FRICTION

In this lesson you will learn about

* Friction, Advantages and disadvantages
* Methods of minimising friction
* Normal reaction
* Types of friction
* Motion on a Horizontal rough surface
* Block pressed against a vertical wall
* Reference frames
* Block in a lorry

Real life applications:

* Walking: if there is no friction between your shoes or feet and the floor,you would be slippering in one place forever
* Breaks : it is used to stop your car/bike when you step on the breaks.
* When cold, you rub your hands together to warm your hands.the heat comes from friction
* Rubbing the mouse pad of laptops
* Friction is very useful in industry. in wheet flour mill running through the conveyor belt due tofriction.

Important Formulae:

1. N=W=mg
2. $f_s = \mu_s N = \mu_s mg$
3. $f_k = \mu_k N = \mu_k mg$
4. $f_r = \mu_r N = \mu_r mg$
5. $a = -\mu_k g$
6. $s = \frac{u^2}{2\mu_k g}$
7. $t = \frac{u}{\mu_k g}$
8. $a = \frac{F - \mu_k mg}{m}$
9. $a = (\mu_s - \mu_k)g$
10. $\mu_s F = mg$

FRICTION :

The property by virtue of which an opposing force is generated between two rough surfaces in contact with each other and which opposes the sliding of one surface over the other is known as friction.

FRICTIONAL FORCE :

The force which opposes the sliding or relative motion of two bodies in contact with each other, is called frictional force.

Frictional force some times may be in the direction of motion of the body

EX :1 If you are walk f a car. When the car is accelerated, direction of frictional force on the rear wheels will be in the direction of motion and on the front wheels in the opposite direction of motion

CAUSES OF FRICTION

1. A surface through appears smooth by visual inspection or by touch, but when viewed under a powerful microscope, it consists of a large number of surface irregularities.
2. When two bodies are placed one above the other, these surface irregularities interlock together and oppose any attempt to bring a relative motion between the bodies.
3. When a sufficiently large force is applied, these irregularities will be sheared off and breaking of locked joints takes place and the body starts sliding on the surface.
4. Friction is due also to cohesive or adhesive force among molecules at close proximity.

ADVANTAGE OF FRICTION :

* Friction plays an important role in our daily life. While walking friction between the ground and shoes prevent us from slipping
* Without friction motion cannot be conveyed by belts from motor to machine
* Vehicles will not come to rest even if the brakes are applied when there is no friction between tyres and the road.
* When there is no friction knots cannot be tied.
* Nails and screws do not hold the boards together without friction.

DISADVANTAGES OF FRICTION :

* Friction causes wear and tear of moving parts of the machinery.
* Friction generates heat in machine parts which damages the machinery.

METHODS OF REDUCING FRICTION :

* **POLISHING :** Friction can be reduced by making the surface in contact polished and smooth. This will remove the irregularities of the surfaces thereby breaking the inter–locking.
* **LUBRICANTS :** Friction can be reduced by using lubricating materials such as grease, oil or graphite on the surfaces. Friction can be reduced by introducing a layer of gases between sliding surfaces. Lubricants should have low density, high viscosity and they should be non volatile.
* **BALL BEARINGS:** By using ball and roller bearings, the sliding friction is converted into rolling friction, thereby the friction is reduced.

* **STREAMLINING :** Automobiles and aeroplanes are streamlined to reduce the friction due to air.

NOTE : Polishing the surfaces to higher degree leads to increase of friction.

NORMAL REACTION (R) :

* When a body rests on another, the force acting on the bottom surface of the body is called the normal reaction. This is always perpendicular to the surface.
* When the body lies on a horizontal surface

R = W = mg

TYPES OF FRICTION

There are three types of frictional forces

i. Static friction ii. Dynamic friction iii. Rolling friction

* **STATIC FRICTION :** The frictional force, which is effective before motion starts between two surfaces in contact with each other, is known as static friction

Note : 1) Static frictional force is a variable and self adjusting one

2) The maximum frictional force when the body is ready to start is called limiting frictional force

* **DYNAMIC OR KINETIC FRICTION :** The frictional force, which is effective when two surfaces in contact with each other are in relative motion with respect to each other, is known as dynamic friction.
* **ROLLING FRICTION :** The frictional force, which is effective when a body rolls or rotates on a surface is known as rolling friction.

It is due to deformation at the point of contact.

LAWS OF FRICTION

Prof.Coulomb, after extensive experiments, gave some laws of friction. It is known as **laws of Coulomb friction or dry friction**.

* Friction opposes relative motion between two surfaces in contact and is always tangential to the surface of contact.
* Friction depends on the nature of the two surfaces in contact i.e., nature of materials, surface finish etc.
* Friction is independent of the area of contact between the two surfaces
* Friction is directly proportional to the normal reaction acting on the body.
* $F \alpha N \Rightarrow F = \mu N$ Where μ = coefficient of friction

Characteristics of static friction :

a) When there is no component of external force parallel to the two surfaces in contact with each other, the force of static friction is zero.

b) When an external force is applied parallel to one of the surfaces in contact with each other, and the two surfaces are at rest relative to one another, the force of static friction between the two surfaces is equal to the applied force.

c) In the above case, if the surfaces continue to remain at rest relative to one another, the force of static friction always equals to the external force and increases as the external force

increases.

d) The force of static friction between two surface attains a maximum value when, the two surfaces just begin to slide or slip relative to each another.

e) The maximum force of static friction (f_s) equals the external force applied parallel to one of the two surfaces, required to just cause sliding or slipping between the two surfaces.

f) The maximum force of static friction between two surface is also called limiting frictional force.

g) The limiting frictional force between two surfaces is given by $\boxed{f_s = \mu_s N}$

μ_s is called the coefficient of static friction between the two surfaces and N is the normal force between the two surfaces.

h) The static frictional force between two surfaces is $\boxed{f \le \mu_s N}$

i) μ_s is a dimensionless, unitless physical quantity which depends upon the nature of the surfaces in contact with each other, condition of the surfaces (presence of impurities, extent of roughness, presence of lubricant, temperature etc).

j) μ_s between two given surfaces is independent of the normal force between the two surfaces.

k) $\mu_s > 0$, it can also be greater than one, but in most of the cases it is less than one.

