1   Fig. 1.1 shows a circular cylinder of mass 100 kg being raised by a light, inextensible vertical wire AB. There is negligible air resistance.
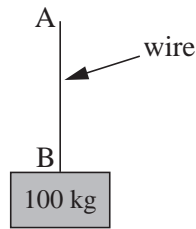

Fig. 1.1

   (i) Calculate the acceleration of the cylinder when the tension in the wire is 1000 N.   [3]

   (ii) Calculate the tension in the wire when the cylinder has an upward acceleration of $0.8\,\mathrm{m\,s^{-2}}$.   [2]

The cylinder is now raised inside a fixed smooth vertical tube that prevents horizontal motion but provides negligible resistance to the upward motion of the cylinder. When the wire is inclined at $30°$ to the vertical, as shown in Fig. 1.2, the cylinder again has an upward acceleration of $0.8\,\mathrm{m\,s^{-2}}$.

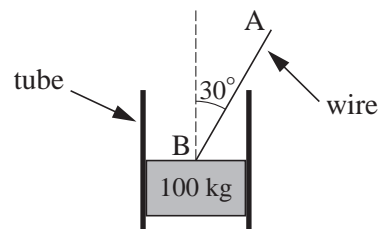
Fig. 1.2

   (iii) Calculate the new tension in the wire.   [3]

2   Boxes A and B slide on a smooth, horizontal plane. Box A has a mass of 4 kg and box B a mass of 5 kg. They are connected by a light, inextensible, horizontal wire. Horizontal forces of 9 N and 135 N act on A and B in the directions shown in Fig. 5.
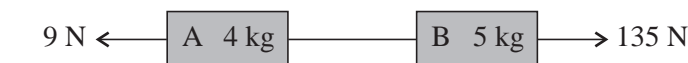

Fig. 5

   Calculate the tension in the wire joining the boxes.   [4]

3   Fig. 3 shows a system in equilibrium. The rod is firmly attached to the floor and also to an object, P. The light string is attached to P and passes over a smooth pulley with an object Q hanging freely from its other end.
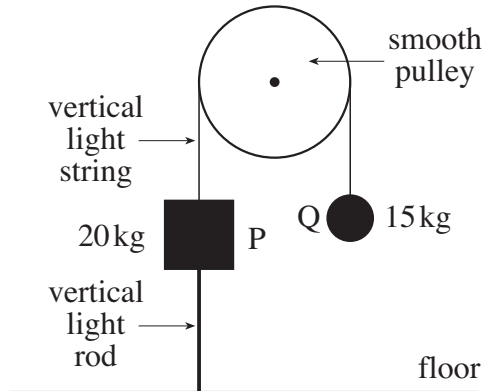

Fig. 3

  (i) Why is the tension the same throughout the string? [1]

  (ii) Calculate the force in the rod, stating whether it is a tension or a thrust. [3]

4   Two trucks, A and B, each of mass 10 000 kg, are pulled along a straight, horizontal track by a constant, horizontal force of P N. The coupling between the trucks is light and horizontal. This situation and the resistances to motion of the trucks are shown in Fig. 4.
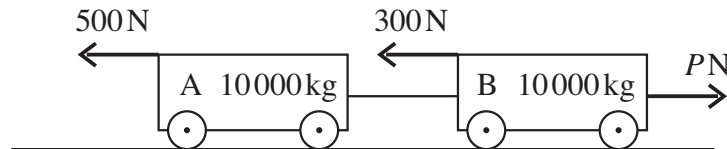

Fig. 4

The acceleration of the system is $0.2 \, \text{m s}^{-2}$ in the direction of the pulling force of magnitude P.

  (i) Calculate the value of P. [3]

Truck A is now subjected to an extra resistive force of 2000 N while P does not change.

  (ii) Calculate the new acceleration of the trucks. [2]

  (iii) Calculate the force in the coupling between the trucks. [2]

5 A train consists of an engine of mass 10 000 kg pulling one truck of mass 4000 kg. The coupling between the engine and the truck is light and parallel to the track.

The train is accelerating at $0.25 \, \text{m s}^{2}$ along a straight, level track.

