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1. A particle  $P$  of mass  $1.5 \text{ kg}$  is moving along a straight horizontal line with speed  $3 \text{ m s}^{-1}$ . Another particle  $Q$  of mass  $2.5 \text{ kg}$  is moving, in the opposite direction, along the same straight line with speed  $4 \text{ m s}^{-1}$ . The particles collide. Immediately after the collision the direction of motion of  $P$  is reversed and its speed is  $2.5 \text{ m s}^{-1}$ .

(a) Calculate the speed of  $Q$  immediately after the impact. (3)

(b) State whether or not the direction of motion of  $Q$  is changed by the collision. (1)

(c) Calculate the magnitude of the impulse exerted by  $Q$  on  $P$ , giving the units of your answer. (3)

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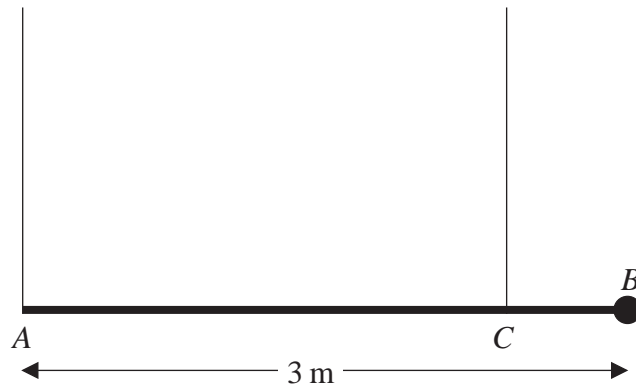
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2.

**Figure 1**



A plank  $AB$  has mass 40 kg and length 3 m. A load of mass 20 kg is attached to the plank at  $B$ . The loaded plank is held in equilibrium, with  $AB$  horizontal, by two vertical ropes attached at  $A$  and  $C$ , as shown in Figure 1. The plank is modelled as a uniform rod and the load as a particle. Given that the tension in the rope at  $C$  is three times the tension in the rope at  $A$ , calculate

(a) the tension in the rope at  $C$ , (2)

(b) the distance  $CB$ . (5)

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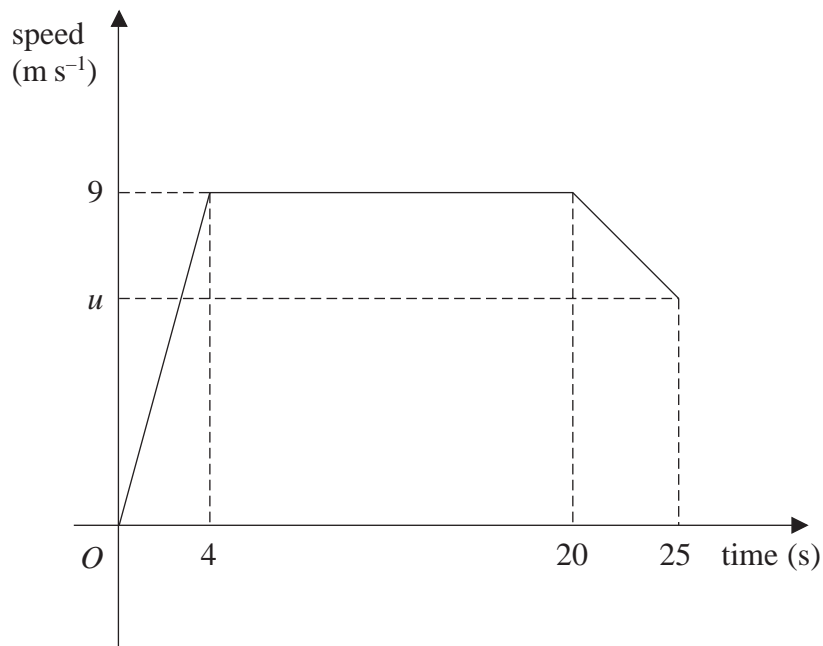
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3.

Figure 2



A sprinter runs a race of 200 m. Her total time for running the race is 25 s. Figure 2 is a sketch of the speed-time graph for the motion of the sprinter. She starts from rest and accelerates uniformly to a speed of  $9 \text{ m s}^{-1}$  in 4 s. The speed of  $9 \text{ m s}^{-1}$  is maintained for 16 s and she then decelerates uniformly to a speed of  $u \text{ m s}^{-1}$  at the end of the race. Calculate

- (a) the distance covered by the sprinter in the first 20 s of the race, (2)
  
- (b) the value of  $u$ , (4)
  
- (c) the deceleration of the sprinter in the last 5 s of the race. (3)

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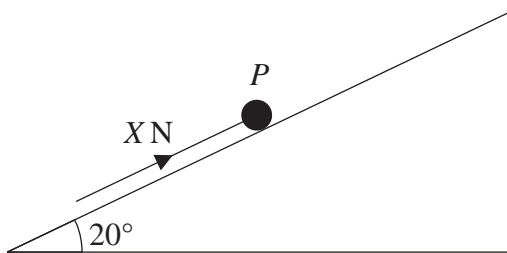
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Figure 3



A particle  $P$  of mass  $2.5$  kg rests in equilibrium on a rough plane under the action of a force of magnitude  $X$  newtons acting up a line of greatest slope of the plane, as shown in Figure 3. The plane is inclined at  $20^\circ$  to the horizontal. The coefficient of friction between  $P$  and the plane is  $0.4$ . The particle is in limiting equilibrium and is on the point of moving up the plane. Calculate

(a) the normal reaction of the plane on  $P$ , (2)

(b) the value of  $X$ . (4)

The force of magnitude  $X$  newtons is now removed.

