# Physics Notes

BY


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Class:10+1
Unit: III
Topic: Laws of Motion

*SYLLABUS*: UNIT-III-*B*

Force and inertia, Newton's first law of motion; Momentum, Newton's second law of motion, Impulse; Newton's third law of motion; Law of conservation of linear momentum and its application;

Equilibrium of concurrent forces; Static and Kinetic friction, laws of friction, rolling friction, lubrication; Example of variable-mass situation.

Dynamics of uniform circular motion, Centripetal force, examples of circular motion (vehicle on level circular road, vehicle on banked road); Inertial and non-inertial frames (elementary idea).


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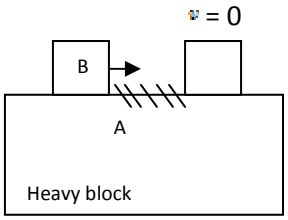
**Q.1. a) What is friction?**
**b) What causes friction?**
**c) 'External friction' and 'Internal Friction'?**

Ans. a) **Friction**:-

Friction is an opposing force which comes into play when one object moves (or tries to move) over another object.



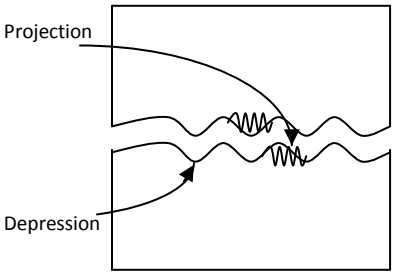

Example:-

Object B stops after covering some distance. Friction between A and B opposes motion of B over A.

b) **Causes of Friction**:-

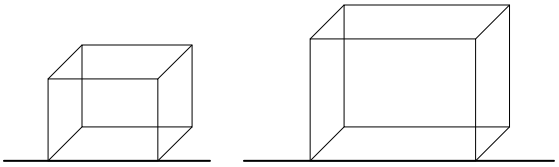
I. Old Views:-

Surfaces have irregularities. Force is required to overcome irregularities.




Limitations:-

1. As per this theory, Friction should depend on 'Area of Surfaces' in contact because irregularities increase with Area.
   As per experiment, Friction is independent of Area.



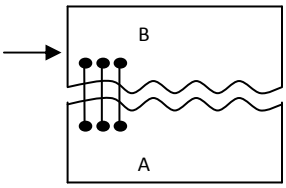
High surface Area in contact Friction same

2. As per this theory, extra smooth surfaces should have very low friction.

   As per experiment, extra smooth surfaces have very high friction.

II. Modern View:-

Atom/Molecule of body A come in close contact with atoms/molecules of body B. Because at point of contact, attraction is high. Two surfaces get 'Cold Welded'. It becomes difficult to move one surface over the other.

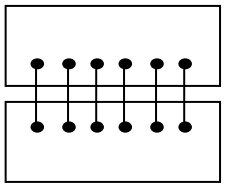


**Justifications for experiments**:-

1. Area of Contact:-

(No. of points of contact) x (Pressure at a point)
remains constant

So, if surface area decreases, no. of points in contact also decreases but pressure at a point increases.



2. Extra Smooth:-

If surfaces are extra smooth, no. of atoms in contact also increase So, friction increases.

c) **Friction into two types**:-

a) External Friction:-

Which aries when two bodies in contact with each other try to move or there is an actual relative motion between the two. The external friction is also called contact friction.

b) Internal Friction:-

Which aries on account of relative motion between every two layers of a liquid. Internal friction is also referred to as viscosity of the liquid.

**Q.2. Explain**

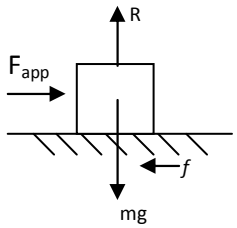
**a) Static friction**

**b) Limiting friction**

**c) Kinetic friction**

Ans. a) **Static Friction**:-

As $F_{app}$ increase, Friction also increase. Friction is self adjusting.

