is at its lowest point. [4]

6



Two smooth uniform spheres  $A$  and  $B$ , of equal radius, have masses  $2 \text{ kg}$  and  $m \text{ kg}$  respectively. They are moving on a horizontal surface when they collide. Immediately before the collision,  $A$  has speed  $5 \text{ m s}^{-1}$  and is moving towards  $B$  at an angle of  $\alpha$  to the line of centres, where  $\cos \alpha = 0.6$ .  $B$  has speed  $2 \text{ m s}^{-1}$  and is moving towards  $A$  along the line of centres (see diagram). As a result of the collision,  $A$ 's loss of kinetic energy is  $7.56 \text{ J}$ ,  $B$ 's direction of motion is reversed and  $B$ 's speed after the collision is  $0.8 \text{ m s}^{-1}$ . Find

- (i) the speed of  $A$  after the collision, [3]
- (ii) the component of  $A$ 's velocity after the collision, parallel to the line of centres, stating with a reason whether its direction is to the left or to the right, [3]
- (iii) the value of  $m$ , [3]
- (iv) the coefficient of restitution between  $A$  and  $B$ . [2]

7  $S_A$  and  $S_B$  are light elastic strings.  $S_A$  has natural length 2 m and modulus of elasticity 120 N;  $S_B$  has natural length 3 m and modulus of elasticity 180 N. A particle  $P$  of mass 0.8 kg is attached to one end of each of the strings. The other ends of  $S_A$  and  $S_B$  are attached to fixed points  $A$  and  $B$  respectively, on a smooth horizontal table. The distance  $AB$  is 6 m.  $P$  is released from rest at the point of the line segment  $AB$  which is 2.9 m from  $A$ .

(i) For the subsequent motion, show that the total elastic potential energy of the strings is the same when  $AP = 2.1$  m and when  $AP = 2.9$  m. Deduce that neither string becomes slack. [3]

(ii) Find, in terms of  $x$ , an expression for the acceleration of  $P$  in the direction of  $AB$  when  $AP = (2.5 + x)$  m. [3]

(iii) State, giving a reason, the type of motion of  $P$  and find the time taken between successive occasions when  $P$  is instantaneously at rest. [3]

For the instant 0.6 seconds after  $P$  is released, find

(iv) the distance travelled by  $P$ , [3]

(v) the speed of  $P$ . [2]

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