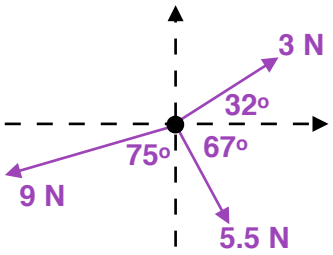
Coefficient of Friction

Starter

1. **(Review of last lesson)** Find the magnitude and direction of the resultant force acting on the particle.



2. **(Review of last lesson)** A trolley is on a level, smooth floor. A girl is trying to push it with a force of 10 N at 15° to the horizontal. Her brother prevents it from moving by pushing horizontally with a force in the opposite direction. With what force does he push?

Notes

Smooth ⇒ no frictional force
Rough ⇒ frictional force present

Key ideas about friction

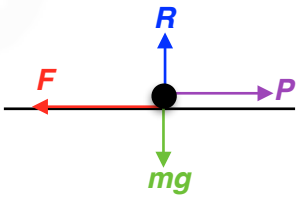
1. Friction acts in the ***opposite direction to motion***
2. The maximum value of the frictional force is called the ***limiting friction*** value or F_{lim}.
3. By N3L, ***as the force pushing*** an object ***increases*** so does the frictional force resisting motion. The ***friction force*** opposing 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 fictional force is $F_{lim} = \mu R.$
7. ***Stationary*** objects: the fictional force is $F_{lim} \leq \mu R.$
8. 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 $R(\rightarrow)$

Working:

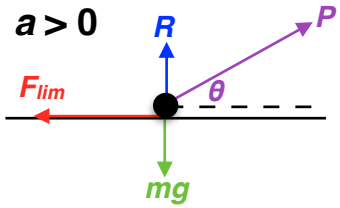
(a) ***Accelerating***

(i) $R(\uparrow)$: $R + P\sin\theta = mg$

$R = mg - P\sin\theta$

(ii) $F_{lim} = \mu R$: $F_{lim} = \mu(mg - P\sin\theta)$

(iii) $F = ma(\rightarrow)$: $P\cos\theta - F_{lim} = ma$



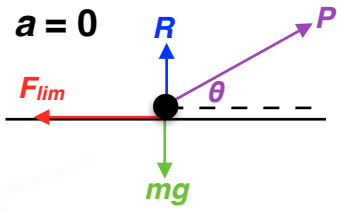
(b) ***Stationary or moving with constant speed***

(i) $R(\uparrow)$: $R + P\sin\theta = mg$

$R = mg - P\sin\theta$

(ii) $F_{lim} = \mu R$: $F_{lim} = \mu(mg - P\sin\theta)$

(iii) $R(\rightarrow)$: $P\cos\theta = F_{lim}$



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 an angle of 20^o to the horizontal will the acceleration increase or decrease.

(c) Find the new acceleration.

In general:

Horizontal force: $a = \dfrac{P - \mu mg}{m}$

Force at an angle θ to the horizontal: $a = \dfrac{P(\sin\theta + \cos\theta) - \mu mg}{m}$

$= \dfrac{P\sqrt{2}\sin(\theta + 45) - \mu mg}{m}$

So maximum acceleration is when $\theta = 45^o$.

Finding the contact force

The contact force between two surfaces is the resultant from the frictional force and the normal contact force.

The magnitude of the contact force, C: $C = \sqrt{R^2 + F_{lim}^2}$

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.

Video: Friction

Video: Motion on rough horizontal plane

Motion on rough horizontal plane EQ

Solutions to Starter and E.g.s

Exercise

p481 21B Qu 1i, 2-9

Summary

When solving friction problems 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

The magnitude of the contact force, C: $C = \sqrt{R^2 + F_{lim}^2}$