

# GCE Examinations

## Mechanics

### Module M1

Advanced Subsidiary / Advanced Level

Paper A

Time: 1 hour 30 minutes

#### *Instructions and Information*

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Candidates may use any calculator except those with a facility for symbolic algebra and/or calculus.

Full marks may be obtained for answers to ALL questions.

Mathematical and statistical formulae and tables are available.

This paper has 7 questions.

When a numerical value of  $g$  is required, use  $g = 9.8 \text{ m s}^{-2}$ .

#### *Advice to Candidates*

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You must show sufficient working to make your methods clear to an examiner. Answers without working will gain no credit.



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1. Two particles,  $P$  and  $Q$ , of mass  $2\text{ kg}$  and  $1.5\text{ kg}$  respectively are at rest on a smooth, horizontal surface. They are connected by a light, inelastic string which is initially slack. Particle  $P$  is projected away from  $Q$  with a speed of  $7\text{ ms}^{-1}$ .
- (a) Find the common speed of the particles after the string becomes taut. **(3 marks)**
- (b) Calculate the impulse in the string when it jerks tight. **(2 marks)**
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2. Particle  $A$  has velocity  $(8\mathbf{i} - 3\mathbf{j})\text{ ms}^{-1}$  and particle  $B$  has velocity  $(15\mathbf{i} - 8\mathbf{j})\text{ ms}^{-1}$  where  $\mathbf{i}$  and  $\mathbf{j}$  are perpendicular, horizontal unit vectors.
- (a) Find the speed of  $B$ . **(2 marks)**
- (b) Find the velocity of  $B$  relative to  $A$ . **(2 marks)**
- (c) Find the acute angle between the relative velocity found in part (b) and the vector  $\mathbf{i}$ , giving your answer in degrees correct to 1 decimal place. **(2 marks)**
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3.

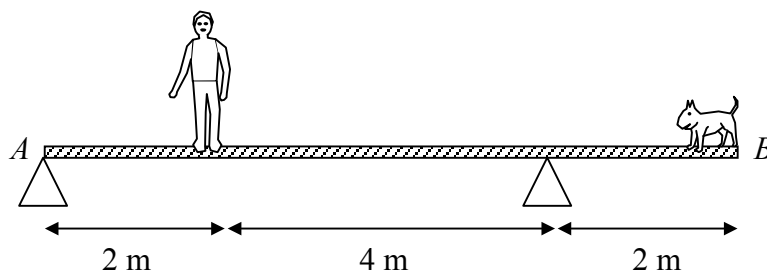


Fig. 1

Figure 1 shows a uniform plank  $AB$  of length  $8\text{ m}$  and mass  $30\text{ kg}$ . It is supported in a horizontal position by two pivots, one situated at  $A$  and the other  $2\text{ m}$  from  $B$ . A man whose mass is  $80\text{ kg}$  is standing on the plank  $2\text{ m}$  from  $A$  when his dog steps onto the plank at  $B$ .

Given that the plank remains in equilibrium and that the magnitude of the forces exerted by each of the pivots on the plank are equal,

- (a) calculate the magnitude of the force exerted on the plank by the pivot at  $A$ , **(5 marks)**
- (b) find the dog's mass. **(3 marks)**

If the dog was heavier and the plank was on the point of tilting,

- (c) explain how the force exerted on the plank by each of the pivots would be changed. **(2 marks)**
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4. A cyclist and her bicycle have a combined mass of 78 kg. While riding on level ground and using her greatest driving force, she is able to accelerate uniformly from rest to  $10 \text{ m s}^{-1}$  in 15 seconds against constant resistive forces that total 60 N.

(a) Show that her maximum driving force is 112 N. **(4 marks)**

The cyclist begins to ascend a hill, inclined at an angle  $\alpha$  to the horizontal, riding with her maximum driving force and against the same resistive forces. In this case, she is able to maintain a steady speed.

(b) Find the angle  $\alpha$ , giving your answer to the nearest degree. **(4 marks)**

(c) Comment on the assumption that the resistive force remains constant

(i) in the case when the cyclist is accelerating,

(ii) in the case when she is maintaining a steady speed. **(2 marks)**

5.

