

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

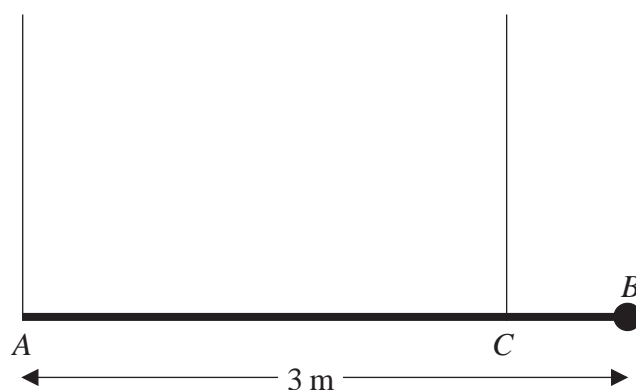
(a) Calculate the speed of Q immediately after the impact. (3)

(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)

2.

Figure 1



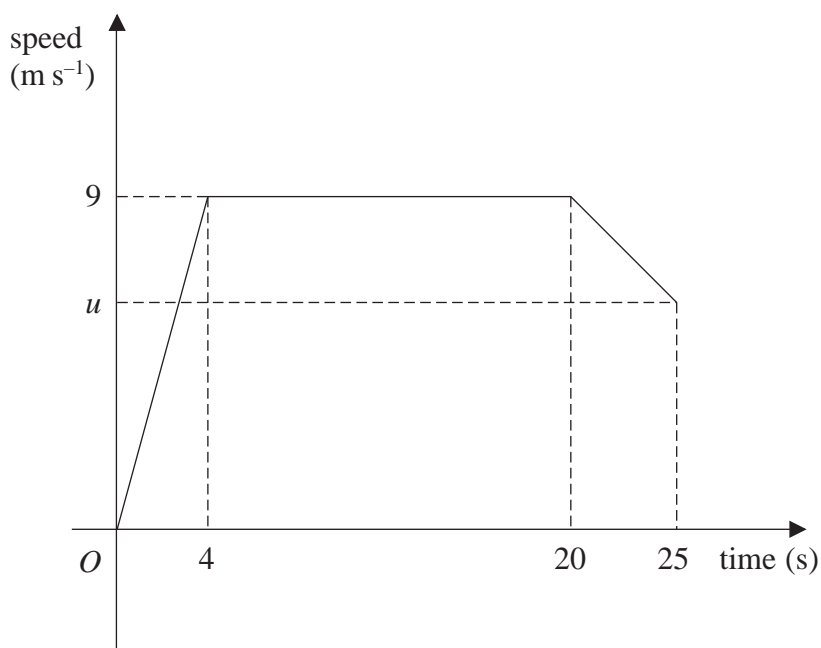
A plank AB has mass 40 kg and length 3 m. A load of mass 20 kg is attached to the plank at B . The loaded plank is held in equilibrium, with AB horizontal, by two vertical ropes attached at A and C , as shown in Figure 1. The plank is modelled as a uniform rod and the load as a particle. Given that the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

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 m s^{-1} in 4 s. The speed of 9 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

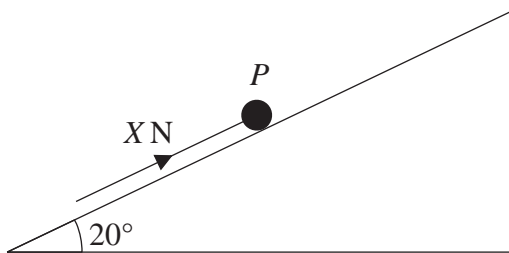
- (a) the distance covered by the sprinter in the first 20 s of the race, (2)

- (b) the value of u , (4)

- (c) the deceleration of the sprinter in the last 5 s of the race. (3)

4.

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° 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)

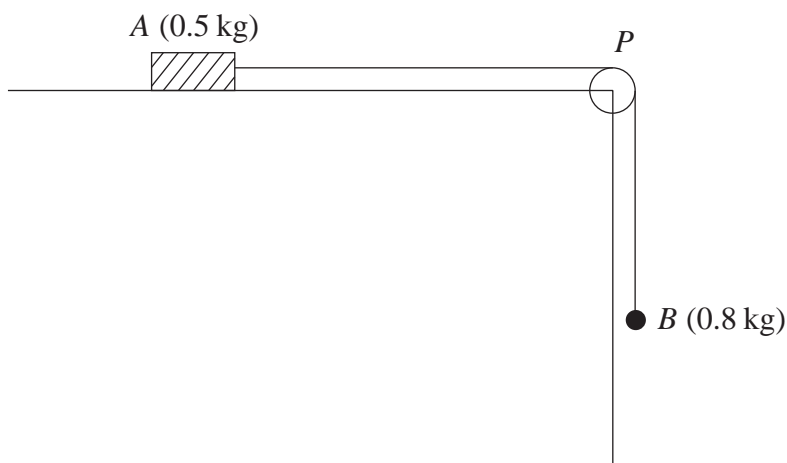
(b) the value of X . (4)

The force of magnitude X newtons is now removed.

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

5.

Figure 4



A block of wood A of mass 0.5 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 kg which hangs freely below the pulley, as shown in Figure 4. The coefficient of friction between A and the table is μ . The system is released from rest with the string taut. After release, B descends a distance of 0.4 m in 0.5 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 μ . (5)
- (d) State how in your calculations you have used the information that the string is inextensible. (1)

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 N . At A the speed of S is 20 m s^{-1} , and at B the speed of S is 16 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 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 Ns and the stone continues to move against a constant resistance of 0.3 N .

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

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 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 \vec{PQ} , show that

$$d^2 = 25t^2 - 92t + 292. \tag{5}$$

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)