Ex1: A force of 98N is required to just move a body of mass 100kg over ice . calculate the coefficient of static friction between ice and the body. ($g=9.8\ m/s^2$)

Sol: Normal reaction (N)= mg

force required to move the body $f_s = \mu_s N = \mu_s mg$ 98N= μ_sx100kgx9.8 m/s^2

The coefficient of static friction $\mu_s = \frac{98}{100x9.8} = 0.1$

Ex 2: A conveyor belt is used to carry cans from one part of a factory to another. each can has mass 350g. if μ_s=3/4 and each can is in limiting friction on the belt, find the frictional force acting on each can .($g=980\ cm/s^2$)

Sol: Normal reaction (N)= mg

$N=350gx980\ cm/s^2$

limiting frictional force $f_s = \mu_s N = \mu_s mg$

$f_s = \frac{3}{4}x350x980 = 257250dyne$

Ex 3: The angle of friction between two surfaces is 37^0 . if $cas37^0=4/5$,$sin37^0=3/5$ coefficient of static friction between those two surfaces is.

Sol : If μ_s is coefficient of static friction and α is angle of friction , $\tan\alpha = \mu_s$

The coefficient of static friction $\mu_s = \tan\alpha = \tan37^{0=} \sin37^0/cas37^0 = 3/4$

Ex 4: A horizontal force of $4\sqrt{3}$ kg.wt is just sufficient to pull a body of 8kg.wt on a horizontal surface. Find the coefficient of static friction between those two surfaces.

Sol: limiting frictional force $f_s = \mu_s N = \mu_s mg$

$4\sqrt{3}$x9.8N = μ_sx8x9.8N

The coefficient of static friction $\mu_s = \frac{4\sqrt{3}}{8} = \frac{\sqrt{3}}{2}$

TEACHING TASK

Single correct option questions:

1. ..... is dimensionless quantity

   A) normal reaction B) static friction C) limiting friction D) coefficient of friction

2. When normal reaction is halved the coeffient of friction is

   A) halved B) unchaged C) Doubled D) None

3. Two masses m1 and m2 (m1>m2) are falling from the same height when same air resistance acts on them.

   A) m1 has more acceleration B) m1 reaches the ground the early

   C) m1 has more velocity on striking the ground D) All the above

4. Which of the following is correct

   A) Using ball bearings, sliding friction changes to rolling friction

   B) Lubricants decrease friction since inter molecular forces are weak in liquids.

   C) Over polishing increase friction since surface adhesion increases

   D) All of the above

5. A cycle is fitted with small brakes and another is fitted with very big brakes. The one which is more effective is

   A) Small brakes B) Big brakes C) both are equally effective D) None

More than one answer questions

6. Friction is ..... force

   a) Contact b) Non-conservative c) Self- adjusting d) electro magnetic

   A)only a,b B)only b,c C) only a,b,c D) all the above

7. The contact force exerted by a body. A on another body B is equal to the normal force between the bodies. We conclude that

   a) the surface must be frictionless

   b) the force of friction between the bodies is zero

   c) the magnitude of normal force equals that of friction

   d) the bodies may be rough but they dont slip on each other

   A) a , c are true B) a,b,d are true C)b,d are true D) all are true.

Assertion and Reasoning questions

A) Both A and R are true and R is the correct explanation for A.

B) Both A and R are true and R is not correct explanation of A.

C) A is true but R is false.

D) A is false but R is true

8. A : On polishing the surface the friction decreases upto certain limit but increases beyond that

R : On polishing the surface, the irregularities are cut off

9. A: When a bicycle is being pedaled, the friction on the front wheel is in a direction opposite to the motion of bicycle

R : The rear wheel while being pedalled, pushes the front wheel on rough road due to which the friction opposes the relative motion

Match the following:

10. a) static friction — e) constant for a given pair of surfaces
b) Limiting friction — f) independent of area of contact
c) kinetic friction — g) self adjusting
d) rolling friction — h) has the least magnitude for a given normal reaction

A) a-e, b-f,c-g, d-f B) a-h, b-f c-e d-g
C) a-g b-e c-f d-h D) a-g, b-h c-f d-e

11. a) frictional force — e) reduction of friction
b) rolling friction — f) adhesive force
c) ball bearing — g) deformation at the point of contact
d) excessive polishing — h) increase of friction
i) conservative force

A) a- i b-e c-h d-f B) a- f, b-i, c-e d-g
C) a-f b-g c-e d-h D) a-,i b-f, c-h d-e

Comprehension type questions

12. Friction may be defined as the opposing force which comes into play tangentially between the surfaces so nas to destroy the relative motion between them. Friction is advantageous and also an evil. There are methods to reduce the excess friction.

i)Friction is ..... force along common tangent to the contacting the surfaces.

A) contact and conservative B)contact and non conservative
C) non contact D) conservative

ii) Automobiles and aeroplanes are specially designed

A) streamlining reduces the friction B) streamlining increases the friction
C) to be enough strong to carry heavy loads D)none of the above.

Fill in the blanks:

13. If a person is walking due north, the frictional force diercts .....

14. Frictional force ..... relative motion between two bodies

15. The laws of friction were proposed by .....

16. If normal force is doubled, force of friction is .....
17. If normal force is doubled, coefficient of friction is .....

