

Solve Friction Problems

Information Sheet

The Friction Model

Friction acts tangentially along surfaces in contact in the direction that opposes motion.

Before sliding occurs :

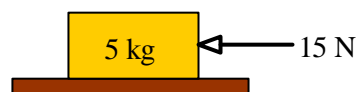
- friction is just sufficient to maintain equilibrium and prevent motion.
- $F < F_{MAX}$

On the point of sliding and when sliding occurs :

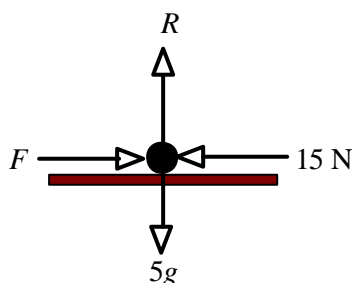
- $F = \mu R$
where F is the friction force acting between two surfaces in contact, μ is the **coefficient of friction** and R is the normal contact force.
(Note that this is the notation suggested in the FSMQ specification, but you can use N rather than R for the normal contact force if you wish)

Example

A 5 kg box on a horizontal table is pushed by a horizontal force of 15 N as shown below. If the coefficient of friction is 0.4, will the box move?



Solution



The sketch shows the forces acting on the box. Note that the weight of a box of mass 5 kg is $5g$ where $g = 9.8 \text{ ms}^{-2}$

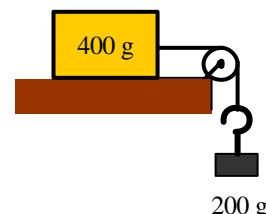
Since the vertical forces are in equilibrium $R = 5g$

The maximum possible friction is $F = \mu R = 0.4 \times 5g = 19.6 \text{ N}$

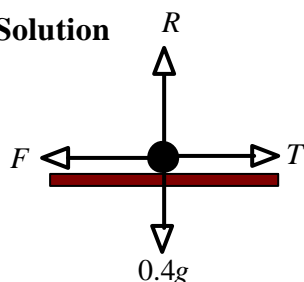
The pushing force, 15 N, is less than this and so cannot overcome the friction. **The box will not move.**

Example

A 400 g package lying on a horizontal surface is attached to a horizontal string which passes over a smooth pulley. When a mass of 200 g is attached to the other end of the string, the package is on the point of moving. Find m the coefficient of friction.



Solution



The forces acting on the package are as shown.

Since the vertical forces are in equilibrium $R = 0.4g$

On the point of moving, $F = mR = m0.4g$ and $F = T$

As the pulley is smooth, the tension in the string, $T = 0.2g$

This gives $m0.4g = 0.2g$ and so $m = \frac{0.2g}{0.4g} = \frac{1}{2}$



Solve Friction Problems

Worksheet

Take $g = 9.8 \text{ ms}^{-2}$

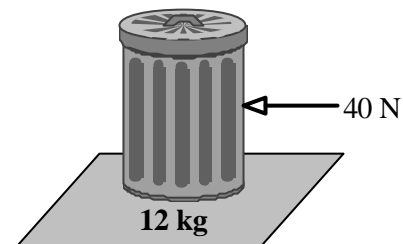
- 1 (a) A parcel of mass 2 kg lies at rest on a rough horizontal surface, as shown.
 (i) Draw a force diagram showing the forces acting on the parcel.
 (ii) Calculate the normal contact force, R .



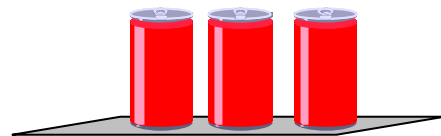
- (b) The parcel is now pushed with a horizontal force P , as shown so that it is just on the point of sliding.
 (i) Draw a force diagram showing the forces now acting on the parcel.
 (ii) If the coefficient of friction is 0.5, find the value of P when the parcel is on the point of sliding.



- 2 A dustbin of mass 12 kg standing on horizontal ground is pushed by a horizontal force of 40 N.
 If the coefficient of friction is 0.4, will the dustbin move?



