1 Fig. 5 shows a block of mass 10 kg at rest on a rough horizontal floor. A light string, at an angle of 30° to the vertical, is attached to the block. The tension in the string is 50 N.

The block is in equilibrium.

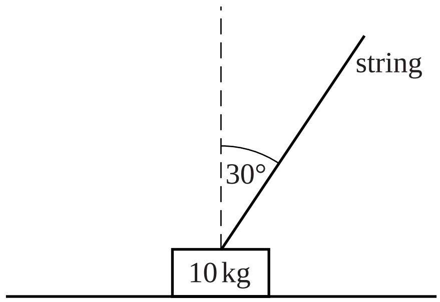

Fig. 5

(i) Show all the forces acting on the block. **[2]**

(ii) Show that the frictional force acting on the block is 25 N. **[2]**

(iii) Calculate the normal reaction of the floor on the block. **[2]**

(iv) Calculate the magnitude of the total force the floor is exerting on the block. **[2]**

2 In this question, positions are given relative to a fixed origin, O. The x-direction is east and the y-direction north; distances are measured in kilometres.

Two boats, the *Rosemary* and the *Sage*, are having a race between two points A and B.

The position vector of the *Rosemary* at time t hours after the start is given by

$$\mathbf{r} = \begin{pmatrix} 3 \\ 2 \end{pmatrix} + \begin{pmatrix} 6 \\ 8 \end{pmatrix} t, \text{ where } 0 \leqslant t \leqslant 2 .$$

The *Rosemary* is at point A when $t = 0$, and at point B when $t = 2$.

(i) Find the distance AB. **[3]**

(ii) Show that the *Rosemary* travels at constant velocity. **[1]**

The position vector of the *Sage* is given by

$$\mathbf{r} = \begin{pmatrix} 3(2t + 1) \\ 2(2t^2 + 1) \end{pmatrix}.$$

(iii) Plot the points A and B.

Draw the paths of the two boats for $0 \leqslant t \leqslant 2$. **[3]**

(iv) What can you say about the result of the race? **[1]**

(v) Find the speed of the *Sage* when $t = 2$. Find also the direction in which it is travelling, giving your answer as a compass bearing, to the nearest degree. **[6]**

(vi) Find the displacement of the *Rosemary* from the *Sage* at time t and hence calculate the greatest distance between the boats during the race. **[4]**

3 Fig. 2 shows a sack of rice of weight 250 N hanging in equilibrium supported by a light rope AB. End A of the rope is attached to the sack. The rope passes over a small smooth fixed pulley.

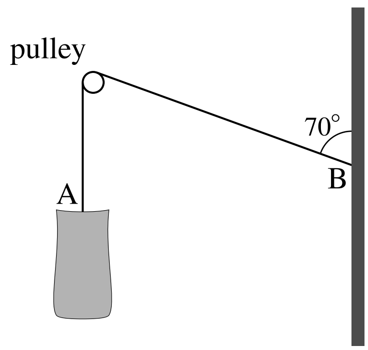

Fig. 2

Initially, end B of the rope is attached to a vertical wall as shown in Fig. 2.

(i) Calculate the horizontal and the vertical forces acting on the wall due to the rope. **[3]**

End B of the rope is now detached from the wall and attached instead to the top of the sack. The sack is in equilibrium with both sections of the rope vertical.

(ii) Calculate the tension in the rope. **[1]**

4 As shown in Fig. 4, boxes P and Q are descending vertically supported by a parachute. Box P has mass 75 kg. Box Q has mass 25 kg and hangs from box P by means of a light vertical wire. Air resistance on the boxes should be neglected.

At one stage the boxes are slowing in their descent with the parachute exerting an upward vertical force of 1030 N on box P. The acceleration of the boxes is a m s^{-2} upwards and the tension in the wire is T N.

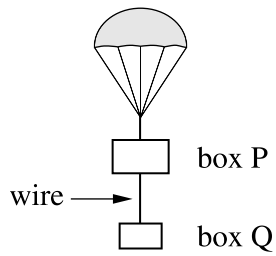

Fig. 4

(i) Draw a labelled diagram showing all the forces acting on box P and another diagram showing all the forces acting on box Q. **[2]**

(ii) Write down separate equations of motion for box P and for box Q. **[3]**

(iii) Calculate the tension in the wire. **[2]**

5 A cylindrical tub of mass 250 kg is on a horizontal floor. Resistance to its motion other than that due to friction is negligible.