Key:1) D, 2) B, 3) D, 4) D, 5) C, 6) D, 7) C, 8) B, 9) A, 10) C, 11) C, 12) i)B, ii) A, 13) due north, 14) opposes, 15) Coulomb, 16) gets doubled, 17) remains same

LEARNER'S TASK

BEGINNERS (Level - I)

Single correct option questions:

1. To keep a particle moving with constant velocity on a frictionless surface, an external force
   1) should act continuously 2) should be a variable force
   3) not necessary 4) should act opposite to the direction of motion
2. Frictional force between two bodies
   1) Adds the motion between the bodies
   2) Destroys the relative motion between the bodies
   3) Sometimes helps and sometimes opposes the motion
   4) Increases the relative velocity between the bodies
3. Theoretically which of the following are best lubricants
   1) Solids 2) Liquids 3) Gases 4) Both 2 and 3
4. When a moving body is suddenly stopped
   1) Frictional force increases 2) Roughness is found on the road
   3) Tyres of the vehicles burst
   4) The frictional force reduces to zero as it is a self adjusting force
5. A block 'B' rests on 'A'. A rests on a horizontal surface 'C' which is frictionless. There is friction between A and B. If 'B' is pulled to the right
   1) B moves forward and A to the left 2) 'B' only moves to the left
   3) 'B' does not move 4) 'A' and 'B' move together to the right
6. Sand is dusted to the railway tracks during rainy season to
   1) Make it always wet 2) Increase friction
   3) To reduce consumption of fuel 4) Make it always dry
7. With increase of temperature, the frictional force acting between two surfaces
   1) Increases 2) Decreases
   3) Remains same 4) May increase or decrease
8. If we imagine ideally smooth surfaces and if they are kept in contact, the frictional force acting between them is

1) Zero 2) A finite value but not zero
3) Very large 4) We can't predict

9. If man is walking, direction of friction is
1) Opposite to direction of motion 2) Same as that of direction of motion
3) Perpendicular to that of direction of motion 4) 45º to the direction of motion

10. Maximum value of static friction is
1) Limiting friction 2) rolling friction 3) static friction 4) normal reaction

11. A static friction is
1) Equal to dynamic friction 2) Always less than the dynamic friction
3) Always greater than the dynamic friction
4) Some times equal to dynamic friction

12. When a bicycle is in motion, the force of friction excreted by the ground on the two wheels is such that it acts
1) in the backward direction on the front wheel and in the forward direction on the rear wheel
2) in the forward direction on the front wheel and in the backward direction on the rear wheel
3) in the backward direction on both the front and rear wheels
4) in the forward direction on both the front and rear wheels

13. Aeroplanes are streamlined to reduce
1) fluid friction 2) sliding friction 3) kinetic friction 4) limiting friction

14. If an external force and the frictional force acting on a body cancel each other the frictional force is
1) Rolling friction 2) Sliding friction 3) Static friction 4) Normal reaction

15. A high pressure tyre rolls more easily than a low pressure tyre because
1) Friction is less in high inflated tyre
2) Friction is more in high inflated tyre
3) Friction is zero in high pressure tyre
4) Produces force in the forward direction

16. While walking on ice one should take small steps to avoid slipping. This is because smaller steps ensure
1) larger friction 2) smaller friction 3) larger normal force 4) smaller normal force

17. In order to stop a car in shortest distance on a horizontal road, one should
1) apply the brakes very hard so that the wheels stop rotating
2) apply the brakes hard enough to just prevent slipping
3) pump the brakes (press and release):
4) shut the engine off and not apply brakes

Key: 1)3, 2) 2, 3) 3, 4) 4, 5)1, 6)2, 7)2, 8)2, 9) 2, 10) 1, 11)3, 12) 1, 13)1, 14) 3 15) 3, 16) 1, 17)3

II. More than one correct option questions

1. Select wrong statement

a) lubricants should have high density b) rolling reduces the friction

c) friction produces heat d) compressed air is good lubricant

A)a,b only B)b,c only C)a,b,c only D) only a

2. The limiting friction between two surfaces depends on

a) on the nature of two surfaces b) on normal reaction

c) on the weight of the body d) on volume of the body

A)a,b correct B)b,c correct C)a,b,c correct D) All correct

***III.* Assertion - A and Reason - R:**

A) Both A and R are true and R is the correct explanation for A.

B) Both A and R are true and R is not correct explanation of A.

C) A is true but R is false. D) A is false but R is true

3. A : Horse has to pull a cart harder during the first few steps of his motion

R : The first few steps are always difficult.

4. A : Frictional force is independent of the velocity of the body

R : friction is due to surface irregularities.

5. A : When you shake hands with your friend the force involved is eletromagnetic in nature.

R : frictional force is electromagnetic in nature.

6. A : Brakes of very small contact area are not used although friction is independent of area of contact.

R : Friction resists relative motion.

Match the following:

7. a) static friction e) the body rolls on the surfacxe

b) sliding friction f) surface of the objects are rest relative to each other

c) kinetic friction g) objects is sliding over another

d) rolling friction h) objects are in motion

A) a- e, b-f, c-g, d-h B) a-f, b-g, c-h, d-e

C) a-g, b-e, c-f, d-h D) a-g, b-h, c-f, d-e

Comprehension type questions

8. Friction is disadvantageous becuse it results in loss of mechanical energy and hence produces many undesirable effects.

i) On a rainy day, it is difficult to drive a car or bus at high speed because the coefficient of friction ..... due to wetting of surface.

A) increased B) decreased C) does not change D) none

ii) As friction is non conservative, when a body moves on rough surface the

mechanicalenergy is .....

A) constant B) non constant C) zero D) infinity

Fill in the blanks:

9. The process ..... is used to reduce the friction among parts of vehicles
10. Friction is ..... on area of contact
11. Polishing highly leads to ..... of friction
12. Friction between two bodies generates .....
13. Among the all the best lubricants theoritically .....

