

Section A (36 marks)

- 1 Fig. 1 shows four forces acting at a point. The forces are in equilibrium.

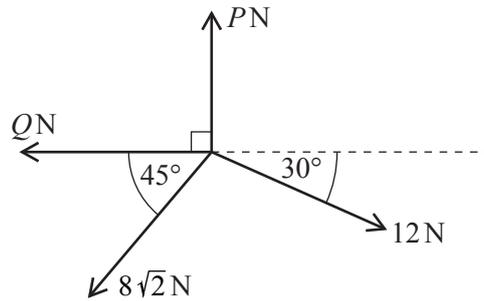


Fig. 1

Show that $P = 14$.

Find Q , giving your answer correct to 3 significant figures.

[5]

- 2 Fig. 2 shows a 6 kg block on a smooth horizontal table. It is connected to blocks of mass 2 kg and 9 kg by two light strings which pass over smooth pulleys at the edges of the table. The parts of the strings attached to the 6 kg block are horizontal.

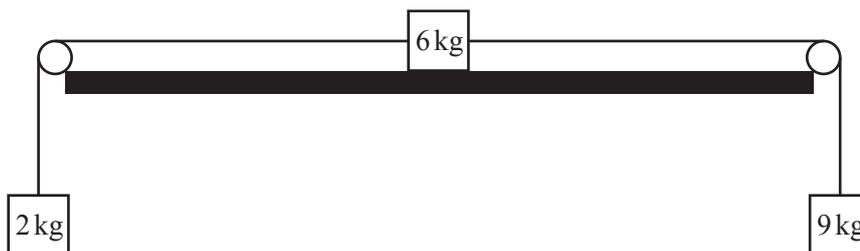


Fig. 2

(i) Draw three separate diagrams showing all the forces acting on each of the blocks.

[3]

(ii) Calculate the acceleration of the system and the tension in each string.

[5]

- 3 The map of a large area of open land is marked in 1 km squares and a point near the middle of the area is defined to be the origin. The vectors $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ are in the directions east and north.

At time t hours the position vectors of two hikers, Ashok and Kumar, are given by:

$$\text{Ashok} \quad \mathbf{r}_A = \begin{pmatrix} -2 \\ 0 \end{pmatrix} + \begin{pmatrix} 8 \\ 1 \end{pmatrix} t,$$

$$\text{Kumar} \quad \mathbf{r}_K = \begin{pmatrix} 7t \\ 10 - 4t \end{pmatrix}.$$

- (i) Prove that the two hikers meet and give the coordinates of the point where this happens. [4]
- (ii) Compare the speeds of the two hikers. [3]
- 4 Fig. 4 illustrates a straight horizontal road. A and B are points on the road which are 215 metres apart and M is the mid-point of AB.

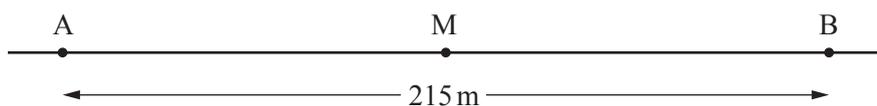


Fig. 4

- (i) Find the car's acceleration. [2]
- (ii) Find how long it takes the car to travel from A to B. [2]
- (iii) Find how long it takes the car to travel from A to M. [3]
- (iv) Explain briefly, in terms of the speed of the car, why the time taken to travel from A to M is more than half the time taken to travel from A to B. [1]
- 5 A golf ball is hit at an angle of 60° to the horizontal from a point, O, on level horizontal ground. Its initial speed is 20 ms^{-1} . The standard projectile model, in which air resistance is neglected, is used to describe the subsequent motion of the golf ball. At time t s the horizontal and vertical components of its displacement from O are denoted by x m and y m.
- (i) Write down equations for x and y in terms of t . [2]
- (ii) Hence show that the equation of the trajectory is
- $$y = \sqrt{3}x - 0.049x^2. \quad [2]$$
- (iii) Find the range of the golf ball. [2]
- (iv) A bird is hovering at position (20, 16).
Find whether the golf ball passes above it, passes below it or hits it. [2]

Section B (36 marks)

- 6 The battery on Carol and Martin's car is flat so the car will not start. They hope to be able to "bump start" the car by letting it run down a hill and engaging the engine when the car is going fast enough. Fig. 6.1 shows the road leading away from their house, which is at A. The road is straight, and at all times the car is steered directly along it.
- From A to B the road is horizontal.
 - Between B and C, it goes up a hill with a uniform slope of 1.5° to the horizontal.
 - Between C and D the road goes down a hill with a uniform slope of 3° to the horizontal. CD is 100 m. (This is the part of the road where they hope to get the car started.)
 - From D to E the road is again horizontal.