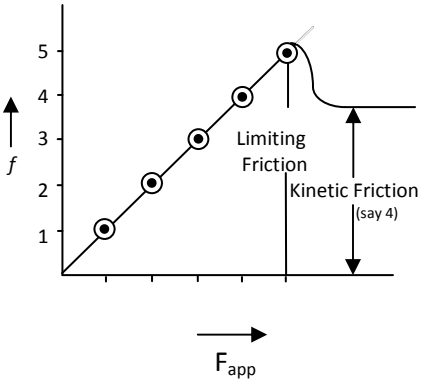



$F_{app}$ → Applied force

$f$ → Friction force

Definition:-

The opposing force that comes into play when one body tends to move over the surface of another, but the actual motion has yet not started is called static friction.




b) **Limiting Friction**:-

Max. value of static friction when body just starts moving over the other.

*Example*:- $F_{limiting}$ = 5 in diagram

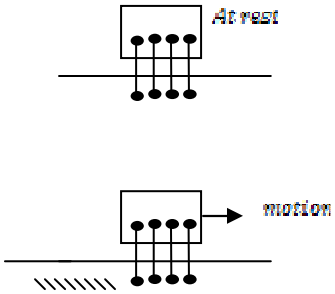
c) **Kinetic Friction**:-

Kinetic Friction is value of opposing force when one body moves over the surface of another body.

*Example*:- $F_{kinetic}$ = 4 (say) in diagram

**Q.3. Why Kinetic friction is less than Limiting friction?**

Ans. When we try to move a static object over the other. Strong atomic attraction oppose the motion of one surface over the other. Once the object stars moving atomic bonds make and break process comes into play. This process requires less applied force. It is because of this reason Kinetic Friction is less than upper limit of static friction.

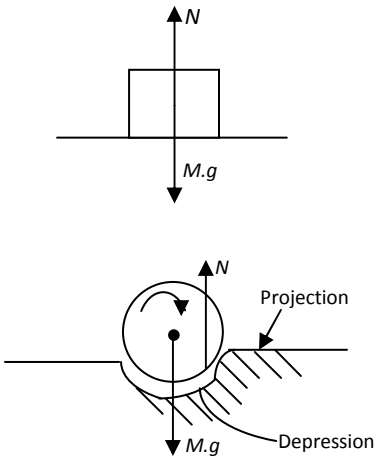



**Q.4. What cause rolling friction?**

Ans. When object rolls, lower surface gets a 'Depression' and 'Projection' as shown in fig.

Normal reaction *N* shifts in forward direction and is not in line with Mg.

*N* and *Mg* create anti clockwise torque which opposes the motion of object.

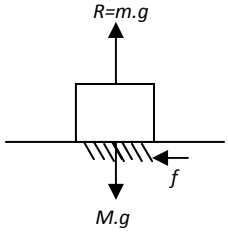


**Q.5. a) State four Laws of friction?**
**b) Perform experiments to confirm the same.**

Ans.a) **<u>Law 1</u>**:-

Force of friction α Normal Reaction

$F \alpha R$

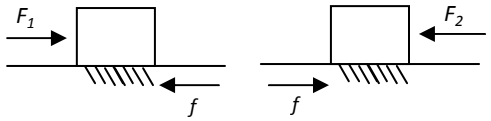



**<u>Law 2</u>**:-

Direction of friction is opposite to 'Tendency to move'.

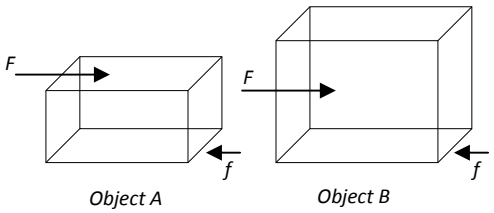
$F_1$ → towards right

$f$ → towards left




**<u>Law 3</u>**:-

Force of friction F is independent of Area in contact.




**<u>Law 4</u>**:-

Friction depends on material of surfaces in contact.

