CHAPTER 10

Application of Motion in Physical Sciences

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Introduction

Physics is a branch of science that deals with the structure of matter and how the fundamental constituents of the universe interact, it studies objects ranging from the very small using quantum mechanics to the entire universe using general relativity (Tegmark & Smolin, 2021). Motion is a change in the position of a body with time which involves how things move. Description of how things/objects move without regard to force Kinematics. While description of why objects move as they do is referred to as dynamics Holton and Brush (2022). It is expected that as you go through this chapter you be able to distinguish between the two types of motion and solve problems on motion

Types of motion

1. Random Motion
   This is the motion that does not follow any definite pattern. e g. Motion of gas molecules in a container.
2. Rotational Motion
   This is the motion of a body in a circular path about a fixed point. e g. Rotating wheel.
3. Oscillatory Motion.
   This is the two-and-fro motion of a body about a given point. e g. sewing.
4. Translational Motion.
   This is the movement of a body in such a way that all point is moved in parallel direction through equal distances. Cite E g. a car moving in a straight-line road Holton and Brush (2022).

1. Random Motion

Examples of random motion are

(i) Molecular movement of gas.
(ii) Dashing of objects in air e g. insect or feather thrown into the air

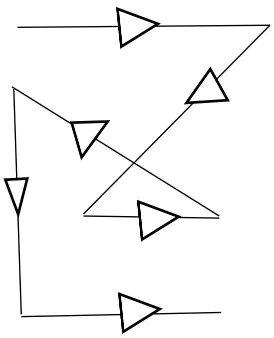


Fig. 1 Motion of an insect or butterfly

2. **Linear Motion**

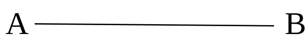


Fig. 2

3. **Translational Motion**

Examples of translational rectilinear motion are.

(i) The movement of a car from one point to another.
(ii) Human movement or the movement of a man

3. Rotational motion: this is the movement of a body in a rotational manner about its axis.

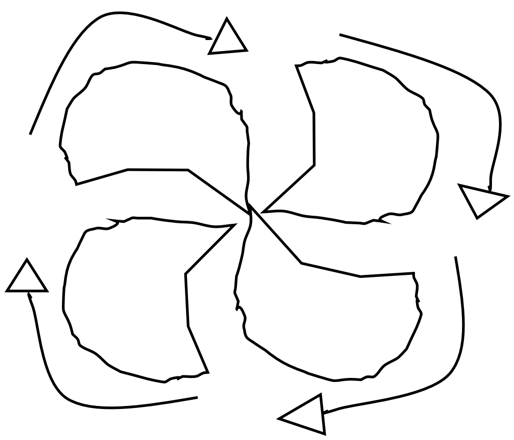


Fig. 3a: The blades of an electric fan rotating on its axis

4. **Rotational Motion**

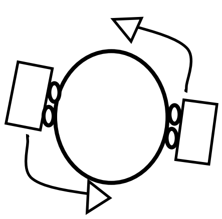


Fig. 3b: Rotational motion

Examples of rotational motion are.

(i) The rotational of electric fan blades.
(ii) The movement of a car's wheels.
(iii) The rotational car about a roundabout.
(iv) The rotation of the earth about its axes.

5. Oscillatory Motions

A two-and-fro movement about a fixed point. E g. arises due to the slight displacement of an object from the initial position to a new position and back to the initial position

Examples of oscillatory movement are.

(i) Simple pendulum
(ii) Vibration of a linked quitter string.
(iii) Oscillation of load tied to a vertical string.
(iv) Hitting or punching a bag.

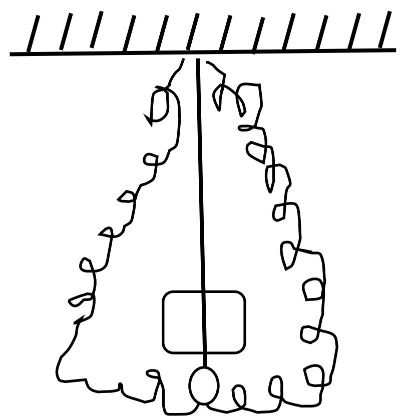


Fig. 4 Oscillatory motion

5. **Relation motion**

Relation motion is the movement of objects about another body. a car traveling on a road is said to be in motion concerning the poles and the trees on the side. The people sitting in a car are also in motion concerning the poles and the trees on the roadside. They are at rest concerning another.

