UNIT3–LAWSOFMOTION

GREETINGSStudents,Thisclass wearegoingtodiscussaboutimpulse,KineticFriction.**Impulse**

Ifaverylargeforceactsonanobjectforaveryshortduration,thentheforceiscalledimpulsiveforceorimpulse.

Ifa force(F)actson theobject inavery shortintervalof time(D*t*),fromNewton'ssecond lawin magnitudeform

$$Fdt=dp$$

$$\int_i^f dp = \int_{t_i}^{t_f} F\,dt$$

$$p_f - p_i = \int_{t_i}^{t_f} F\,dt$$

p_i = initial momentum of the object at time t_i

p_f = final momentum of the object at time t_f

$p_f - p_i = \Delta p =$ change in momentum of the object during the time interval $t_f - t_i = \Delta t$.

The integral $\int_{t_i}^{t_f} F\,dt = J$ is called the impulse and it is equal to change in momentum of the object.

If the force is constant over the time interval, then

$$\int_{t_i}^{t_f} F\,dt = F\int_{t_i}^{t_f} dt = F(t_f - t_i) = F\Delta t$$

$$F\Delta t = \Delta p \qquad (3.24)$$

Equation (3.24) is called the 'impulse-momentum equation'.

For a constant force, the impulse is denoted as $J = F\Delta t$ and it is also equal to change in momentum (Δp) of the object over the time interval Δt.

Impulse is a vector quantity and its unit is Ns.

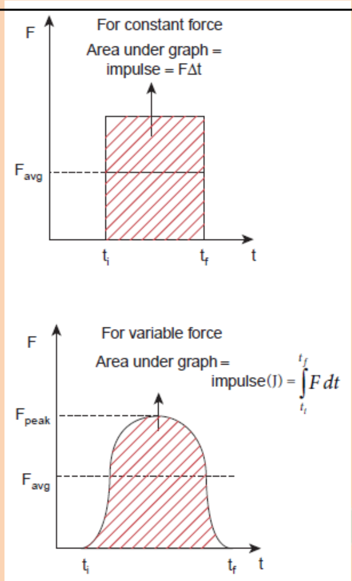
The average force acted on the object over the short interval of time is defined by

$$F_{avg} = \frac{\Delta p}{\Delta t} \qquad (3.25)$$

Integratingovertimefrom an initialtime*t*$_i$to a finaltime*t*$_f$,wegetactontheobjectisgreateriftissmaller.Whenevertheomentumofthebodychangesvery quickly,theaverageforcebecomes larger.

Theimpulse canalso be writtenintermsofthe average force.Since_*p*is changeinmomentumof the object andisequaltoimpulse (J),we have

$$J=Favg\ \Delta t$$



Illustration

1. Whenacricketplayercatchesthe ball, hepullshishands graduallyin the directionof theball's motion.Why?

Ifhestopshishandssoon aftercatchingthe ball,the ballcomestorest very quickly.Itmeans thatthe momentumoftheballisbroughttorest veryquickly. So theaverage force acting onthe body will be verylarge. Due tothislargeaverageforce, thehandswillgethurt.Toavoidgetting hurt, the playerbringsthe ballto restslowly.

2. Whenacar meets with an accident,its momentumreducesdrasticallyinaveryshort time.Thisisvery dangerousforthepassengersinsidethecarsincethey willexperience alargeforce.Topreventthis fatalshock, carsaredesignedwith airbagsin suchaway that when thecarmeetswith an accident,the momentumofthe passengers willreduceslowlyso that theaverage forceacting on themwillbe smaller.

3. Theshockabsorbersintwo wheelersplaythesameroleas airbagsinthecar.When thereisabump onthe road, a sudden forceistransferredtothevehicle.Theshockabsorberprolongs the period oftransfer offorceon tothebodyoftherider. Vehicleswithout shockabsorberswillharmthe body due to thisreason.

4. Jumping on a concrete cemented flooris moredangerous than jumping onthe sand.Sandbringsthebodytorest slowlythantheconcrete floor,sothat theaverage forceexperiencedbythebody willbelesser.

FRICTION

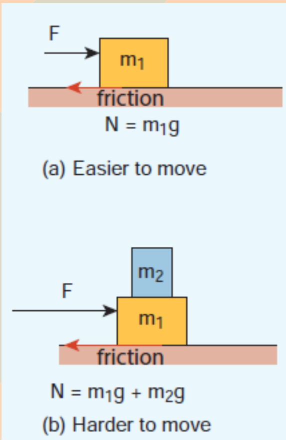
Introduction

- Ifaverygentle forceinthehorizontaldirectionisgiven toanobject at reston thetable,itdoesnotmove. Itis because of the opposingforce exerted bythe surfaceontheobjectwhichresistsits motion.

- Thisforceis calledthe*frictional force which always opposestherelative motion betweenan objectandthesurface whereitisplaced.* Ifthe force appliedisincreased, theobjectmoves after acertainlimit.
- *Relative motion*:whena force parallel tothesurfaceisapplied onthe object, theforcetriestomove the objectwithrespect tothe surface.This 'relativemotion'isopposed on theobjectina directionoppositeto applied force.
- Frictionalforcealwaysactsontheobjectparalleltothe surfaceon whichthe object isplaced. Therearetwo kindsoffriction namely
- 1) Staticfrictionand2) Kineticfriction.