$F \alpha R$

$F = \mu.R$

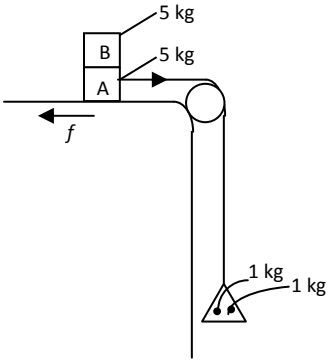
↓

Co-efficient of friction → It depends on material of surfaces in contact

**FIRST LAW**:-

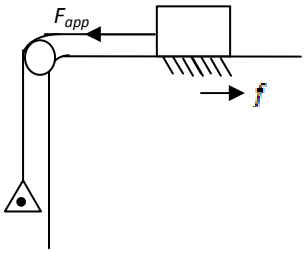
In this case take two blocks *A* and *B*. Now place the block *B* on the block *A*. The weight is doubled. Therefore, the normal reaction also becomes double. Repeat this experiment and found to be tow times the force of Limiting Friction in case of block *A*. Thus when *R* is doubled, *F* is also double.

Hence, F α R



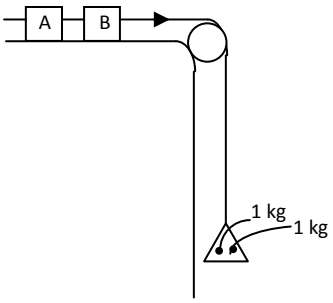

**SECOND LAW**:-

In equilibrium *R* = mg and *F* = *P* i.e. Force of Limiting Friction is equal and opposite to the applied force *P*. Hence the direction of the force of Limiting Friction is always opposite to the intended direction of motion of the block. In which Force would be to the right.



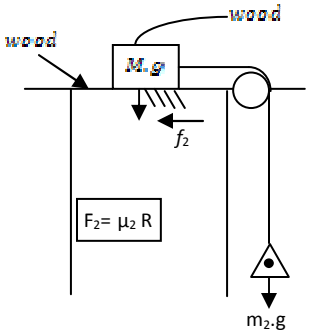

**THIRD LAW**:-

Join the two blocks *A* and *B*. Repeat this example. In this case, when block *B* is place over the block *A*. The total normal reaction in town cases is same, but the area of apparent contact is same. Thus Limiting Friction does not depend upon apparent area of contact between the bodies so, long as normal reaction R between them remains the same.




**FOURTH LAW**:-

We take two blocks, one of wood and other of metal of the same weight, *F* either case is different. This proves that force of Limiting friction depends on the nature of material of the bodies in contact.



**Q.6.** **a) Define co-efficient of friction.**
**b) Compare co-efficient of static friction or kinetic friction.**

Ans. a) **<u>Co-efficient of friction</u>**:-

Ratio of Force of Limiting friction and Normal reaction.

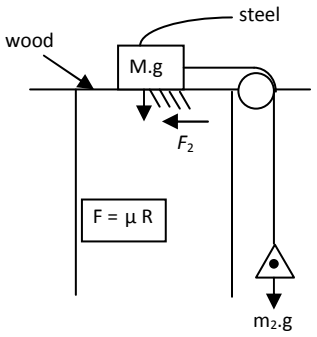
According to First Law of Limiting Friction

$$F \alpha R$$

$$\boxed{F = \mu R}$$

Where μ is a constant of Proportionality

$$\boxed{\mu = \frac{F}{R}}$$



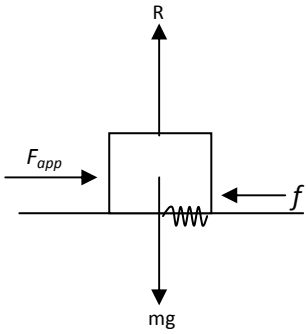

b)

| **Surfaces in Contact** | **Coefficient of Limiting Friction** | **Coefficient of Kinetic Friction** |
|---|---|---|
| Wood on wood | 0.70 | 0.40 |
| Wood on Leather | 0.50 | 0.40 |
| Steel on steel (mild) | 0.74 | 0.57 |
| Steel on steel (hard) | 0.78 | 0.42 |
| Steel on steel (greased) | 0.10 | 0.05 |

**Q.7.** **a) What is 'angle of friction'?**
**b) Write it in terms of 'Co-efficient of Friction'.**

Ans. **<u>Angle of Friction</u>**:-

Angle of Friction is angle between Normal Reaction R and Resultant (of *f* and R) as shown.