Examples of relative motion are:

(i) Pulling on a spinal spring.
(ii) Bending a ruler one bean.
(iii) Pulling a string tied to a block of wood or pushing the block.

Causes of motion

Force causes motion. when is force applied to any object it causes change.

Fig 5a

Fig 5b

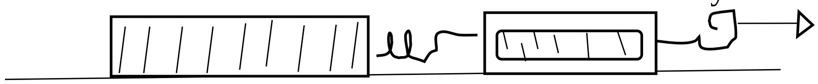


Fig 5c

Force

Force is defined as the push or pull on an object with mass which causes it to change its velocity. Force is an external agent capable of changing a body's state of rest or motion (de Lange and Pierrus, 2010). When force is applied to a body it changes the position of the body from that point to another point as a result of displacement takes place. When an additional force is applied to a body it will overcome the first position of the force. It is a vector quantity donated by F and measured in Encyclopedia (2020).

Types of force

a) Contact force,
b) Field force,
c) Electric force, and
d) Frictional force

Contact force: this exists when there is a touch, hold or contact with the object in question.

It is further divided into

i. Like force (Push)
ii. Unlike force (pull)
iii. Frictional (viscous) force

Field force: this exists in or is confined/restricted to a given region or space i.e., a region in space where a body experiences the effect of a force; which occurs as a result of the influence of some physical agencies. It is further divided into:

a. Magnetic force: this is the force that attracts magnetic substances e.g., mails towards a magnet.
b. Gravitational force: this is a force that attracts or pulls objects irrespective of their masses towards the centre of the earth's surface.

Electric force: this is a force that keeps current (negatively charged particles) through a conductor of electricity.

Friction and reducing friction

When a body slides over the surface of another body, there is an opposing force acting opposite to the direction of motion. This opposing force is called friction when a body is rolled on a rough surface, it will come to rest in a short time due to the friction on a rough surface. If the surface is smooth, friction will be less, and the body roll for a longer time. Friction is defined as a form of force that opposes or prevents the relative sliding motion of objects in contact with the surface, this is a vector quantity that exists in solid, liquid, and gas (Encyclopedia (2020).

Limiting friction

When a body is placed over another body, a force acts between the surfaces in contact and this force is called limiting friction.

Application (advantages) of friction

1. The types of a motor car and bicycle are made rough to increase friction
2. It is the friction between the belt aid and the pulley that helps in the rotation of various parts of a machine.
3. When the ground becomes slippery after rain, it is made rough by spreading sand in order not to cause slipping.
4. Without friction the brake of a motor car cannot work.
5. Without friction between the feet and ground it will not be possible to walk without falling James and Kevin (2022).

Method of reducing friction

1. Streamlining: streamlining is used to reduce friction due to the shape of the object which ensures that only a small surface area of the object is in head-on contact with the fluid such as air, water, etc. during motion example of objects that are streamlined are airplanes, ships, boat, sub-marines that are to look like fish.
2. Ball bearing: shafts are fixed on the ball bearing so that friction will be reduced because rolling friction is less than sliding friction. Ball bearing is provided in

i. The shafts of motors
ii. The axle of a motor car
iii. The tire or wheel of a cycle

iv. Dynamos.

3. Lubricating: lubricants are viscous liquids or oil that are applied between two surfaces in contact they help in overcoming or reducing friction.

