Coefficient of Friction

Notes

Smooth ⇒ no frictional force

Rough ⇒ frictional force present

Key ideas about friction

1. Friction acts in the ***opposite direction to motion***
2. The maximum value of the frictional force is called the ***limiting friction*** value or F_{lim}.
3. By N3L, ***as the force pushing*** an object ***increases*** so does the frictional force resisting motion. The ***friction force*** opposing motion ***increases*** until it reaches F_{lim}, i.e. the maximum frictional force.
4. If an object is ***on the point of moving***, the object is said to be in ***limiting equilibrium.***
5. The limiting frictional force between two surfaces is proportional to the normal contact force. If the limiting frictional is F_{lim} and the normal contact force is R, then $F_{lim} = \mu R$, where μ is a constant. The constant μ is called the ***coefficient of friction*** and has no units.
6. ***Moving*** objects: the frictional force is $F_{lim} = \mu R.$
7. ***Stationary*** objects: the frictional force is $F_{lim} \leq \mu R.$
8. For all rough surfaces: $0 <$ Frictional force $\leq \mu R.$
9. If contact between two surfaces is smooth, $\mu = 0.$

N.B. Experiments indicate that friction when in motion, friction is slightly less than the limiting friction value.

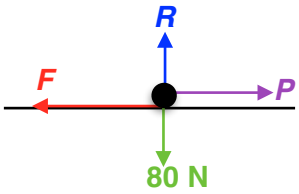
E.g. 1 A horizontal force P newtons is applied to a body of weight 80 N, standing in rough contact with a horizontal plane. The coefficient of friction between the body and the plane is 0.5. What is the magnitude of the frictional force, F, when:

(a) $P = 10$ N

(b) $P = 40$ N

(c) $P = 50$ N?

State in each case whether or not the body moves.



Solving friction problems

When doing friction questions you can do the following three things:

- $R(\uparrow)$ — resolve vertically to find R, the normal contact force.
- $F_{lim} = \mu R$ — to find the limiting (maximum) frictional force.
- $R(\rightarrow)$ or $F = ma(\rightarrow)$ — resolve or use $F = ma$ horizontally

N.B. The difference is just which order you do them in — often this does not matter.

E.g. 2 A particle of mass m kg lies on a rough horizontal plane. The coefficient of friction between the particle and the place is μ. A force of P N acts at an angle θ above the horizontal. For the situations where the particle is:

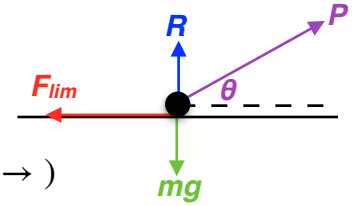
(a) accelerating and

(b) in limiting equilibrium or moving with constant speed:

(i) Resolve vertically, $R(\uparrow)$

(ii) Use $F_{lim} = \mu R$

(iii) Use $F = ma(\rightarrow)$ or resolve horizontally $R(\rightarrow)$



E.g. 3 A small block of weight 32 N is lying in rough contact on a horizontal plane. A horizontal force of P newtons is applied to the block until it is just about to move the block.

(a) If $P = 8$, find the coefficient of friction, μ, between the block and the plane.

(b) If $\mu = 0.4$, find the value of P.

E.g. 4 A particle of mass 5 kg, resting on a rough plane, is acted on by a force of 23 N. The coefficient of friction between the particle and surface is $\frac{1}{3}$.

(a) Find the acceleration when the force acts horizontally.
(b) If the force acts at 20° to the horizontal will the acceleration increase or decrease?
(c) Find the new acceleration.

Finding the contact force between two surfaces

The contact force, C, is the resultant from the frictional and the normal contact force.

$$C = \sqrt{R^2 + F_{lim}^2}$$

E.g. 5 A particle of mass 12 kg is being pulled along a rough surface by a horizontal force of P N such that its acceleration is 3 m/s^2. The coefficient of friction between the particle and surface is $\frac{3}{4}$.

(a) Find the value of P.
(b) Find the magnitude and direction of the contact force.

Exercise

1. A person tries to pull a small cupboard across a floor. The mass of the cupboard is 80 kg and the coefficient of friction is 0.5. Describe what happens if the cupboard is pulled with a horizontal force of:
   (a) 200 N, (b) 400 N.
2. A small block of weight 24 N rests in rough contact with a horizontal plane. A light string is attached to the block and is inclined at 30° to the plane. The block is just about to slip when the tension in the string is 12 N. Find:
   (a) the coefficient of friction between the block and the plane
   (b) the magnitude of the contact force.
3. A block of weight 20 N is at rest on a horizontal surface. When a force of magnitude 12 N is applied to the block at an angle of 30° above the horizontal via a string, it is on the point of moving. Find:
   (a) the coefficient of friction between the block and the surface
   (b) the magnitude of the contact force.
4. A box of mass 2 kg is placed on a table. A string attached to the box passes over a smooth peg at the edge of the table, and a ball of mass 1 kg is tied to the other end.
   (a) If the coefficient of friction between box and table is 0.2, find the acceleration of the box and the ball.
   (b) Find the magnitude of the contact force between the box and the table.
5. A block of mass 5 kg is being pulled along a rough surface by a force, D, which acts at 30° to the horizontal. The frictional force resisting the motion is 15 N. Find:
   (a) the force D given that the block is accelerating at 3 m/s^2 and
   (b) the normal contact force between the block at the rough surface.
   (c) How large does D have to be for the block to leave the surface?
6. A truck is pulled along a horizontal track by two cables against resistance forces totally 1100 N, with an acceleration of 0.8 m/s^2. One cable is horizontal and has a tension of 800 N. The other cable is inclined at 40° to the track and has a tension of 1000 N. Find:
   (a) the mass of the truck
   (b) the vertical force exerted by the track on the truck.
7. A small block of mass 5 kg is being pulled along a rough horizontal plane by a string inclined at 60° to the plane. There is a frictional force of 18 N and the acceleration of the block is 3 m/s^2.
   (a) Draw a diagram, marking on all the forces that act on the block.
   Find (b) the tension in the string and
   (c) the normal reaction exerted by the plane on the block.