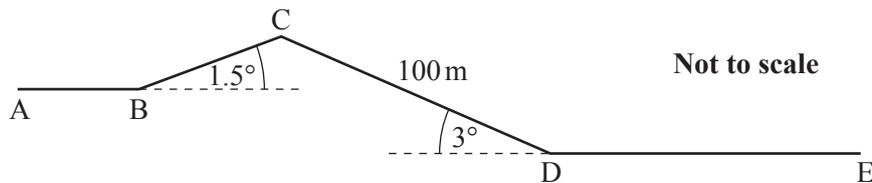


Fig. 6.1

The mass of the car is 750 kg, Carol's mass is 50 kg and Martin's mass is 80 kg.

Throughout the rest of this question, whenever Martin pushes the car, he exerts a force of 300 N along the line of the car.

- (i) Between A and B, Martin pushes the car and Carol sits inside to steer it. The car has an acceleration of 0.25 ms^{-2} .

Show that the resistance to the car's motion is 100 N. [3]

Throughout the rest of this question you should assume that the resistance to motion is constant at 100 N.

- (ii) They stop at B and then Martin tries to push the car up the hill BC.

Show that Martin cannot push the car up the hill with Carol inside it but can if she gets out.

Find the acceleration of the car when Martin is pushing it and Carol is standing outside. [6]

- (iii) While between B and C, Carol opens the window of the car and pushes it from outside while steering with one hand. Carol is able to exert a force of 150 N parallel to the surface of the road but at an angle of 30° to the line of the car. This is illustrated in Fig. 6.2.

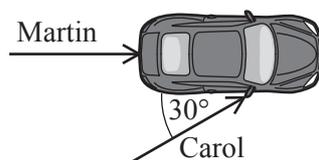


Fig. 6.2

Find the acceleration of the car. [4]

- (iv) At C, both Martin and Carol get in the car and, starting from rest, let it run down the hill under gravity. If the car reaches a speed of 8 ms^{-1} they can get the engine to start.

Does the car reach this speed before it reaches D? [5]

- 7 A box of emergency supplies is dropped to victims of a natural disaster from a stationary helicopter at height of 1000 metres. The initial velocity of the box is zero.

At time t s after being dropped, the acceleration, $a \text{ ms}^{-2}$, of the box in the vertically downwards direction is modelled by

$$a = 10 - t \quad \text{for } 0 \leq t \leq 10,$$

$$a = 0 \quad \text{for } t > 10.$$

- (i) Find an expression for the velocity, $v \text{ ms}^{-1}$, of the box in the vertically downwards direction in terms of t for $0 \leq t \leq 10$.

Show that for $t > 10$, $v = 50$. [4]

- (ii) Draw a sketch graph of v against t for $0 \leq t \leq 20$. [3]

- (iii) Show that the height, h m, of the box above the ground at time t s is given, for $0 \leq t \leq 10$, by

$$h = 1000 - 5t^2 + \frac{1}{6}t^3.$$

Find the height of the box when $t = 10$. [4]

- (iv) Find the value of t when the box hits the ground. [2]

- (v) Some of the supplies in the box are damaged when the box hits the ground. So measures are considered to reduce the speed with which the box hits the ground the next time one is dropped. Two different proposals are made. Carry out suitable calculations and then comment on each of them.

(A) The box should be dropped from a height of 500 m instead of 1000 m. [2]

(B) The box should be fitted with a parachute so that its acceleration is given by

$$a = 10 - 2t \quad \text{for } 0 \leq t \leq 5,$$

$$a = 0 \quad \text{for } t > 5. \quad \text{[3]}$$

END OF QUESTION PAPER

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