Examples of lubrication are:

i. Lubricating of wheels
ii. Sprockets by the use of ball bearing

4. Polishing: friction between two surfaces in contact can be reduced by polishing them, for example,

i. The level bearing in watches minimizes the interlocking and projections

5. Use of pencils and polystyrene. The banking method is used to reduce sideways friction.

Disadvantages of friction

1. It reduces the efficiency of machine
2. It caused the heating of engines
3. It reduces motion
4. It causes wear and tear in machines

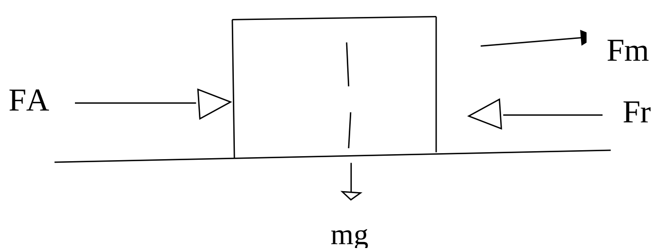
Types of solid friction

Solid friction is of two types

i. Static or stationary friction
ii. Kinetic, sliding or dynamic friction

Stationary/static friction is defined as the force that acts on to prevent two surface in contact from sliding's a body resting on another from sliding.

The body either moves on a horizontal surface or an inclined plane in a straight line.



A= force applied

M= moving force

Fr= limiting friction

Fig 6

$\mu_0 = E_m = \frac{E_m}{mg}$ - - - - - - - - (1)

N.B.

(i) R= W = mg

(ii) Fr = Fm

$\mu_0 = \frac{F}{mg}$

Fr= $\mu_0 mg$

Fm

mgsinΘ

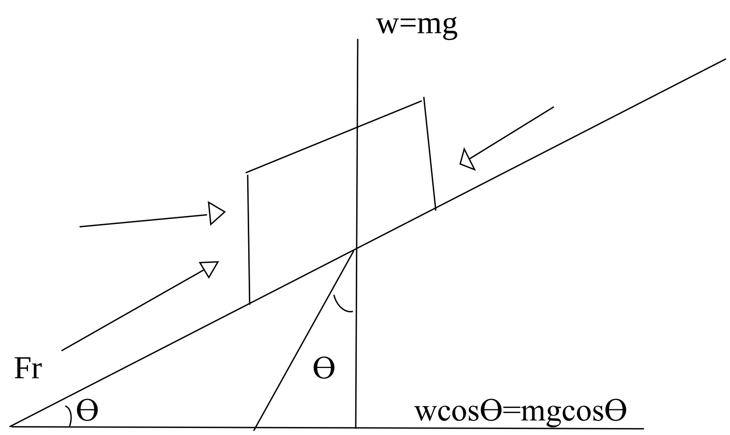


Fig 7

Stationary/static friction

Fm = mgSinΘ - - - - - (3)

R = w= mgCosΘ - - - - (4)

$\mu_0 = \frac{Fm}{R}$

$\frac{\text{mgSin}\Theta}{\text{mgCos}\Theta}$= tanΘ

Fm = moving force

Fr = limiting frictional force

Fa = force applied

R = normal reaction between surfaces

W= weight

μ_0= coefficient of stationary friction

Fm = minimum parallel force to the plane required to just slide the object.

ϴ = amgle of friction

Example

5kg

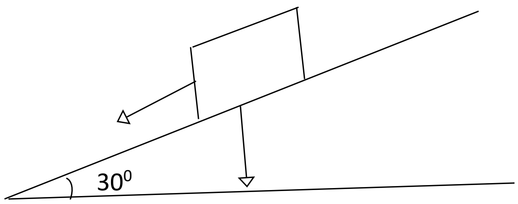


Fig 8

From the diagram above

i. Therefore, parallel to the plane to slide it downwards
ii. Normal reaction between the surfaces
iii. Coefficient of friction

Solution

Fm = mgSinϴ

5 x 10 x Sin30^0

5 x 10 x 0.5

5 x 10 x ½

5 x 5 x 1

25 newtons.

(ii)Reaction R = wCosϴ

mgCosϴ

5 x 10 x Cos 30^0

50 x 00886

4303N

(iii) $\mu_0 = \frac{Fm}{R}$

$\frac{25}{4303}$= 0.5774 aprox. 0.6 = Tanϴ

μ_0= Tanϴ

30^0

0.5774

0.6

Slidding; dynamic or kinetic friction

Slidding, dynamic or kinetic friction is defined as the frictional force that exist between two surface in relative motion

$\mu_0 = \frac{F^1}{R} = \frac{F^1 m}{mp}$

Where F^1 is the dynamic friction force, R is the normal force reaction between surface and μ_0 the coefficient of kinetic friction