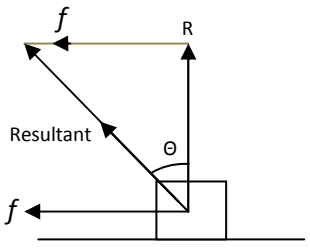



**<u>Relation θ and μ</u>**:-

$$\text{Tan}\theta = \frac{f}{R}$$

$$\text{Tan}\,\theta = \frac{\mu R}{R} \qquad \boxed{f = \mu R}$$

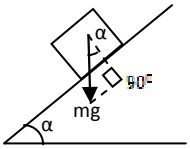
$$\boxed{\text{Tan}\,\theta = \mu}$$



**Q.8. What is 'angle of Repose'?**
**Write it in terms of co-efficient of friction'.**

Ans. **<u>Angle of Repose</u>**:-

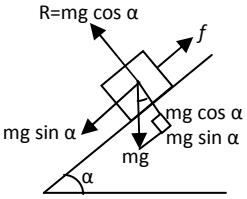
It is defined as the minimum angle of inclination of a plane with the horizontal such that a body place on the plane just begins to slide down.




*Or*

Minimum angle at which a body just begins to slide m.g. mg sinα tries to move object along the plane.

Friction *f* opposes it object just starts sliding down when

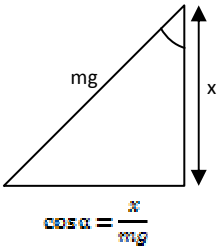



m.g. sinα = *f*

= μR

m⁄.g. sinα = μ.m⁄.g. cosα

| Tanα = μ |
|---|




**Q.9. Derive an expression for acc of a body down an inclined angle.**

Ans. acc, a $= \frac{F_{net}}{mass}$

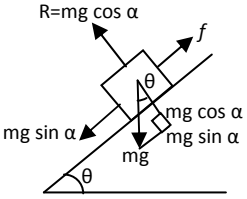
a $= \frac{m.g.sin\theta - f}{m}$

a $= \frac{m.g.sin\theta - \mu(R)}{m}$

a $= \frac{m.g.sin\theta - \mu.m.g.cos\theta}{m}$

a $= \frac{m.g.(sin\theta - \mu cos\theta)}{m}$

| Acceleration, $a$ = g(sinθ – μcosθ) |
|---|



**Q.10. a) Is friction a necessary evil? Comment?**
**b) Discuss methods for controlling?**

Ans.a) **Friction is a Necessity (Advantages of friction)**:-

1. Walking will not be possible without friction .Our foot pressing the ground will only slip.

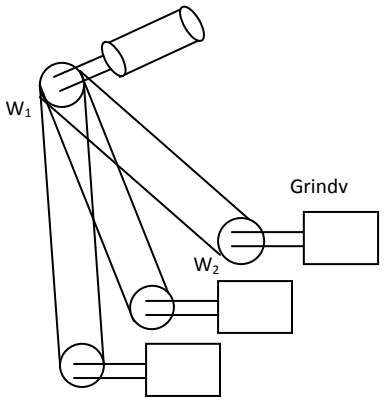
2. No two bodies will stick to each other if there is no friction.

3. Brakes of the vehicles will not work without friction.

4. Nuts and bolts for holding the parts of machinery together will not work.

5. Writing on black board or on paper will also not be possible without friction.

6. The transfer of motion from one part of a machine to the other part through belts will not be possible without friction.
Diagram:-




7 Adhesive will lose their purpose.

8. Cleansing with sand paper will not be possible without friction.

**Friction is an evil (Disadvantages of friction)**:-

1. Friction always opposes the relative motion between any two bodies in contact. Therefore, extra energy has to be spent in overcoming friction. This friction involves unnecessary expenditure of energy. It means output is always less than input.

2. Friction cause wear and tear of the parts of machinery in contact. Thus their life time reduces.

3. Frictional forces result in the production of heat, which causes danger to the machinery.

b) **Methods for controlling friction**:-

i) By Polishing:-

Polishing makes the surfaces smoother. Therefore, Friction reduces.

ii) By Lubrication:-

Lubricants like oil, grease etc. Fill up the irregularities of the surfaces, making them smoother. Hence friction decreases.