Key: 1) D, 2) C, 3) C, 4) B, 5) A, 6) B, 7) B, 8) i) B, ii) B, 9) lubrication, 10) independent, 11) increase of friction, 12) heat, 13) gases.

Kinetic friction or Sliding friction or Dynamic friction

a) It is the force of friction which acts between two surfaces, only when they slide or slip relative to each other.

b) The force of kinetic friction between two surfaces (f_k) equals the force needed to be applied to one of the surfaces, parallel to the surfaces in contact with other, such that the two surfaces slide relative to each other with uniform velocity.

c) More force is needed to set a body into motion, than to keep it moving with uniform velocity on a surface.

d) The force of kinetic friction between two given surfaces is less than the limiting frictional force between the two surfaces ($f_k < f_s$)

e) The force of kinetic friction between two surfaces is independent of relative velocity between the two surfaces, provided the velocity is neither too low nor too large.

f) The force of kinetic friction between two surfaces is given by $\boxed{f_k = \mu_k N}$

g) μ_k is the coefficient of kinetic friction, which is a dimensionless, unitless constant and depends upon the nature of the surfaces in contact with each other and the condition of the surfaces in contact with each other.

f) $\mu_k < \mu_s$ for a given pair of surfaces.

Ex: what are the values of force of friction f and acceleration of the block a if the force F is gradually increased.

Rolling friction :

a) Rolling friction comes into play when a body such as a wheel rolls on a surface.

b) Rolling friction arises out of the deformation of the two surfaces in contact with each other.

c) Greater the deformation, greater is the rolling frictional force.

d) The rolling frictional force is inversely proportional to the radius of the rolling body.

e) The rolling frictional force between two given surfaces is less than kinetic and limiting frictional forces.

f) If μ_R is the coefficient of rolling friction $\mu_R < \mu_k < \mu_s$ for a given pair of surfaces.

g) Ball bearings are used in machinery parts because rolling friction is least.

h) Radial tyres used in cars reduce rolling friction.

i) Rolling friction is directly propotional to Normal force

$$f_r \propto N \text{ or } f_r = \mu_r N \text{, therefore } \mu_r = \frac{f_r}{N}$$

Where μ_r is called co-effcient of rolling friction

co-effcient of friction $\mu_r = \frac{Rolling friction(f_r)}{Normal force(N)}$

Comparision of μ_s, μ_k and μ_r

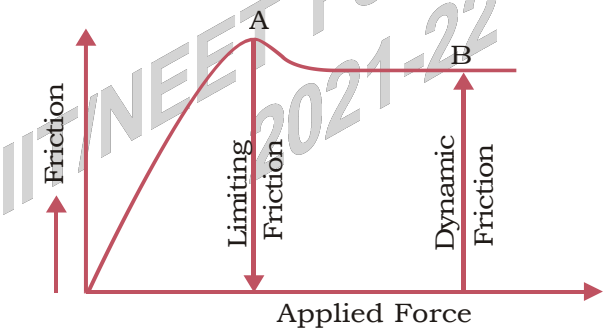
The force of Kinetic friction is always less than the force of static/limiting friction

$\mu_k R < \mu_s R \quad \therefore \mu_k < \mu_s \rightarrow (1) \qquad \mu_r R < \mu_k R \quad \therefore \mu_r < \mu_k \rightarrow (2)$

relation between three kinds of coefficients of friction is $\mu_r < \mu_k < \mu_s$

GRAPHICAL REPRESENTATION

1) Here we notice that until the static friction reaches its maximum value applied force is directly proportional to the frictional force. Thus the angle made by the straight line with X-axis is equal to 45^0. Slope of the line m = tan 45^0 = 1

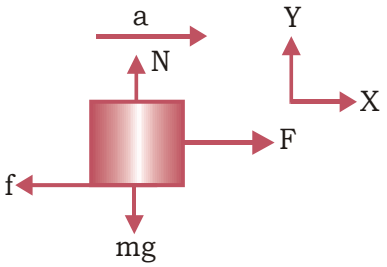


2) However, the magnitude of force required to keep the body sliding under friction with constant velocity is slightly less than the force required to start the motion. The friction in this condition is called dynamic friction.

3) Hence dynamic friction is less than the limiting friction for the same body on the same surface. Even if the applied force is increased the dynamic friction is remains constant.

Example: Given that $\mu_s = 0.5, \mu_k = 0.4$ and g = 10 m/s^2.

Sol: Free body diagram of block is



$\sum F_y = 0, \quad \therefore N - mg = 0$ or

N = mg = (1) (10) = 10 N

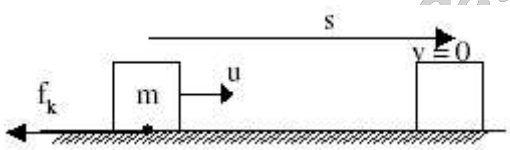
$f_L = \mu_s N = (0.5)(10) = 5N$

$f_k = \mu_k N = (0.4)(10) = 4N$

Below is explained in tabular form, how the force of friction f depends on the applied force F.
mass of the body 1kg

F	f	F_{net}=F–f	Acceleration of block $a = \frac{F_{net}}{m}$	Diagram
0	0	0	0	
2N	2N	0	0	f=2N F=2N
4N	4N	0	0	f=4N F=4N
5N	5N	0	0	f_L=5N F=5N
6N	4N	2N	$2m/s^2$	a=2m/s² f_k=4N F=6N
8N	4N	4N	$2m/s^2$	a=4m/s² f_k=4N F=8N

Sliding block on a horizontal surface comming to rest :



a) If a block having initial velocity u slides on a rough horizontal surface and comes to rest, the acceleration of the block is $\boxed{a = -\mu_k g}$

b) Distance travelled by the block before comming to rest is $\boxed{S = \frac{u^2}{2\mu_k g}}$

c) time taken by the block to come to rest is $\boxed{t = \frac{u}{\mu_k g}}$

MOTION ON A HORIZONTAL ROUGH SURFACE

* When a body of mass m on a horizontal rough surface is pulled or pushed with a horizontal force F,
* If the body does not move, the frictional force is equal to the applied force in backward direction.
* If the body is about to move. Then the
  Friction force = $\mu_s R = \mu_s mg$
* If the applied force f > $\mu_s mg$, the body moves forward.