N.B. F^1 = Fm

$\mu_0 = \frac{F^1}{R} = \frac{F^1 m}{mp}$

worked example 5.2

when a box of mass 4.5kg is given in an initial speed of 5m/s, it slides along a horizontal floor to a distance of 3m before coming to rest. What is the coefficient of kinetic friction between the box and the floor [g= $10ms^{-2}$]

s= 3m

m= 4.5kg

v= $5m/s^1$

f x S = ½ mv^2

Fm x 3 = ½ x 4.5 x $(5)^2$

Fm = ½ x $\frac{45 X 25}{3}$

Fm = $\frac{45 X 25}{6}$

Mg = 45 x 10

$\frac{45 X 25}{6}$x $\frac{1}{45 X 10}$

$\frac{5}{6}$ X$\frac{1}{2}$

$\frac{5}{12}$.

Laws of solid friction

(1) It opposes motion
(2) The limiting friction force is independent of the surface area in contact
(3) The ratio of F/R is practically constant between any two surface where F is the limiting frictional force and R is the normal reaction between the surface.
(4) The limiting frictional force is directly proportional to the normal reaction between any two surfaces.
(5) The limiting frictional force depends on the nature of the surfaces in contact.
(6) The limiting frictional force is independent of the relative velocity between the surfaces.
(7) The coefficient of static stationary friction (μ_0) is greater than the coeeficient of sliding dynamic or kinetic friction ie $\mu_0 > \mu_4 >, ie\ \mu_s > \mu_k\ or\ \mu_k < \mu_s$ Gale (2017).

Circular Motion

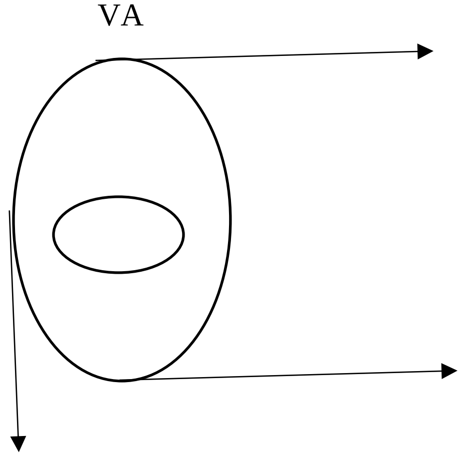
Circular motion is a motion in a circular path in which the speed of the body remains constant while its direction continuously changes eg

(1) Stone whirled in horizontal circle
(2) Planets going round the sun
(3) The earth moving round the sun
(4) A racing car moving round a circular track
(5) Clothes drying in a spin driver

Experiment: stone attached to the end of a spring and whirled in a horizontal circle. A stone is tied to the end of the rope and whirled in a horizontal circular path. The direction is constantly changing as the stone moves round the circular path.

Though the speed of the stone is constant, its direction is changing all the time as it moves. This implies that velocity changes as the stone moves round the circle

A



Planets

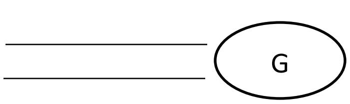


Fig 9

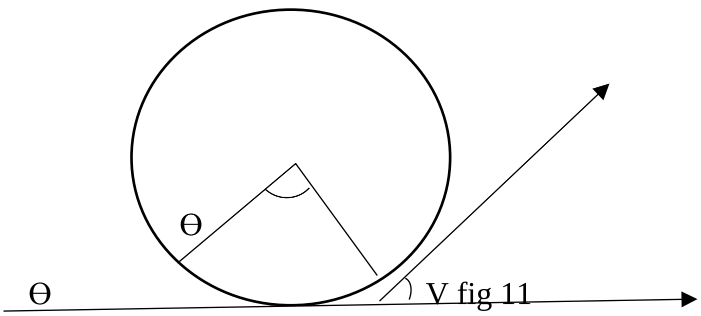
VB C VC

Circular motion

Fig 10

Angular velocity

Angular velocity W about Θ is defined as the change of the angle per second measured in rad^{-1} or rad/s



Equation 1

$W=\frac{\theta}{t}$

$\Theta = wt$

In moving through an acr S of a circle the radius of the angle moved is Θ.

