

# Mechanics-M1 - 2012-June

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## Question 1

Two particles  $A$  and  $B$ , of mass  $5m$  kg and  $2m$  kg respectively, are moving in opposite directions along the same straight horizontal line. The particles collide directly. Immediately before the collision, the speeds of  $A$  and  $B$  are  $3 \text{ m s}^{-1}$  and  $4 \text{ m s}^{-1}$  respectively. The direction of motion of  $A$  is unchanged by the collision. Immediately after the collision, the speed of  $A$  is  $0.8 \text{ m s}^{-1}$ .

- (a) Find the speed of  $B$  immediately after the collision. (3)

In the collision, the magnitude of the impulse exerted on  $A$  by  $B$  is  $3.3 \text{ N s}$ .

- (b) Find the value of  $m$ . (3)
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## Question 2

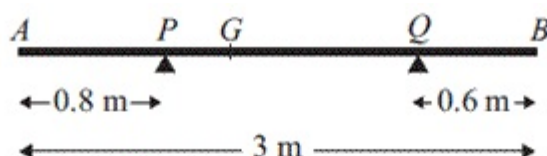


Figure 1

A non-uniform rod  $AB$  has length  $3 \text{ m}$  and mass  $4.5 \text{ kg}$ . The rod rests in equilibrium, in a horizontal position, on two smooth supports at  $P$  and at  $Q$ , where  $AP = 0.8 \text{ m}$  and  $QB = 0.6 \text{ m}$ , as shown in Figure 1. The centre of mass of the rod is at  $G$ . Given that the magnitude of the reaction of the support at  $P$  on the rod is twice the magnitude of the reaction of the support at  $Q$  on the rod, find

- (a) the magnitude of the reaction of the support at  $Q$  on the rod, (3)
- (b) the distance  $AG$ . (4)
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### Question 3

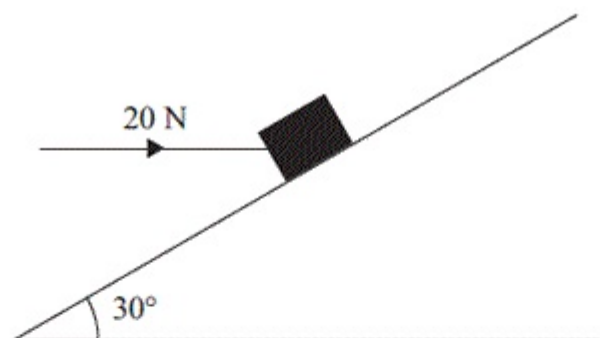


Figure 2

A box of mass  $5\text{ kg}$  lies on a rough plane inclined at  $30^\circ$  to the horizontal. The box is held in equilibrium by a horizontal force of magnitude  $20\text{ N}$ , as shown in Figure 2. The force acts in a vertical plane containing a line of greatest slope of the inclined plane. The box is in equilibrium and on the point of moving down the plane. The box is modelled as a particle.

Find

- (a) the magnitude of the normal reaction of the plane on the box, (4)
- (b) the coefficient of friction between the box and the plane. (5)

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### Question 4

A car is moving on a straight horizontal road. At time  $t = 0$ , the car is moving with speed  $20\text{ m s}^{-1}$  and is at the point  $A$ . The car maintains the speed of  $20\text{ m s}^{-1}$  for  $25\text{ s}$ . The car then moves with constant deceleration  $0.4\text{ m s}^{-2}$ , reducing its speed from  $20\text{ m s}^{-1}$  to  $8\text{ m s}^{-1}$ . The car then moves with constant speed  $8\text{ m s}^{-1}$  for  $60\text{ s}$ . The car then moves with constant acceleration until it is moving with speed  $20\text{ m s}^{-1}$  at the point  $B$ .

- (a) Sketch a speed-time graph to represent the motion of the car from  $A$  to  $B$ . (3)
- (b) Find the time for which the car is decelerating. (2)

Given that the distance from  $A$  to  $B$  is  $1960\text{ m}$ ,

- (c) find the time taken for the car to move from  $A$  to  $B$ . (8)
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## Question 5

A particle  $P$  is projected vertically upwards from a point  $A$  with speed  $u \text{ m s}^{-1}$ . The point  $A$  is 17.5 m above horizontal ground. The particle  $P$  moves freely under gravity until it reaches the ground with speed  $28 \text{ m s}^{-1}$ .

- (a) Show that  $u = 21$  (3)

At time  $t$  seconds after projection,  $P$  is 19 m above  $A$ .

- (b) Find the possible values of  $t$ . (5)

The ground is soft and, after  $P$  reaches the ground,  $P$  sinks vertically downwards into the ground before coming to rest. The mass of  $P$  is 4 kg and the ground is assumed to exert a constant resistive force of magnitude 5000 N on  $P$ .

- (c) Find the vertical distance that  $P$  sinks into the ground before coming to rest. (4)
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## Question 6

[In this question  $\mathbf{i}$  and  $\mathbf{j}$  are horizontal unit vectors due east and due north respectively and position vectors are given with respect to a fixed origin.]

A ship  $S$  is moving with constant velocity  $(-12\mathbf{i} + 7.5\mathbf{j}) \text{ km h}^{-1}$ .

- (a) Find the direction in which  $S$  is moving, giving your answer as a bearing. (3)

At time  $t$  hours after noon, the position vector of  $S$  is  $\mathbf{s}$  km. When  $t = 0$ ,  $\mathbf{s} = 40\mathbf{i} - 6\mathbf{j}$ .

- (b) Write down  $\mathbf{s}$  in terms of  $t$ . (2)

A fixed beacon  $B$  is at the point with position vector  $(7\mathbf{i} + 12.5\mathbf{j}) \text{ km}$ .

- (c) Find the distance of  $S$  from  $B$  when  $t = 3$  (4)

- (d) Find the distance of  $S$  from  $B$  when  $S$  is due north of  $B$ . (4)
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## Question 7



Figure 3

Two particles  $P$  and  $Q$ , of mass 0.3 kg and 0.5 kg respectively, are joined by a light horizontal rod. The system of the particles and the rod is at rest on a horizontal plane. At time  $t = 0$ , a constant force  $F$  of magnitude 4 N is applied to  $Q$  in the direction  $PQ$ , as shown in Figure 3. The system moves under the action of this force until  $t = 6$  s. During the motion, the resistance to the motion of  $P$  has constant magnitude 1 N and the resistance to the motion of  $Q$  has constant magnitude 2 N.

Find

- (a) the acceleration of the particles as the system moves under the action of  $F$ , (3)
- (b) the speed of the particles at  $t = 6$  s, (2)
- (c) the tension in the rod as the system moves under the action of  $F$ . (3)

At  $t = 6$  s,  $F$  is removed and the system decelerates to rest. The resistances to motion are unchanged. Find

- (d) the distance moved by  $P$  as the system decelerates, (4)
  - (e) the thrust in the rod as the system decelerates. (3)
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