Newton's Third Law (Ch7)

1

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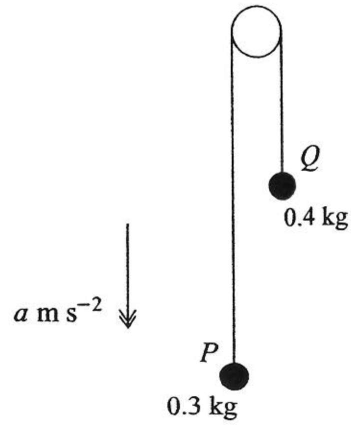

Particles P and Q, of masses 0.3 kg and 0.4 kg respectively, are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley. The system is in motion with the string taut and with each of the particles moving vertically. The downward acceleration of P is a m s^{-2} (see diagram).

(i) Show that $a = -1.4$. [4]

Initially P and Q are at the same horizontal level. P's initial velocity is vertically downwards and has magnitude 2.8 m s^{-1}.

(ii) Assuming that P does not reach the floor and that Q does not reach the pulley, find the time taken for P to return to its initial position. [3]

1 A trailer of mass 600 kg is attached to a car of mass 1100 kg by a light rigid horizontal tow-bar. The car and trailer are travelling along a horizontal straight road with acceleration 0.8 m s^{-2}.

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(i) Given that the force exerted on the trailer by the tow-bar is 700 N, find the resistance to motion of the trailer. [4]

(ii) Given also that the driving force of the car is 2100 N, find the resistance to motion of the car. [3]

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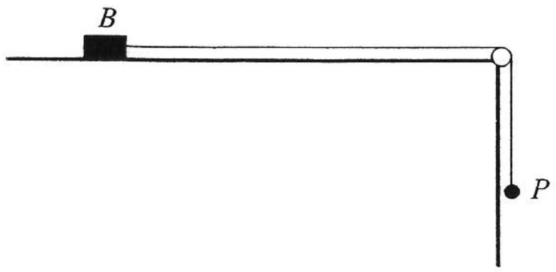

A block B of mass 0.4 kg and a particle P of mass 0.3 kg are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. B is in contact with the table and the part of the string between B and the pulley is horizontal. P hangs freely below the pulley (see diagram).

(i) The system is in limiting equilibrium with the string taut and P on the point of moving downwards. Find the coefficient of friction between B and the table. [5]

(ii) A horizontal force of magnitude X N, acting directly away from the pulley, is now applied to B. The system is again in limiting equilibrium with the string taut, and with P now on the point of moving **upwards**. Find the value of X. [3]

2 A trailer of mass 500 kg is attached to a car of mass 1250 kg by a light rigid horizontal tow-bar. The car and trailer are travelling along a horizontal straight road. The resistance to motion of the trailer is 400 N and the resistance to motion of the car is 900 N. Find both the tension in the tow-bar and the driving force of the car in each of the following cases.

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(i) The car and trailer are travelling at constant speed. **[3]**

(ii) The car and trailer have acceleration $0.6\,\text{m}\,\text{s}^{-2}$. **[6]**

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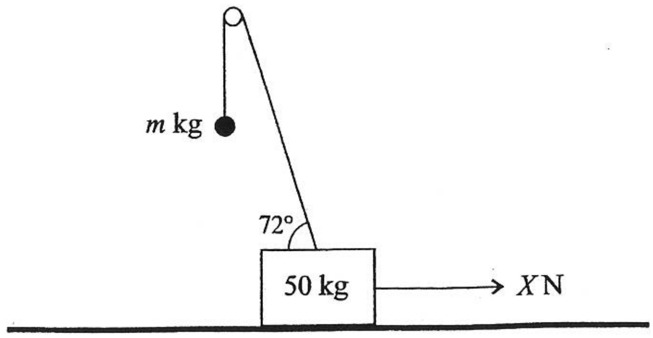

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A block of mass 50 kg is in equilibrium on smooth horizontal ground with one end of a light wire attached to its upper surface. The other end of the wire is attached to an object of mass m kg. The wire passes over a small smooth pulley, and the object hangs vertically below the pulley. The part of the wire between the block and the pulley makes an angle of 72° with the horizontal. A horizontal force of magnitude X N acts on the block in the vertical plane containing the wire (see diagram).

The tension in the wire is T N and the contact force exerted by the ground on the block is R N.

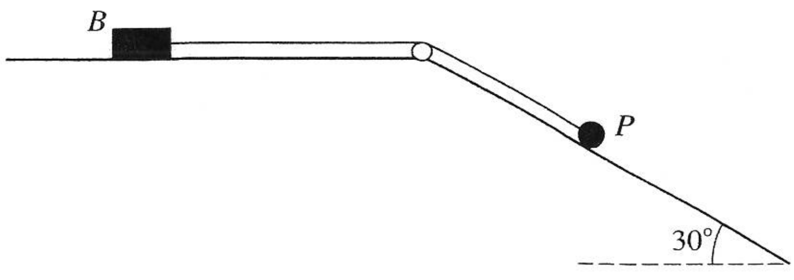
(i) By resolving forces on the block vertically, find a relationship between T and R. [2]

It is given that the block is on the point of lifting off the ground.