The first attempt to move the tub is by pulling it with a force of 150 N in the **i** direction, as shown in Fig. 8.1.

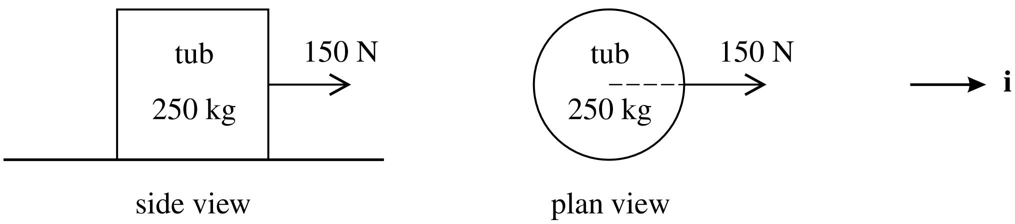

Fig. 5.1

(i) Calculate the acceleration of the tub if friction is ignored. **[2]**

In fact, there is friction and the tub does not move.

(ii) Write down the magnitude and direction of the frictional force opposing the pull. **[2]**

Two more forces are now added to the 150 N force in a second attempt to move the tub, as shown in Fig. 8.2.

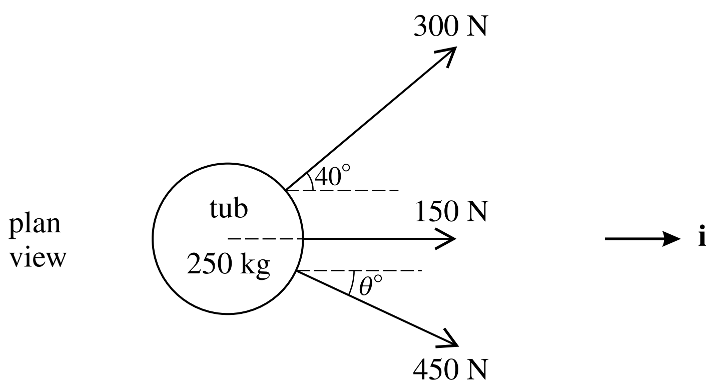

Fig. 5.2

Angle θ is acute and chosen so that the resultant of the three forces is in the **i** direction.

(iii) Determine the value of θ and the resultant of the three forces. **[6]**

With this resultant force, the tub moves with constant acceleration and travels 1 metre from rest in 2 seconds.

(iv) Show that the magnitude of the friction acting on the tub is 661 N, correct to 3 significant figures. **[5]**

When the speed of the tub is 1.8 m s^{-1}, it comes to a part of the floor where the friction on the tub is 200 N greater. The pulling forces stay the same.

(v) Find the velocity of the tub when it has moved a further 1.65 m. **[5]**

6 An empty open box of mass 4 kg is on a plane that is inclined at 25° to the horizontal.

In one model the plane is taken to be smooth.

The box is held in equilibrium by a string with tension T N parallel to the plane, as shown in Fig. 6.1.

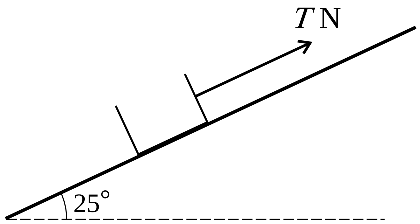

Fig. 6.1

(i) Calculate T. **[2]**

A rock of mass m kg is now put in the box. The system is in equilibrium when the tension in the string, still parallel to the plane, is 50 N.

(ii) Find m. **[3]**

In a refined model the plane is rough.

The empty box, of mass 4 kg, is in equilibrium when a frictional force of 20 N acts down the plane and the string has a tension of P N inclined at 15° to the plane, as shown in Fig. 6.2.

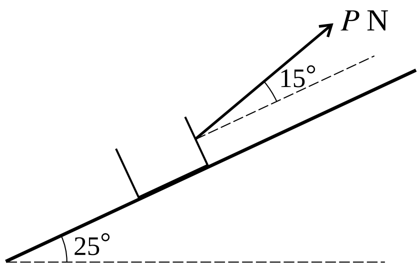

Fig. 6.2

(iii) Draw a diagram showing all the forces acting on the box. **[2]**

(iv) Calculate P. **[5]**

(v) Calculate the normal reaction of the plane on the box. **[4]**