$\Theta= \frac{s}{r}$

Equation 2

$S= r\Theta$

Dividing throughout with t

$\frac{s}{t}=\frac{r\theta}{t}$

$S= r \times \frac{s}{t}$

Equation 3

$V= rw$

Hence the period T of the motion is given as

$T = \frac{2\pi}{w}$

W= 2πF

Equation 4

$T= \frac{2\pi}{w} = \frac{2\pi}{2\pi F} = \frac{1}{F}$

Centripetal Force: when a stone is attached to string and whirled round at constant speed in a horizontal circle, the stone moves with constant (same) speed out at different directions and acceleration (a) direction towards the centre of the circle due to the tension in the string that produces a force Gale (2017).

$a= vw = rw^2 = \frac{v^2}{r} w= \frac{v}{r}$

rw^2 X $\frac{v^2}{r} w$ X $\frac{v}{r}$

therefore, that is required to keep this object (stone) stone moving in circular is called centripetal force.

Thus F= ma

Mvw

Mrw^2

$\frac{mv^2}{r}$

Worked Example 1

An object of mass 4kg moves in a circle radius 8m at uniform speed of 22m/s

Calculate

a. The angular velocity
b. The centripetal force

Solution

Given that mass =4kg

Radius = 8m at uniform speed

V= speed

V= 32 m/s

a. Angular velocity

$w = \frac{v}{r}$

$\frac{\mathbf{32}}{\mathbf{8}}$

4 radius

b. Centripetal force= mrw^2
   $4 X 8 X (4)^2$
   32 X 16 N
   512N

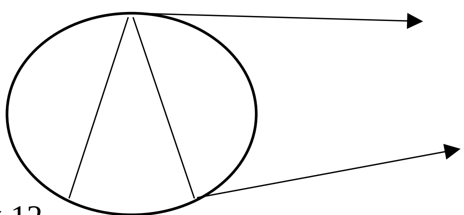


fig 12

Worked Example 2:

An object of mass 400g attached to the end of a string is whirled round in a horizontal circle of radius 2.0m with a constant speed of 8m/s. calculate the centripetal force of the object.

W= 2πF

V= speed

V= 8m/s

M= 400g, =0.4kg

r= radius

r= 2m

v= wr

r= 2

8= 2w

W=$\frac{8}{2.0}$

= 4 radia

F= mrw^2

$0.4 \times 2 \times (4)^2$

$0.4 \times 2 \times 16$

12.8N

Worked example 3

An object of mass 25kg moves at 5m/s round a circular path of radius 5m, calculate

a. The centripetal acceleration
b. The centripetal force
   Solution
a. Given that a=$\frac{v^2}{r}$

Where r= 5m, v=5m/s

Then

a=$\frac{v^2}{r}$

$\frac{5^2}{5} = \frac{25}{5}$

a= $5ms^2$

b. Centripetal force F=$\frac{mv^2}{r}$

   F=$\frac{m \times v^2}{r} = \frac{25 \times 25}{5}$

   =125N

Practical situation of centripetal force

1. Centripetal dryers: this is used in laundries. Inside this dryers, wet clothes are whirled at high speed in wire basket in order for moist water to wave or dry away
2. The gravitation attraction which keeps planets and satellites in an orbital movement.

3. Centrige is used in separating suspended solid materials from liquid
4. Centripetal force keeps vehicle travelling round curves from topping over. Because frictional force exerted onwards by the road on car tyres and curves on a road or bicycles race track are banked or raised the outer-edged.

Revision exercise

(1)a. What is motion?
b. Explain types of motion

(2) What do you understand by the following (i) Random motion (ii) Translational motion (iii) Rotational motion (iv) Oscillatory motion

(3) What do you understand by the term relative motion?

(4) State the causes of motion and explain their effects and how they are applied

(5) a. Friction is an important factor in human life. Explain

b. Explain limiting friction

c. State the laws of solid friction and its applications.

d. State and explain the method of reducing friction

(6) Banking is one of the methods of reducing friction. Explain

(7) Define circular motion

(8) a. Define angular velocity and derive the formula

b. Distinguish between speed and velocity

(9) Define Centripetal Force

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