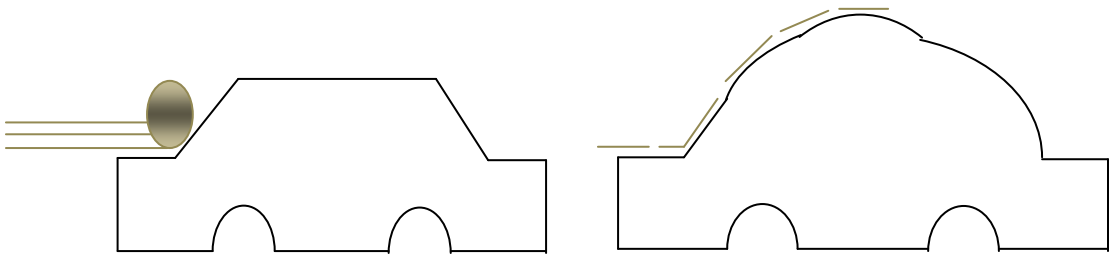
iii) By Proper selection of materials:-

Tyres are made up of rubber. This is because friction between rubber and concrete is much less than friction between iron and concrete. Hence, friction depends upon nature of material.

iv) By streamlining**:-**

Friction due to air is considerably reduced by streamlining the shape of the body moving through air.

Example jets, aeroplanes, fast moving cars etc. One given streamline shape.

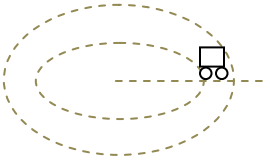


v) By using ball bearings:-

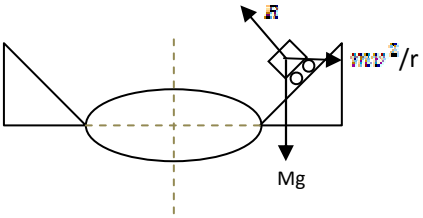
Rolling friction is less than sliding friction. In which sliding friction converted into rolling friction.

**Q.11. a)What is Banking of Roads?**
**b)Derive formula for "Angle of Banking"? (Without friction)?**

Ans.a) when a vehicle moves on horizontal (flat) circular road, Vehicle skids away from centre at high speed.



$V_{max} = \sqrt{\mu . r . g}$ $\left[ m . \frac{V_{max}^2}{r} = \mu . (m . g) \right]$

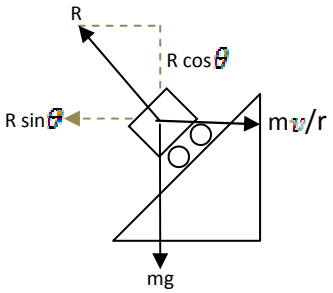



Banking:-

Increasing the outer edge level of road to enable high speed on curves, is called Banking

b) Mark Forces:- mg, R, $mv^2/r$

Under Balanced Conditions




Horizontal component of R will balanced $mv^2/r$

$R \cos\theta = mv^2/r$

Vertical component of R will balanced mg

$R \sin\theta = mg$

(1) by (2), we get

$$\text{Tan } \theta = \frac{v^2}{rg}$$

**Q.12. Derive expression for Speed, Tension at**

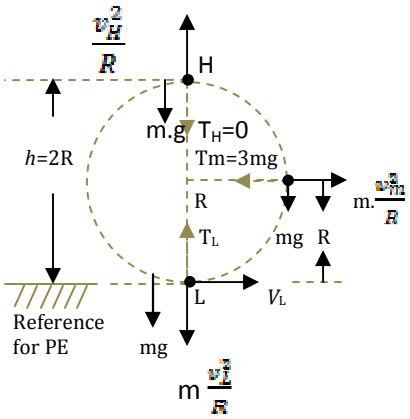
**a) Highest position**

**b) Lowest position**

**c) Middle position**

**For a mass moving in vertical circle with the help of a string (just looping the loop)?**

Ans.a) **Highest Position**:-




For just looping the loop at H

$T_H + m.g = m.\frac{V_H^2}{R}$

$T_H = m.\frac{V_H^2}{R} - m.g$

For looping the loop at H. $T_H > 0$

For just looping the loop $T_H = 0$

$$VH = \sqrt{Rg}$$

b) **Lowest Position**:-

Speed at Lowest Position, $V_L$ = ?