(c) Show that  $P$  remains in equilibrium on the plane. (4)

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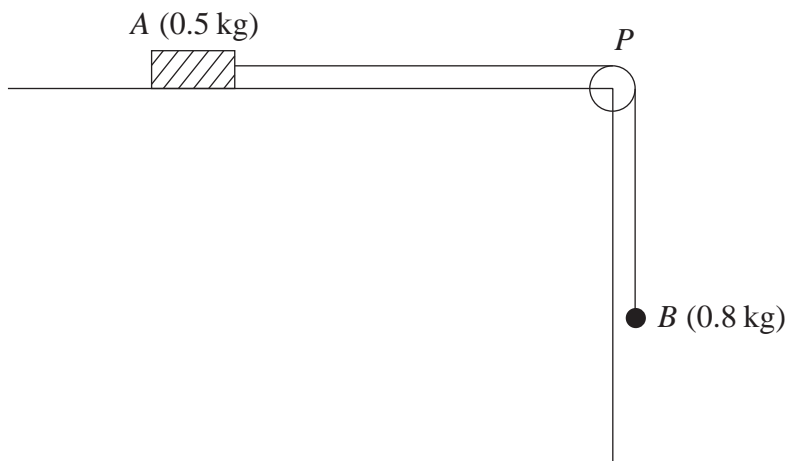
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Figure 4



A block of wood  $A$  of mass  $0.5\text{ kg}$  rests on a rough horizontal table and is attached to one end of a light inextensible string. The string passes over a small smooth pulley  $P$  fixed at the edge of the table. The other end of the string is attached to a ball  $B$  of mass  $0.8\text{ kg}$  which hangs freely below the pulley, as shown in Figure 4. The coefficient of friction between  $A$  and the table is  $\mu$ . The system is released from rest with the string taut. After release,  $B$  descends a distance of  $0.4\text{ m}$  in  $0.5\text{ s}$ . Modelling  $A$  and  $B$  as particles, calculate

- (a) the acceleration of  $B$ , (3)
- (b) the tension in the string, (4)
- (c) the value of  $\mu$ . (5)
- (d) State how in your calculations you have used the information that the string is inextensible. (1)

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**Question 5 continued**

A series of horizontal lines for writing an answer.

**Q5**

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**(Total 13 marks)**

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6. A stone  $S$  is sliding on ice. The stone is moving along a straight horizontal line  $ABC$ , where  $AB = 24\text{ m}$  and  $AC = 30\text{ m}$ . The stone is subject to a constant resistance to motion of magnitude  $0.3\text{ N}$ . At  $A$  the speed of  $S$  is  $20\text{ m s}^{-1}$ , and at  $B$  the speed of  $S$  is  $16\text{ m s}^{-1}$ . Calculate

(a) the deceleration of  $S$ , (2)

(b) the speed of  $S$  at  $C$ . (3)

(c) Show that the mass of  $S$  is  $0.1\text{ kg}$ . (2)

At  $C$ , the stone  $S$  hits a vertical wall, rebounds from the wall and then slides back along the line  $CA$ . The magnitude of the impulse of the wall on  $S$  is  $2.4\text{ N s}$  and the stone continues to move against a constant resistance of  $0.3\text{ N}$ .

(d) Calculate the time between the instant that  $S$  rebounds from the wall and the instant that  $S$  comes to rest. (6)

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7. Two ships  $P$  and  $Q$  are travelling at night with constant velocities. At midnight,  $P$  is at the point with position vector  $(20\mathbf{i} + 10\mathbf{j})$  km relative to a fixed origin  $O$ . At the same time,  $Q$  is at the point with position vector  $(14\mathbf{i} - 6\mathbf{j})$  km. Three hours later,  $P$  is at the point with position vector  $(29\mathbf{i} + 34\mathbf{j})$  km. The ship  $Q$  travels with velocity  $12\mathbf{j}$  km  $\text{h}^{-1}$ . At time  $t$  hours after midnight, the position vectors of  $P$  and  $Q$  are  $\mathbf{p}$  km and  $\mathbf{q}$  km respectively. Find

(a) the velocity of  $P$ , in terms of  $\mathbf{i}$  and  $\mathbf{j}$ , (2)

(b) expressions for  $\mathbf{p}$  and  $\mathbf{q}$ , in terms of  $t$ ,  $\mathbf{i}$  and  $\mathbf{j}$ . (4)

At time  $t$  hours after midnight, the distance between  $P$  and  $Q$  is  $d$  km.

(c) By finding an expression for  $\overrightarrow{PQ}$ , show that

$$d^2 = 25t^2 - 92t + 292. \quad (5)$$

Weather conditions are such that an observer on  $P$  can only see the lights on  $Q$  when the distance between  $P$  and  $Q$  is 15 km or less. Given that when  $t = 1$ , the lights on  $Q$  move into sight of the observer,

(d) find the time, to the nearest minute, at which the lights on  $Q$  move out of sight of the observer. (5)

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