Then the frictional force = $\mu_K mg$

The body moves forward with an acceleration a = $\frac{F - \mu_k mg}{m}$

* If a minimum force, required to move the body is applied and it is further continued, the body moves with an acceleration. a=($\mu_s - \mu_k$)g

Ex 1: A block is projected along a rough horizontal road with a speed of 10m/s. if the coefficient of kinetic friction μ_k is 0.1 .how far will it travels before coming to rest

Sol: μ_k = 0.1, (g=10 m/s^2) frictional force $s = \frac{v^2 - u^2}{2a} = \frac{0 - 10^2}{2X - 1} = \frac{100}{2} = 50m$

retardation due to friction = $-\frac{f_k}{m} = \frac{-\mu_k mg}{m} = -\mu_k g$

retardation due to friction=-0.1x10m/s^2=-1m/s^2

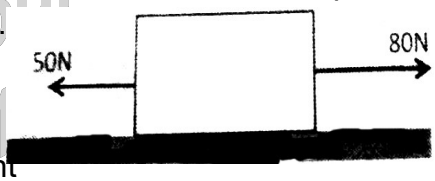
according to $v^2 - u^2 = 2as$, u=10m/s, v=0

distance travelled $s = \frac{v^2 - u^2}{2a} = \frac{0 - 10^2}{2X - 1} = \frac{100}{2} = 50m$

Ex 2: A rectangular block of mass 20 kg placed on a horizontal surface is pulled to right by a force of 80N and to the left by a force of 50N.

if it slides with constant velocity,

find the coefficient of kinetic friction.



Sol: Net applied force=80N-50N=30N to wards right

since the body is moving with constant velocity the force of friction =net applied force

$f_k = 30N = \mu_k mg$ $\mu_k = \frac{30N}{20kgX10\,m/s^2} = 0.15$

Ex 3: A stone of mass 10kg sliding on ice with a velocity of 2m/s is stopped by friction in 10s find the force of friction(assumed to be constant) acting on it is.

Sol : $a = \frac{v - u}{t} = \frac{0 - 2}{10} = \frac{-2}{10} = -0.2m/s^2$

frictional force =ma

frictional force =10kg X $-0.2m/s^2$=-2N

Ex 4: A force of 6 N acts on a body of mass 4kg resting on a rough surface (coefficient of friction is 0.3, g = 10 ms^{-2}.) The acceleration of the body in ms^{-2} is

Sol : Applied force F=6N

force of limiting friction $f_s = \mu_s N = \mu_s mg$ =0.3x4x10N=12N

i.e, f_s >F body is continue in the same state of rest.

so, acceleration a=0

Ex 5: Brakes are applied to a car moving with disengaged engine, bringing it to a halt after 5 s. What is its velocity at the moment when the brakes are applied if the coefficient of friction between the road and the tyres is 0.4? (g=10 m/s^2)

Sol: t=5s μ_k =0.4, acceleration $a = -\mu_k g$ =-0.4x10 m/s^2= -4m/s^2

according to $v = u + at$ (or) 0=u-4x5$\Rightarrow$ u=20m/s

Ex 6: Abook weighing 800 g is kept on a horizontal table. How many force is exerted by the table on the book? (Take = 10 ms^{-2})

Sol: The book exerts a force to its weight on the table.

This force is called ' action'.

Action = W= mg = 0.8 x 10 = 8 N

According to Newton's III law of motion , the table exerts an equal and opposite force on the book. It is called reaction.

R = Action = 8 N It acts vertically upwards.

Example 7: Figure below show a trolley of mass 300 g lying on a smooth horizontal surface. A boy pulls it with a force 1.2 N. If a constant frictional force of 0.3 N acts on it, how much distance it will travel in 0.8 s?

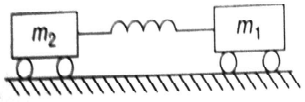
Solution: Since the two forces are acting in opposite direction, net force acting on the trolley = $F_1 \_ F_2$ = 1.2 N - 0.3 N= 0.9 N

We know that Newton's II law of motion gives us F = ma (or) 0.9 N = 0.3 kg x a

$\therefore a = \frac{0.9N}{0.3kg}$ = 3 ms^{-2}, S = ut + $\frac{1}{2}$ at^2 = 0 + $\frac{1}{2}$ x 3 x (0.8)^2 = $\frac{1}{2}$ x 3 x 0.8 x 0.8 = 0.96 m

Example 7: Two trolleys m_1 = 0.2 kg and m_2 = 0.3 kg are held against a compressed spring on a smooth horizontal table, as shown in the figure below.

Solution: When the spring is cut, m is found to move towardds right with an initial acceleration of 6 ms^{-2} .



Find the initial acceleration of m_2.

$\therefore$ $F_2 = F_1$

i.e, $m_2 a_2 = -m_1 a_1$

0.3 kg x a_2 =-0.2 kg x 6 ms^{-1}

$\therefore a_2 = -\frac{0.2 \times 6}{0.3}$, a_2 = -4 ms^{-2}

Negative sign implies that is in opposite directionof that of m_1 i.e, a_1

$\therefore$ Acceleration of m_2 = 4 ms^{-2} towards left.