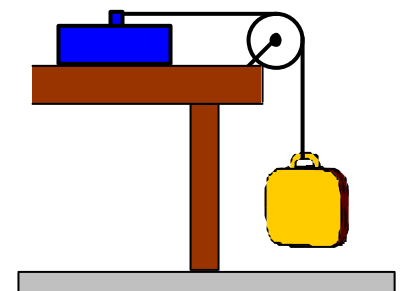
- 3 A conveyor belt is used to carry cans from one part of a factory to another. Each can has mass 350 g.
 If $\mu = \frac{3}{4}$ and each can is just on the point of sliding, find the frictional force acting on each can.



- 4 A sledge has mass 15 kg. A horizontal pull of 25N will just move the sledge when it is on a horizontal surface of compacted snow.
 (a) Draw a diagram showing the forces acting on the sledge, modelled as a particle, when it is just on the point of sliding on this horizontal surface.
 (b) Find a value for μ , the coefficient of friction between the surfaces.

- 5 One end of a light inextensible string is attached to a tool box of mass 2.5 kg which is lying on a horizontal table.
 The string passes over a smooth pulley and is tied at the other end to a bag of mass 1.4 kg.

- (a) Draw a diagram showing the forces acting on the tool box.
 (b) If the tool box is just on the point of sliding, find a value for μ the coefficient of friction.



More Difficult Problems

Information Sheet

More complex problems can be solved using the model $F = \mu R$ (when an object is on the point of sliding or when sliding is occurring) together with other equations.

In particular, the following may be useful:

Newton's Second Law

Resultant force = mass \times acceleration

where the resultant force is in newtons, the mass in kg and the acceleration in ms^{-2}

The equations for motion in a straight line with constant acceleration

$$v = u + at \quad s = \frac{(u + v)t}{2} \quad s = ut + \frac{1}{2}at^2 \quad \text{and} \quad v^2 = u^2 + 2as$$

where u is the initial velocity, v is the final velocity, a is the acceleration, t is the time taken and s is the displacement.

Example

A car of mass 1.2 tonnes is travelling along a straight horizontal road at a speed of 20 ms^{-1} when it brakes sharply then skids. Friction brings the car to rest. If the coefficient of friction between the tyres and road is 0.8, calculate

- the deceleration
- the distance travelled by the car before it comes to rest.

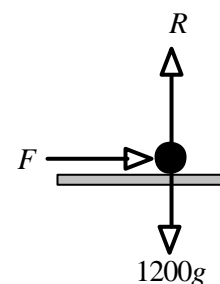


Solution

- The sketch shows the forces acting on the car when it is skidding.

Since the vertical forces are in equilibrium $R = 1200g$

Since the car is skidding $F = \mu R = 0.8 \times 1200g$
 $= 9408 \text{ N}$



The friction F causes deceleration a which is given by Newton's Second Law, $F = ma$

$$-9408 = 1200a \quad \text{so} \quad a = -\frac{9408}{1200} = -7.84$$

The deceleration is **7.84 ms^{-2}**

- Using $v^2 = u^2 + 2as$ with initial speed $u = 20 \text{ ms}^{-1}$, final speed $v = 0 \text{ ms}^{-1}$ and acceleration $a = -7.84 \text{ ms}^{-2}$

$$0^2 = 20^2 - 2 \times 7.84s \quad \Rightarrow \quad 15.68s = 400 \quad \Rightarrow \quad s = \frac{400}{15.68} = 25.51\dots$$

The car travels **25.5 m** (to 3 sf) before coming to rest.

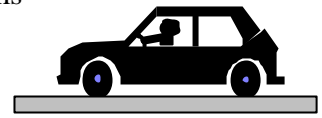


More Difficult Problems

Take $g = 9.8 \text{ ms}^{-2}$

Worksheet

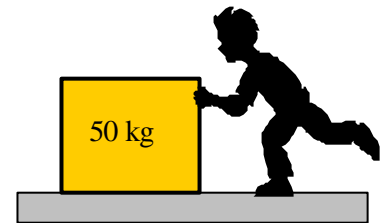
- 1 A car of mass 1 tonne is travelling along a straight horizontal road at 15 ms^{-1} when it brakes sharply then skids. Friction brings the car to rest. If the coefficient of friction between the tyres and road is 0.75, calculate
- the deceleration
 - the time taken for the car to come to rest.



