GCE Examinations

Mechanics
Module M1

Advanced Subsidiary / Advanced Level

Paper E

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 8 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. Three forces ($^{-}5\mathbf{i} + 4p\mathbf{j}$) N, ($2q\mathbf{i} + 3\mathbf{j}$) N and ($\mathbf{i} + \mathbf{j}$) N act on a particle A of mass 2 kg.

Given that A is in equilibrium, find the values of p and q. **(4 marks)**

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2. An underground train accelerates uniformly from rest at station A to a velocity of 24 m s^{-1}. It maintains this speed for 84 seconds, until it decelerates uniformly to rest at station B. The total journey time is 116 seconds and the magnitudes of the acceleration and deceleration are equal.

(a) Find the time it takes the train to accelerate from rest to 24 m s^{-1}. **(2 marks)**

(b) Illustrate this information on a velocity-time graph. **(2 marks)**

(c) Using your graph, or otherwise, find the distance between the two stations. **(3 marks)**

3.

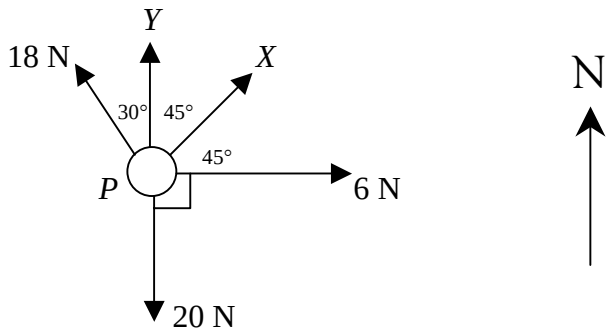

Fig. 1

Figure 1 shows the forces acting on a particle, P. These consist of a 20 N force to the South, a 6 N force to the East, an 18 N force 30° West of North and two unknown forces X and Y which act to the North-East and North respectively.

Given that P is in equilibrium,

(a) show that X has magnitude $3\sqrt{2}$ N, **(4 marks)**

(b) find the exact value of Y. **(4 marks)**

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4.

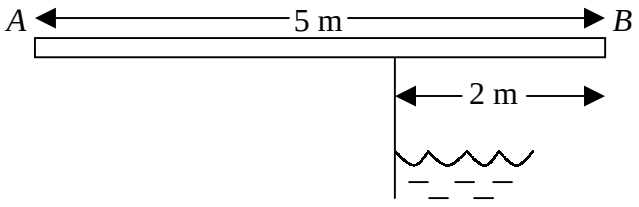

Fig. 2

Figure 2 shows a uniform plank *AB* of mass 50 kg and length 5 m which overhangs a river by 2 m. When a boy of mass 20 kg stands at *A*, his sister can walk to within 0.3 m of *B*, at which point the plank is in limiting equilibrium.

(a) What is the mass of the girl? **(4 marks)**

(b) Find the smallest extra weight which must be placed at *A* to enable the girl to walk right to the end *B*.

(3 marks)

(c) How have you used the fact that the plank is uniform? **(1 mark)**

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5. A cricket ball of mass 0.3 kg is approaching a batsman at $^{-}30\mathbf{i}$ m s^{-1}. The batsman hits the ball with a 1.5 kg bat moving with velocity $15\mathbf{i}$ m s^{-1}. Contact between bat and ball lasts for 0.2 seconds. Immediately after this, bat and ball move with velocities $5\mathbf{i}$ m s^{-1} and $v\mathbf{i}$ m s^{-1} respectively.

(a) Suggest a suitable model for the cricket ball. **(1 mark)**

(b) Calculate the value of *v*. **(4 marks)**

(c) Find the magnitude of the force with which the batsman hits the ball. **(3 marks)**

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6. A boy kicks a football vertically upwards from a height of 0.6 m above the ground with a speed of 10.5 m s^{-1}. The ball is modelled as a particle and air resistance is ignored.

(a) Find the greatest height above the ground reached by the ball. **(4 marks)**

(b) Calculate the length of time for which the ball is more than 2 m above the ground.

(6 marks)

Turn over

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7. A particle has an initial velocity of $(\mathbf{i} - 5\mathbf{j})$ m s^{-1} and is accelerating uniformly in the direction $(2\mathbf{i} + \mathbf{j})$ where **i** and **j** are perpendicular unit vectors.

Given that the magnitude of the acceleration is $3\sqrt{5}$ m s^{-2},

(a) show that, after t seconds, the velocity vector of the particle is

$$[(6t + 1)\mathbf{i} + (3t - 5)\mathbf{j}] \quad \text{m s}^{-1}\,. \qquad \textbf{(6 marks)}$$

(b) Using your answer to part *(a)*, or otherwise, find the value of t for which the speed of the particle is at its minimum.

(5 marks)

8.

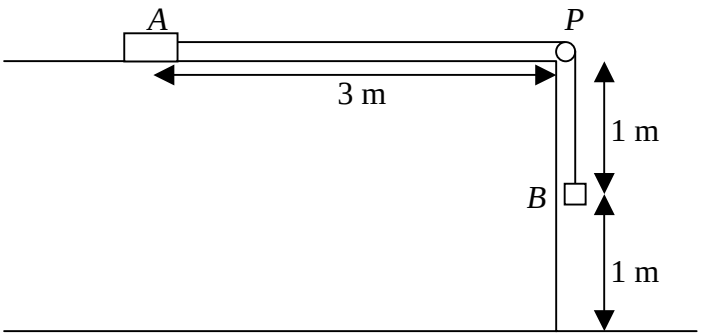

Fig. 3

Figure 3 shows two particles A and B, of mass $5M$ and $3M$ respectively, attached to the ends of a light inextensible string of length 4 m. The string passes over a smooth pulley which is fixed to the edge of a rough horizontal table 2 m high. Particle A lies on the table at a distance of 3 m from the pulley, whilst particle B hangs freely over the edge of the table 1 m above the ground. The coefficient of friction between A and the table is $\frac{3}{20}$.

The system is released from rest with the string taut.

(a) Show that the initial acceleration of the system is $\frac{9}{32}g$ m s^{-2}. **(8 marks)**

(b) Find, in terms of g, the speed of A immediately before B hits the ground. **(4 marks)**

When B hits the ground, it comes to rest and the string becomes slack.

(c) Calculate how far particle A is from the pulley when it comes to rest. **(7 marks)**

END

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