Ex 8: A toy rocket weighing 500 g is standing vertically on ground .How much force should act on it so that it starts ascending with a uniform accelera tion of 5 ms^{-2} (Take g = 10 ms^{-2})

Sol : To go up, the upwards force should acting on the rocket must be greater than its weight 'mg'.

Net force acting on rocket

$F_{net} = F_{up} - mg$----------(i)

By Newton's II law,

$F_{net} = ma$----------(ii)

From equation (i) and (ii),

$F_{up} - mg = ma$

$F_{up} = mg + ma = m(g + a) = 0.5\ kg\ (10 + 5)\ ms^{-1}$

$= 0.5 \times 15\ kgms^{-2} = 7.5\ N$

Ex 9: A force produces an acceleration of 2.0 ms^{-2} in a body A and 5.0 ms^{-2} in another body B. Find the ratio of the masses of A to the mass of B.

Sol : Let the mass of the body A be m_A and that of the body B be m_B. We have

$F = (m_A)(2.0\ ms^{-2})$

$F = (m_B)(5.0\ ms^{-2})$

Thus $(m_A)(2.0\ ms^{-2}) = (m_B)(5.0\ ms^{-2})$

Or $\frac{m_A}{m_B} = \frac{5.0}{2.0} = 2.5$

TEACHING TASK

Single correct option questions:

1. A body of mass 2kg is slipping on a frictionless horizontal table with a velocity of 4 m/s. The necessary force in newton to keep the body moving with the same velocity will be

   1) Zero 2) 8 3)50 4)200

2. Brakes stop a train in certain distance. When the breaking force is made one fourth, the brakes will stop the train in a distance which is now

   1) same 2)half 3) double 4) four times

3. A body of mass 6kg. is in uniform motion along a straight line when a force of 12N is acting on it. If g = 10 ms^{-2}, the frictional force acting on the body, is

   1) 6 N 2) 12 N 3) 18 N 4) 24 N

4. A force of 4 N acts on a body of mass 4kg resting on a rough surface (coefficient of friction is 0.2, g = 10 ms^{-2}.) The acceleration of the body in ms^{-2} is

   1) 1 2) 0.5 3) 0.25 4) Zero

5. A car of mass 1000kg moving with a velocity of 10ms^{-1} is acted upon by a forward force of 1000 N due to engine and retarding force of 500N due to friction. Its velocity after 10s is

   1) 10 ms^{-1} 2) 15 ms^{-1} 3) 25 ms^{-1} 4) 20 ms^{-1}

6. Brakes are applied to a car moving with disengaged engine, bringing it to a halt after 2s. What is its velocity at the moment when the brakes are applied if the coefficient of friction between the road and the tyres is 0.4?

   1) 3.92 ms^{-1} 2) 7.84 ms^{-1} 3) 11.2ms^{-1} 4) 19.6 ms^{-1}

7. A car running with a velocity 72 kmph on a level road, is stopped after travelling a distance of 30m after disengaging its engine (g = 10ms^{-2}). The coefficient friction between the road and the tyres is

1) 0.33 2) 4.5 3) 0.67 4) 0.8

8. The coefficient of friction between a car's wheels and a roadway is 0.5. The least distance in which the car can accelerate from rest to a speed of 72 kmph is g=10 ms^{-2}

1) 10m 2) 20 m 3) 30 m 4)40m

9. An eraser weighing 2N is pressed against the black board with a force of 5N. The coefficient of friction is 0.4) How much force parallel to the black board is required to slide the eraser upwards?

1) 2 N 2) 2.8 3) 4 N 4) 4.8 N

10. Two bodies having the same mass, 2 kg each, have different surface area 50m^2 and 100m^2 in contact with a horizontal plane. If the coefficient of friction is 0.2 the forces of friction that come into play when they are in motion, will be in the ratio

1) 1 : 1 2)1:2 3) 2: 1 4) 1 : 4

11. A body of mass 60kg is pushed with just enough force to start it moving on a rough surface with $\mu_s = 0.5$ and $\mu_k = 0.4$ and the force continues to act afterwards. The acceleration of the body is

1) 0.98 m/sec^2 2) 3.92m/sec^2 3) 4.90m/sec^2 4) Zero

12. If $\mu_s, \mu_k, and\ \mu_r$ are the coefficients of static, kinetic and rolling friction repectively then

1) $\mu_s > \mu_k < \mu_r$ 2) $\mu_s < \mu_k > \mu_r$ 3) $\mu_s > \mu_k > \mu_r$ 4) $\mu_s = \mu_k = \mu_r$

II. More than one correct option questions

13. Frictional force between the two bodies --------- motion.

a) opposes b) sometimes cooperative

c) never change d) depends on area of contact

A) only a, b B) only b, c C) only a,b,c D) all the above

14. A block is placed on a rough floor on a horizontal force F is applied on it.The force of friction f by the floor on the block is measured for different values of F and a graph is plotted between them

a) a graph is straight line having slope 75^0

b) graph is straight line parallel to the F axis

c) the graph is with slope 45^0 for small Fand a straight line parallel to F axis for large F

d) there is a small kink on the graph.

A) a &c are true B) a,b & d are true C) c & d are true D) all are true

Assertion and Reasoning

A) Both A and R are true and R is the correct explanation for A.

B) Both A and R are true and R is not correct explanation of A.

C) A is true but R is false. D) A is false but R is true

15. A : Ball bearings are good lubricants
R : Ball bearings convert translatory motion into rotatory motion.

16. A : The value of dynamic friction is less than the limiting friction
R : Once the motion has started , the inertia of rest hasbeen overcome.

17. A : A coin placed on a rotating disc files away if the angular velocity is gradually incresed
R : Friction cannot provide the sufficient centripetal force.