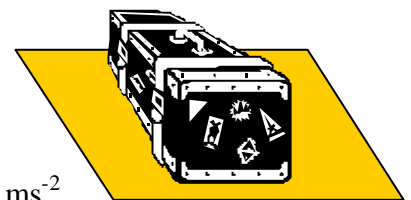
- 2 A cup of coffee of mass 250 g lies on a table in a train carriage. The train accelerates at 1.2 ms^{-2} out of a station.
- Draw the forces acting on the cup of coffee.
 - If the cup does not slip, find the value of the friction force that acts on the cup of coffee.
 - If the cup is just about to slip, find the coefficient of friction between the cup and the surface of the table.



- 3 A child is trying to push a load of mass 50 kg across a floor. The child exerts a force of 70 N.
- Modelling the floor as smooth and the load as a particle, calculate the acceleration of the load.
 - Assuming that a constant resistive force of 56 N acts, calculate
 - the acceleration of the load.
 - the coefficient of friction, μ , between the load and the ground, assuming the resistive force is due only to friction.



- 4 A trunk of mass 30 kg is standing on a horizontal floor. The coefficient of friction, μ , between the trunk and floor is 0.3.
- Find the maximum value the friction can attain.
 - Find the force that is necessary
 - to keep the trunk sliding over the floor with constant speed.
 - to cause the trunk to slide over the floor with acceleration 0.2 ms^{-2} .



- 5 A pick-up truck carrying a load of mass 150 kg accelerates from some traffic lights at 1.4 ms^{-2} . Find the smallest possible value of the coefficient of friction if the load does not slip.



- 6 A boy skims a stone across a frozen pond. The stone has a mass of 100 g, and the coefficient of friction, μ , between the stone and the ice is 0.1. If the stone has an initial speed of 8 ms^{-1} , find how far it will travel before it comes to rest.



Teacher Notes

Unit Advanced Level, Dynamics

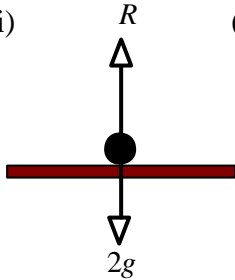
Notes on Activity

The PowerPoint demonstration with the same name includes the main points and examples given on the information sheets. Some of the problems used in this activity originally appeared in the book *Mechanics 1* which was funded by the Nuffield Foundation and published by Longman in 1994 (ISBN 0-582-09979-X).

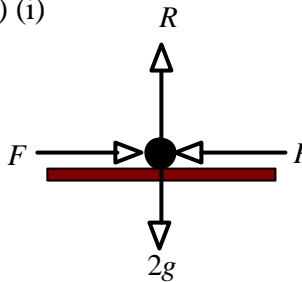
Answers

Page 2

1 (a) (i) (ii) 19.6 N



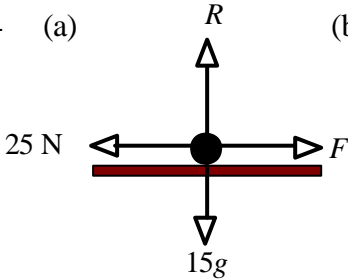
(b) (i) (ii) 9.8 N



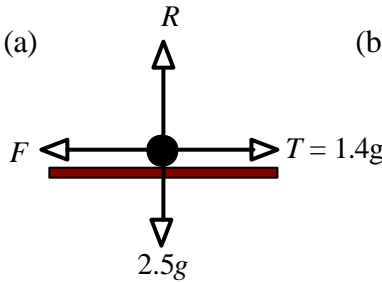
2 No (Maximum Friction = 47.04 N)

3 2.57 N (3sf)

4 (a) (b) $m = 0.170$ (3sf)



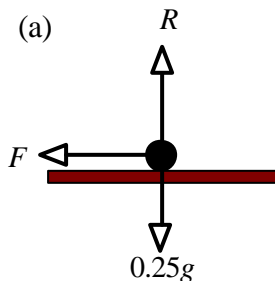
5 (a) (b) $m = 0.56$



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1 (a) 7.35 ms^{-2} (b) 2.04 seconds (3 sf)

2 (a) (b) 0.3 N (c) 0.122 (3 sf)



3 (a) 1.4 ms^{-2} (b) (i) 0.28 ms^{-2} (ii) 0.114 (3sf)

4 (a) 88.2 N (b) (i) 88.2 N (ii) 94.2 N

5 0.143 (3 sf) 6 32.7 metres