(ii) Show that $T = 515$, correct to 3 significant figures, and hence find the value of m. [4]

(iii) By resolving forces on the block horizontally, write down a relationship between T and X, and hence find the value of X. [2]

3



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The diagram shows a small block B, of mass 3 kg, and a particle P, of mass 0.8 kg, which are attached to the ends of a light inextensible string. The string is taut and passes over a small smooth pulley. B is held at rest on a horizontal surface, and P lies on a smooth plane inclined at 30° to the horizontal. When B is released from rest it accelerates at $0.2\,\text{m}\,\text{s}^{-2}$ towards the pulley.

(i) By considering the motion of P, show that the tension in the string is 3.76 N. **[4]**

(ii) Calculate the coefficient of friction between B and the horizontal surface. **[5]**

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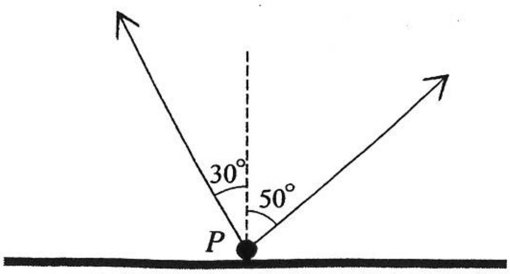

A particle P of weight 30 N rests on a horizontal plane. P is attached to two light strings making angles of 30° and 50° with the upward vertical, as shown in the diagram. The tension in each string is 15 N, and the particle is in limiting equilibrium. Find

(i) the magnitude and direction of the frictional force on P, [3]

(ii) the coefficient of friction between P and the plane. [5]

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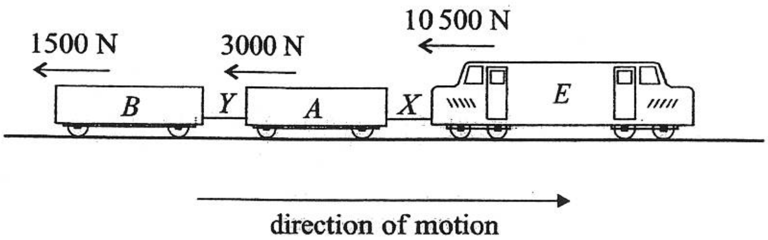

A train of total mass 80 000 kg consists of an engine E and two trucks A and B. The engine E and truck A are connected by a rigid coupling X, and trucks A and B are connected by another rigid coupling Y. The couplings are light and horizontal. The train is moving along a straight horizontal track. The resistances to motion acting on E, A and B are 10 500 N, 3000 N and 1500 N respectively (see diagram).

(i) By modelling the whole train as a single particle, show that it is decelerating when the driving force of the engine is less than 15 000 N. [2]

(ii) Show that, when the magnitude of the driving force is 35 000 N, the acceleration of the train is 0.25 m s^{-2}. [2]

(iii) Hence find the mass of E, given that the tension in the coupling X is 8500 N when the magnitude of the driving force is 35 000 N. [3]

The driving force is replaced by a braking force of magnitude 15 000 N acting on the engine. The force exerted by the coupling Y is zero.

(iv) Find the mass of B. [5]

(v) Show that the coupling X exerts a forward force of magnitude 1500 N on the engine. [2]

5 A car is towing a trailer along a straight road using a light tow-bar which is parallel to the road. The masses of the car and the trailer are 900 kg and 250 kg respectively. The resistance to motion of the car is 600 N and the resistance to motion of the trailer is 150 N.

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(i) At one stage of the motion, the road is horizontal and the pulling force exerted on the trailer is zero.

(a) Show that the acceleration of the trailer is $-0.6\,\text{m s}^{-2}$. [2]

(b) Find the driving force exerted by the car. [3]

(c) Calculate the distance required to reduce the speed of the car and trailer from $18\,\text{m s}^{-1}$ to $15\,\text{m s}^{-1}$. [2]

(ii) At another stage of the motion, the car and trailer are moving down a slope inclined at 3° to the horizontal. The resistances to motion of the car and trailer are unchanged. The driving force exerted by the car is 980 N. Find

(a) the acceleration of the car and trailer, [4]

(b) the pulling force exerted on the trailer. [3]

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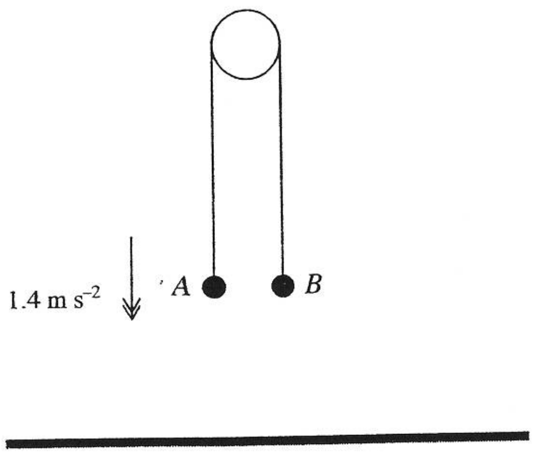

Particles A and B are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley. The particles are released from rest, with the string taut, and A and B at the same height above a horizontal floor (see diagram). In the subsequent motion, A descends with acceleration $1.4\,\text{m s}^{-2}$ and strikes the floor 0.8 s after being released. It is given that B never reaches the pulley.