Match the following:

18. a) non conservative force 1) depends on mass
b) conservative force of path 2) work done independent
c) deceleration due to friction on 3) workdone depends on path rough horizontal surface d) accelerating force 4) independent of mass on a smooth inclined surface.
A) a-3, b-4, c-2, d-1 B) a-2, b-1, c-4, d-3 C) a-3, b-2, c-4, d-1 D) a-1, b-3, c-4, d-2

Comprehension type questions:-

19. The coefficients of static and dynamic friction of the body mass 1 kg are 0.7 and 0.4 The minimum force required to create motion is applied on a body and if it is further continued, ($g=10\ m/s^2$)
i) The value of force act on the body is
A)7 N B)4 N C)3N D)11N
ii) The resultent acceleration attained by the body in ms^{-2} is
A)7 B)4 C)11 D)3

20. If a block having initial velocity 3m/s slides on a rough horizontal surface and comes to rest, the coefficients of dynamic friction 0.3 ($g=10\ m/s^2$)
i) Distance travelled by the block before comming to rest is
A) 9 m B) 4 m C) 1.5 m D) 3 m
ii)time taken by the block to come to rest is
A) 1 s B) 2 s C) 1.5 s D) 3 s

Fill in the blanks:

21. A foce of 120 N is required to initiate motion in a body, then the force required to move the body against kinetic friction is 120N

22. In f-F graph the slope of the line is .....

23. A force of 6 N acts on a body of mass 4 kg, resting on a rough surface of coefficient of friction 0.2. The force still needed to move the body is ..... ($g=10\ m/s^2$)

24. If a body moves with velocities 3 m/s and 4 m/s on a rough surface, the ratio of kinetic friction in two situations is .....

Key: 1)1, 2)4, 3)2, 4)4, 5)2 , 6)2, 7)3, 8)4,9)1, 10)1, 11)1, 12) 3 13) A, 14) C, 15) A, 16) B, 17) A, 18) C, 19) i) C, ii) D, 20) i) C, ii) A, 21) less than, 22) one, 23) 2 N, 24) 1 : 1.

LEARNER'S TASK

BEGINNERS (Level - I)

Single correct option questions:

1. A man slides down on a telegraphic pole with an acceleration equal to one-fourth of acceleration due to gravity. The frictional force between man and pole is equal to in terms of man's weight w

   1) w / 4 2) w / 2 3) 3w / 4 4) w

2. Brakes are applied to a car moving with disengaged engine, bringing it to a halt after 1s. What is its velocity at the moment when the breaks are applied if the coefficient of friction between the road and the tyres is 0.4?

   1) 3.92 ms^{-1} 2) 7.84 ms^{-1} 3) 11.2ms^{-1} 4) 19.6 ms^{-1}

3. A car running with a velocity 20 m/s on a level road, is stopped after travelling a distance of 30m after disengaging its engine (g = 10ms^{-2}). The coefficient friction between the road and the tyres is

   1) 0.33 2) 4.5 3) 0.67 4) 0.8

4. If the above car got a stopping distance of 80m on cement road then μ_k is (g=10 m/s^2)

   1) 0.2 2) 0.25 3) 0.3 4) 0.35

5. A body of mass 6kg. is in uniform motion along a straight line when a force of 12N is acting on it. If g = 10 ms^{-2}, the frictional force acting on the body, is

   1) 6 N 2) 12 N 3) 18 N 4) 24 N

6. In the above problem the coefficient of friction between them is

   1) 0.01 2) 0.2 3) 0.3 4) Zero

7. A body of mass 2kg is slipping on a frictionless horizontal table with a velocity of 4 m/s. The necessary force in newton to keep the body moving with the same velocity will be

   1) Zero 2) 8 3) 0.50 4) 200

8. A 10kg mass is resting on a horizontal surface and horizontal force of 80N is applied. If μ = 0.2, the ratio of acceleration with out and with friction is (g = 10ms^{-2})

   1) 3/4 2) 4/3 3) 1/2 4) 2

9. A boy pulls a 5kg block along a 20m long horizontal surface at a constant velocity by applying a horizontal force F. If the coefficient of kinetic friction is 0.2, how much work does the boy do on the block?

   1) 100J 2) 300J 3) 200J 4) 400J

Key: 1) 1, 2) 1, 3) 3, 4) 2, 5) 2, 6) 2, 7) 1, 8) 2 , 9) 3,

ACHIEVERS (Level - II)

More than one correct option questions

1. A block is placed on a rough floor and a horizontal force F is applied on it. The force of friction f by the floor on the block is measured for different values of F and a graph is plotted between them.

   a) The graph is a straight line of slope 1

   b) the graph is a straight line parallel to the F–axis

   c) The graph is a straight line of slope 1 for small F and a straight line parallel to the F–axis for large F.

   d) There is a small kink on the graph

   A) a,b correct B) b,c correct C) c,d correct D) all correct

2. The coefficient of friction depends on

   a)The type of materials the surfaces are made of.

   b) the condition of the surface

   c)Temperature

   A) Only a,b B) Only b,c C) Only c,d D) all are correct

Assertion - A and Reason - R

A) Both A and R are true and R is the correct explanation for A.

B) Both A and R are true and R is not correct explanation of A.

C) A is true but R is false. D) A is false but R is true

3. A horse has to pull a cart harder during the first few steps of his motion

   R : The first few steps are always difficult

4. A : Frictional force is independent of the velocity of the body.

   R : Friction is due to surface irregularities

Match the following:

5

a. Limiting friction	1. value is one
b. Rolling	2. kink on the graph
c. Slope of the F-f graph	3.dynamic friction- slope is zero
d. line parallel to F- axis	4. reduces friction

A) a- 2, b- 4, c- 1, d- 3 B) a- 1, b- 2, c- 3, d- 4

C) a- 2, b-1, c-3, d-4 D) a-4, b-3, c-2, d-1

Comprehension type questions:-

If a block having initial velocity 10m/s slides on a rough horizontal surface coefficient 0.5 and comes to rest($g=10m/s^2$)

6 The retardation of the block is in m/s^2

A)5 B)2 C)10 D)0.5

7 The time taken by the block before comming to rest is

A)5s B)2s C)10s D)0.5s

Fill in the blanks:

8. If a body does not move, the friction offered by the floor is ..... & ..... to applied force
9. The kink on f-F graph represents .....
10. Rolling offers ..... friction
11. Ball barings converet ..... motion to ..... motion
12. The straight line in f-F graph represents .....

