GCE Examinations

Mechanics
Module M1

Advanced Subsidiary / Advanced Level

Paper A

Time: 1 hour 30 minutes

Instructions and Information

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

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 kg and 1.5 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 m s^{-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 $(8\mathbf{i} - 3\mathbf{j})$ m s^{-1} and particle B has velocity $(15\mathbf{i} - 8\mathbf{j})$ m s^{-1} where **i** and **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 **i**, giving your answer in degrees correct to 1 decimal place. **(2 marks)**

3.

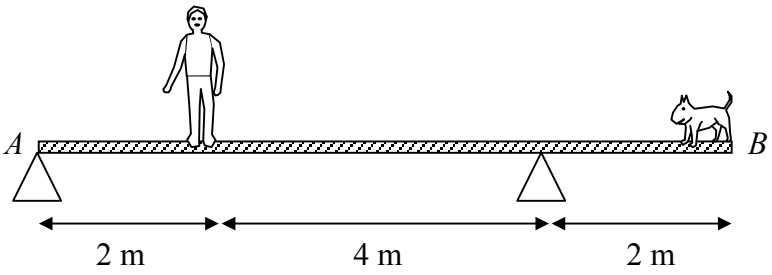


Fig. 1

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

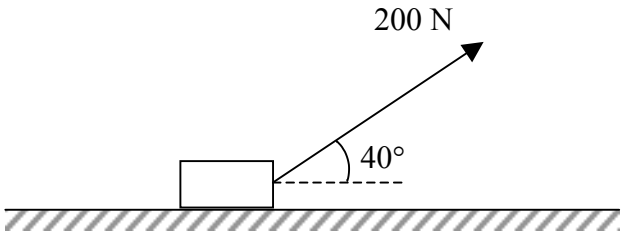


Fig. 2

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° 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°. 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

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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 $m s^{-1}$ 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.

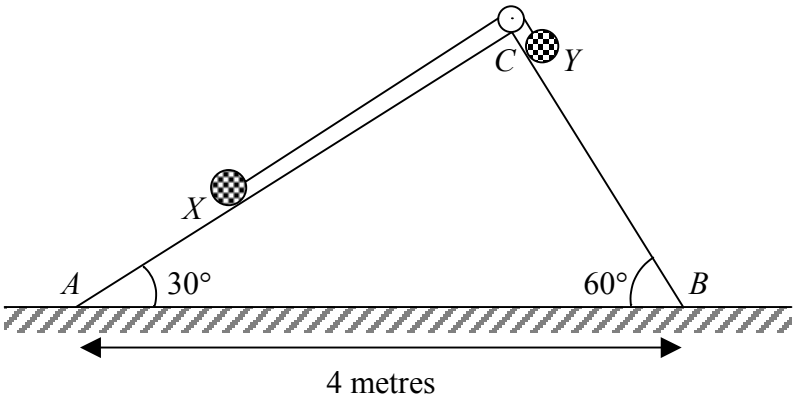


Fig. 3

Figure 3 shows a particle X of mass 3 kg on a smooth plane inclined at an angle 30° to the horizontal, and a particle Y of mass 2 kg on a smooth plane inclined at an angle 60° 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 $\frac{g}{10}\left(2\sqrt{3}-3\right)\ \text{m s}^{-2}$.

(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

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