(i) Calculate the distance A moves before it reaches the floor and the speed of A immediately before it strikes the floor. [4]

(ii) Show that B rises a further 0.064 m after A strikes the floor, and calculate the total length of time during which B is rising. [4]

(iii) Sketch the (t, v) graph for the motion of B from the instant it is released from rest until it reaches a position of instantaneous rest. [2]

(iv) Before A strikes the floor the tension in the string is 5.88 N. Calculate the mass of A and the mass of B. [4]

(v) The pulley has mass 0.5 kg, and is held in a fixed position by a light vertical chain. Calculate the tension in the chain

(a) immediately before A strikes the floor, [2]

(b) immediately after A strikes the floor. [1]

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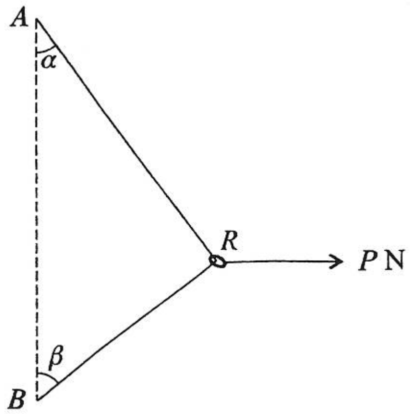

Fig. 1

A smooth ring R of weight W N is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B, where A is vertically above B. A horizontal force of magnitude P N acts on R. The system is in equilibrium with the string taut; AR makes an angle α with the downward vertical and BR makes an angle β with the upward vertical (see Fig. 1).

(i) By considering the vertical components of the forces acting on R, show that $\alpha < \beta$. [3]

(ii)

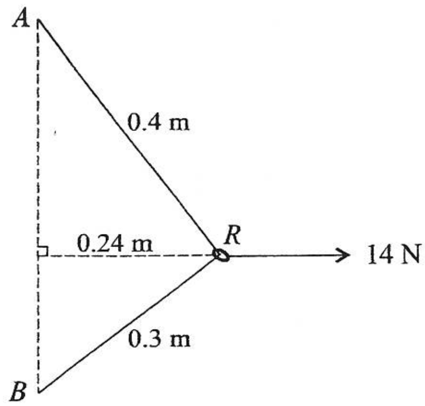

Fig. 2

It is given that when $P = 14$, $AR = 0.4$ m, $BR = 0.3$ m and the distance of R from the vertical line AB is 0.24 m (see Fig. 2). Find

(a) the tension in the string, [3]

(b) the value of W. [3]

(iii) For the case when $P = 0$,

(a) describe the position of R, [1]

(b) state the tension in the string. [1]

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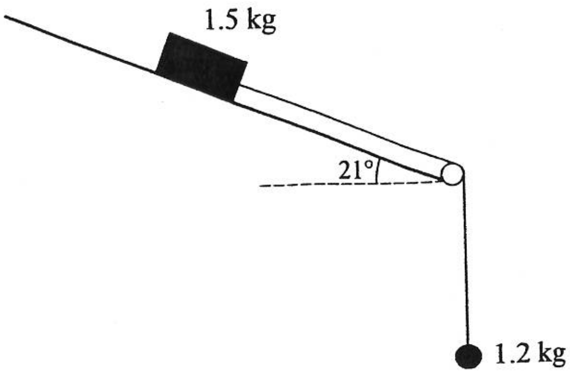

One end of a light inextensible string is attached to a block of mass 1.5 kg. The other end of the string is attached to an object of mass 1.2 kg. The block is held at rest in contact with a rough plane inclined at 21° to the horizontal. The string is taut and passes over a small smooth pulley at the bottom edge of the plane. The part of the string above the pulley is parallel to a line of greatest slope of the plane and the object hangs freely below the pulley (see diagram). The block is released and the object moves vertically downwards with acceleration $a\,\mathrm{m\,s^{-2}}$. The tension in the string is T N. The coefficient of friction between the block and the plane is 0.8.

(i) Show that the frictional force acting on the block has magnitude 10.98 N, correct to 2 decimal places. [3]

(ii) By applying Newton's second law to the block and to the object, find a pair of simultaneous equations in T and a. [5]

(iii) Hence show that $a = 2.24$, correct to 2 decimal places. [2]

(iv) Given that the object is initially 2 m above a horizontal floor and that the block is 2.8 m from the pulley, find the speed of the block at the instant when

(a) the object reaches the floor, [2]

(b) the block reaches the pulley. [4]