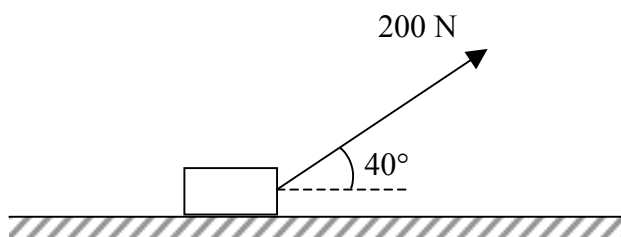


Fig. 2

Figure 2 shows a large block of mass 50 kg being pulled on rough horizontal ground by means of a rope attached to the block. The tension in the rope is 200 N and it makes an angle of  $40^\circ$  with the horizontal. Under these conditions, the block is on the point of moving.

Modelling the block as a particle,

(a) show that the coefficient of friction between the block and the ground is 0.424 correct to 3 significant figures. **(6 marks)**

The angle with the horizontal at which the rope is being pulled is reduced to  $30^\circ$ . Ignoring air resistance and assuming that the tension in the rope and the coefficient of friction remain unchanged,

(b) find the acceleration of the block. **(6 marks)**

*Turn over*

6. Anila is practising catching tennis balls. She uses a mobile computer-controlled machine which fires tennis balls vertically upwards from a height of 2.5 metres above the ground. Once it has fired a ball, the machine is programmed to move position rapidly to allow Anila time to get into a suitable position to catch the ball.

The machine fires a ball at  $24 \text{ m s}^{-1}$  vertically upwards and Anila catches the ball just before it touches the ground.

- (a) Draw a speed-time graph for the motion of the ball from the time it is fired by the machine to the instant before Anila catches it. **(3 marks)**
- (b) Find, to the nearest centimetre, the maximum height which the ball reaches above the ground. **(4 marks)**
- (c) Calculate the speed at which the ball is travelling when Anila catches it. **(4 marks)**
- (d) Calculate the length of time that the ball is in the air. **(3 marks)**
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7.

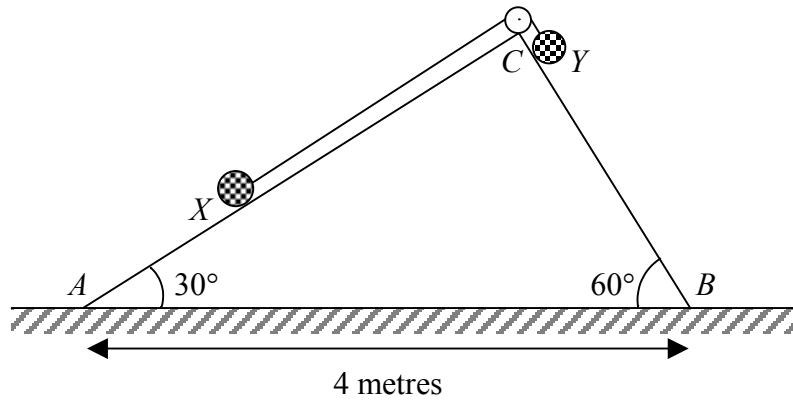


Fig. 3

Figure 3 shows a particle  $X$  of mass 3 kg on a smooth plane inclined at an angle  $30^\circ$  to the horizontal, and a particle  $Y$  of mass 2 kg on a smooth plane inclined at an angle  $60^\circ$  to the horizontal. The two particles are connected by a light, inextensible string of length 2.5 metres passing over a smooth pulley at  $C$  which is the highest point of the two planes.

Initially,  $Y$  is at a point just below  $C$  touching the pulley with the string taut. When the particles are released from rest they travel along the lines of greatest slope,  $AC$  in the case of  $X$  and  $BC$  in the case of  $Y$ , of their respective planes.  $A$  and  $B$  are the points where the planes meet the horizontal ground and  $AB = 4$  metres.

- (a) Show that the initial acceleration of the system is given by  $\frac{g}{10}(2\sqrt{3}-3) \text{ m s}^{-2}$ . **(7 marks)**
- (b) By finding the tension in the string, or otherwise, find the magnitude of the force exerted on the pulley and the angle that this force makes with the vertical. **(7 marks)**
- (c) Find, correct to 2 decimal places, the speed with which  $Y$  hits the ground. **(4 marks)**

**END**