  (i) What is the resultant force on the train in the direction of its motion? [2]

The driving force of the engine is 4000 N.

  (ii) What is the resistance to the motion of the train? [1]

  (iii) If the tension in the coupling is 1150 N, what is the resistance to the motion of the truck? [2]

With the same overall resistance to motion, the train now climbs a uniform slope inclined at 3° to the horizontal with the same acceleration of $0.25 \, \text{m s}^{2}$.

  (iv) What extra driving force is being applied? [3]

6 A box of weight 147 N is held by light strings AB and BC. As shown in Fig. 7.1, AB is inclined at α to the horizontal and is fixed at A; BC is held at C. The box is in equilibrium with BC horizontal and α such that $\sin \alpha = 0.6$ and $\cos \alpha = 0.8$.
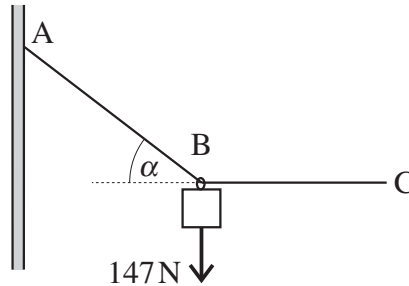

Fig. 7.1

  (i) Calculate the tension in string AB. [3]

  (ii) Show that the tension in string BC is 196 N. [2]

As shown in Fig. 7.2, a box of weight 90 N is now attached at C and another light string CD is held at D so that the system is in equilibrium with BC still horizontal. CD is inclined at β to the horizontal.
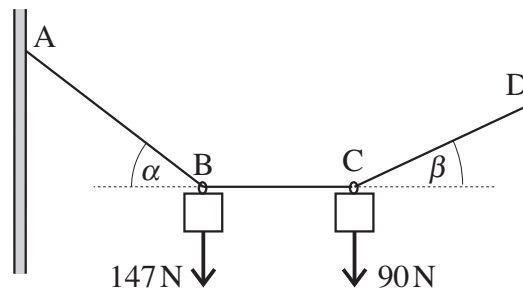

Fig. 7.2

  (iii) Explain why the tension in the string BC is still 196 N. [2]

  (iv) Draw a diagram showing the forces acting on the box at C.

      Find the angle β and show that the tension in CD is 216 N, correct to three significant figures. [7]

The string section CD is now taken over a smooth pulley and attached to a block of mass M kg on a rough slope inclined at 40° to the horizontal. As shown in Fig. 7.3, the part of the string attached to the box is still at β to the horizontal and the part attached to the block is parallel to the slope. The system is in equilibrium with a frictional force of 20 N acting on the block **up** the slope.
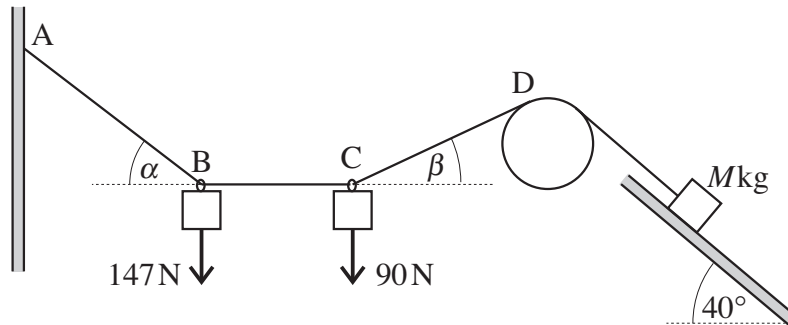

Fig. 7.3

(v) Calculate the value of M. [4]

7 A block of mass 4 kg is in equilibrium on a rough plane inclined at 60° to the horizontal, as shown in Fig. 4. A frictional force of 10 N acts up the plane and a vertical string AB attached to the block is in tension.

Fig. 4

(i) Draw a diagram showing the four forces acting on the block. [1]

(ii) By considering the components of the forces parallel to the slope, calculate the tension in the string. [3]

(iii) Calculate the normal reaction of the plane on the block. [3]