StaticFriction(f_s)

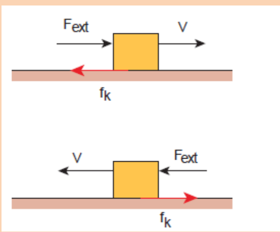
- Staticfrictionistheforcewhichopposestheinitiation of motionofan objecton the surface.Whentheobjectisatrestonthe surface,onlytwoforcesactonit.Theyarethedownwardgravitationalforceandupwardnormalforce . The resultant of these twoforcesontheobjectiszero.



$$0 \le f_s \le \mu_s N,$$

KineticFriction

Ifthe externalforce acting onthe objectisgreaterthan maximumstaticfriction, theobjects begintoslide.Whenan objectslides, thesurface exertsa frictionalforce called**kineticfrictionf$_k$(**alsocalledsliding friction ordynamicfriction). Tomovean object at constant velocity wemustapplyaforce whichisequal in magnitude andopposite tothedirectionof kinetic friction.



Experimentallyitwas foundthatthemagnitude of kineticfriction satisfiesthe relation,

$$f_k = \mu_k N$$

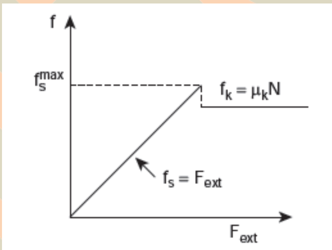
whereμk isthe coefficientof kineticfrictionand Nthe normalforce exertedbythesurfaceontheobject,

$$\mu_k < \mu_s$$

more difficultthanmaintainingit.Thesalient featuresofstatic and kineticfriction

Table 3.2 Salient Features of Static and Kinetic Friction

Static friction	Kinetic friction
It opposes the starting of motion	It opposes the relative motion of the object with respect to the surface
Independent of surface area of contact	Independent of surface area of contact
μ_s depends on the nature of materials in mutual contact	μ_k depends on nature of materials and temperature of the surface
Depends on the magnitude of applied force	Independent of magnitude of applied force
It can take values from zero to $\mu_s N$	It can never be zero and always equals to $\mu_k N$ whatever be the speed (true $v < 10\ ms^{-1}$)
$f_s^{max} > f_k$	It is less than maximum value of static friction
$\mu_s > \mu_k$	Coefficient of kinetic friction is less than coefficient of static friction



ToMoveanObject-Pushorpull?Whichis easier?

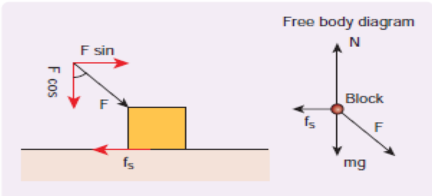
- Whena bodyispushed at anarbitraryangle (0 to$\pi/2$), theappliedforce$F$canberesolvedintotwocomponents asFsinθ parallel tothesurfaceandFcosθperpendicular tothesurface
  .
- Thetotaldownward force acting onthe bodyismg+Fcosθ. Itimplies*that*thenormalforceactingon thebodyincreases.
- SincethereisnoaccelerationalongtheverticaldirectionthenormalforceNisequalto

$$N_{push} = mg + F\cos\theta \quad (3.29)$$

As a result the maximal static friction also increases and is equal to

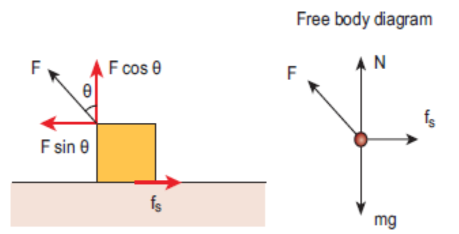
$$f_s^{max} = \mu_s N_{push} = \mu_s\left(mg + F\cos\theta\right) \quad (3.30)$$

Equation (3.30) shows that a greater force needs to be applied to push the object into motion.

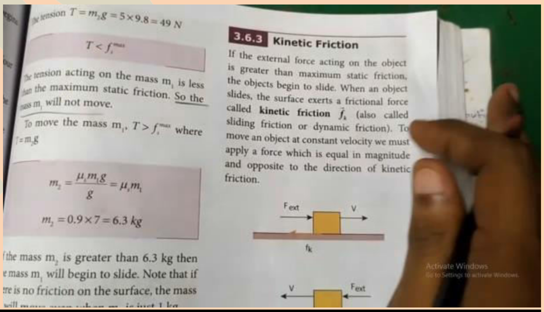


Whenan objectis pulledat anangle θ,the appliedforceisresolvedinto twocomponents. Thetotaldownwardforceactingonthe object is

$$N_{pull} = mg - F\cos\theta \quad (3.31)$$



ThenormalforceislessthanN$_{push}$.Fromequations(3.29)and (3.31),itiseasierto pullanobjectthanto push to makeitmove.


he tension $T = m_2 g = 5 \times 9.8 = 49\ N$

$$T < f_s^{max}$$

he tension acting on the mass m_1 is less an the maximum static friction. So the ss m_1 will not move.

To move the mass m_1, $T > f_s^{max}$ where $T = m_2 g$

$$m_2 = \frac{\mu_s m_1 g}{g} = \mu_s m_1$$

$$m_2 = 0.9 \times 7 = 6.3\ kg$$

the mass m_2 is greater than 6.3 kg then e mass m_1 will begin to slide. Note that if re is no friction on the surface, the mass

3.6.3 Kinetic Friction

If the external force acting on the object is greater than maximum static friction, the objects begin to slide. When an object slides, the surface exerts a frictional force called **kinetic friction** $\vec{f}_k$ (also called sliding friction or dynamic friction). To move an object at constant velocity we must apply a force which is equal in magnitude and opposite to the direction of kinetic friction.

URL:https://www.youtube.com/watch?v=veD7TlhwCE8&feature=youtu.be