As per Law of Conservation of Energy

$(\text{Total Energy})_L = (\text{Total energy})_H$

$K.E_L + P.E_L = K.E_H + P.E_H$

$\frac{1}{2}m.\frac{V_L^2}{R} + mg\,(0) = \frac{1}{2}m.\frac{V_H^2}{R} + mg(2R)$

$$V_L = \sqrt{5Rg}$$

Tension, $T_L$ = ?

$T_L = mg + m.\frac{V_L^2}{R}$

$= mg + 5mg$

$$T_L = 6mg$$

c) **Middle Position $v_m$**:-

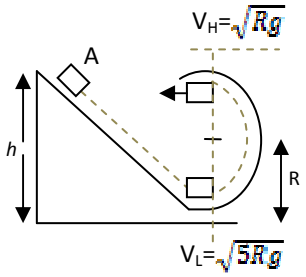
As per Law of Conservation of Energy

$(\text{Total energy})_m = (\text{Total energy})_H$

$K.E_m + P.E_m = K.E_H + P.E_H$

$\frac{1}{2} m.\frac{V_m^2}{R} + m.g\,(R) = \frac{1}{2} m.\frac{V_H^2}{R} + mg(2R)$

$$\boxed{V_m = \sqrt{3Rg}}$$



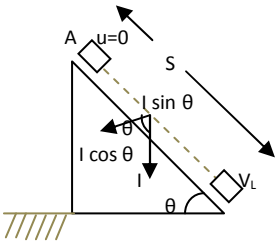

Tension, $T_m$

For just looping the loop

$T_m = m.\frac{V_m^2}{R}$

$= m.\left(\frac{3Rg}{R}\right)$

$$\boxed{T_m = 3mg}$$




As per Law of Conservation of Energy

$T.E_A = T.E._L$

$K.E_A + P.E_A = K.E_L + P.E_L$

$0 + mg(h) = \frac{1}{2} m.V_L^2 + mg(0)$

$mgh = \frac{1}{2} m.V_L^2$

$gh = \frac{1}{2}.V_L^2$

$$\boxed{V_L = \sqrt{2gh}} \quad \text{------} (1)$$

$$\boxed{V_L = \sqrt{5Rg}} \quad \text{------} (2)$$

$\sqrt{2.g.h} = \sqrt{5.R.g}$

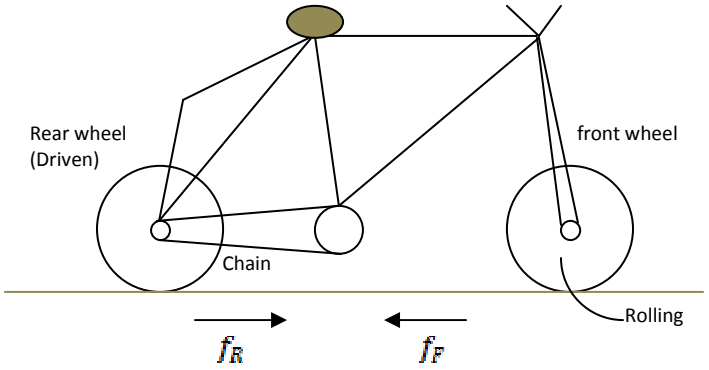
$2.g.h = 5.R.g$

$$\boxed{h = \frac{5}{2}R}$$

**Q.13.** **i) Mark the directions of friction in a moving cycle, when the person is pedaling.**
**ii) Mark the directions of friction in a moving cycle, when the person is not pedaling.**

Ans. Case-I:-

Rear wheel is driven by the cyclist. This is why Friction acts in the Forward direction. Front wheel is rolling that is why Friction acts in backward direction.




Case-II:- No Pedaling

Both the wheels are rolling. So, Friction acts in backward direction.