Key: 1) C, 2) D, 3) B, 4) B, 5) A, 6) A, 7) B, 8) equal, opposit, 9) limiting friction, 10) less, 11) linear, rotatory, 12) kinetic friction

EXPLORERS (Level - III)

Heigher order thinking skils (HOTS)

1. A body of mass 'm' is thrown vertically up with velocity 'u'. If the resistance force due to air is 'f', the time of ascent of the body is

A) $\frac{u}{g+f}$ B) $\frac{mu}{mg+f}$ C) $\frac{u}{g-f}$ D) $\frac{mu}{mg-f}$

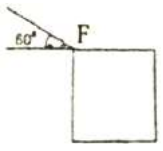
2. A vehicle of mass M is moving on a rough horizontal road with a momentum P. If the coefficient of friction between the tyres and the road is μ, then the stopping distance is

A) $\frac{P}{2\mu Mg}$ B) $\frac{P^2}{2\mu Mg}$ C) $\frac{P^2}{2\mu M^2 g}$ D) $\frac{P}{2\mu M^2 g}$

3. A body of weight 64 N is pushed with just enough force to start it moving across a horizontal floor and the same force continues to act afterwards. If the coefficients of static and dynamic friction are 0.6 and 0.4 respectively. The acceleration of the body will be (acceleration due to gravity = g)

A) $\frac{g}{2}$ B) 0.64g C) $\frac{g}{32}$ D) 0.2g

4. A block of mass $\sqrt{3}$ kg is kept on a frictional surface with $\mu = \frac{1}{2\sqrt{3}}$. The minimum force to be applied as shown to move the block is



A) 5 N B) 20 N C) 10 N D) 20/3 N

Key : 1) B, 2) C, 3) D, 4) B

Additional Practice

1. The external force applied on a body is 10N and the limiting friction between the body and the surface on which it is placed is 15N. Then the body moves with a net force is (5N)

2. An object of mass 10kg moving with a velocity of $5.6ms^{-1}$ on a surface comes to rest after travelling a distance of 16m. Then Coefficient of friction is 0.1 Work done against the friction is (156.8J)

3. A car of mass 1000kg moving with a velocity of $10ms^{-1}$ is acted upon by a forward force of 1000 N due to engine and retarding force of 500N due to friction. Its velocity after 10s is ($15\ ms^{-1}$)

4. A body of mass 2kg is placed on a horizontal surface having coefficient of kinetic friction 0.4 and coefficient of static friction 0.5. If a horizontal force of 2.5N is applied on the body, the frictional force acting on the body will be ($g = 10\ ms^{-2}$) (2.5 N)

5. In the above problem, the minimum force required to slide the body is (10 N)

6. A body of mass 4 kg is initially kept at rest on a horizontal rough uniform of $\mu = 0.7$. A horizontal force P is applied so that it covers a distance of 18 m in 3 seconds. The ratio between applied force (P) and frictional force (f) is ($g = 10\ ms^{-2}$) (11 : 7)

7. What is the smallest radius of a circle at which a bicyclist can travel if his speed 7 m/s and the coefficient of static friction between the tyres and the road is 0.25? (20 m)

RESEARCHERS (Level - IV)

Choose the correct option:

1. It is more difficult to walk on a sandy road than on a concrete road. The most appropriate reason for this is (NSEJS 2014-15)

   a) sand is soft and concrete is hard

   b) the friction between sand and feet is less than that between concrete and feet

   c) the friction between sand and feet is more than that between concrete and feet

   d) the sand is grainy but concrete is solid

2. A bullet of mass 0.02 kg travelling horizontally with a velocity 250 m/s strikes a block of wood of mass 0.23 kg which rests on a rough horizontal surface. After the impact the block and bullet move together and come to rest after travelling a distance of 40 m. The coefficient of sliding friction of the rough surface is ($g = 9.8\ m/s^2$) (2019E)

   1) 0.75 2) 0.61 3) 0.51 4) 0.30

3. A man slides down on a telegraphic pole with an acceleration equal to one.fourth of acceleration due to gravity. The frictional force between man and pole is equal to in terms of man's weight w :(2007E)

   1) $\frac{w}{4}$ 2) $\frac{w}{2}$ 3) $\frac{3w}{4}$ 4) w

4. A body of weight 64 N is pushed with just enough force to start it moving across a horizontal floor and the same force continues to act afterwards. If the coefficients of static and dynamic friction are 0.6 and 0.4 respectively. The acceleration of the body will be (acceleration due to gravity = g) [2014E]

   1) $\frac{g}{2}$ 2) 0.64g 3) $\frac{g}{32}$ 4) 0.2g

5. A body of mass 5kg rests on a rough horizontal surface of coefficient of friction 0.2. The body is pulled through a distance of 10m by a horizontal force 25N. The K.E. acquired by it is [2000E]

1) 200J 2) 150J 3)100J 4)50J

6. Consider a mass 'M' moving in the the positive x direction with an acceleration a as shown below. The minimum acceleration needed to hold a smaller mass m stationary with respect to M on the vertical side of M is (assume that the surfaces of M and m in contact are rough) (2007M)

1) g/m 2) g/M 3) 3g 4) g/μ

Key: 1) d, 2)3 , 3) 3 , 4) 4, 5) 2, 6) 4