**Subject : Physics**

**Class : XI** **Kannada**

## Law of Motion

### NEWTON'S LAW AND LINEAR MOMENTUM

1. **Newton's First Law of Motion:** An object continues to be in the state of rest or of uniform motion unless a force is applied on it.
2. **Newton's Second Law of Motion:** Newton's second law of motion states that the rate of change of linear momentum of a body is directly proportional to the applied force and the change in momentum takes place in the direction of the applied force.

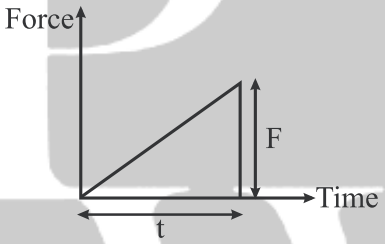
$$\vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{F} = \frac{dm\vec{v}}{dt} = m\vec{a}$$ (Here m = constant)

3. **Newton's third law of motion:** It states that to every action there is an equal and opposite reaction.
4. **Linear momentum,** $\vec{p} = m\vec{v}$

### Impulse

1. Let I is the impulse and F is the force acting in a very short time dt then,
2. Impulse = area under force time graphs




I = area of triangle = $\frac{1}{2} \times$ Base $\times$ Height $= \frac{1}{2}$Ft

3. Impulse in terms of momentum

$I = \vec{P}_2 - \vec{P}_1 = \Delta\vec{P}$ [$\vec{P}$ is the momentum of the particle]

$\Rightarrow I = \int_{\vec{P}_1}^{\vec{P}_2} d\vec{P}$

### Conservation of Linear Momentum

In the absence of any external force

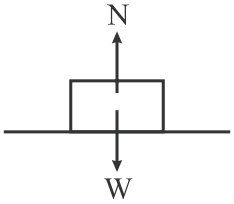
Total initial momentum = Total final momentum

$\Rightarrow P_i = P_f$

### DIFFERENT TYPES OF FORCES

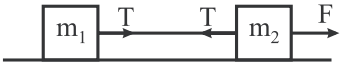
#### Normal Reaction

It is a contact force. It is the force between two surfaces in contact, which is always perpendicular to the surfaces in contact.




#### Tension

Tension force always pulls a body.




Tension is a reactive force. It is not an active force.

Tension across massless pulley or frictionless pulley remains constant.

Rope becomes slack when tension force becomes zero.

**Spring Force**

$F = -kx$

$x$ is displacement of the free end from its natural length or deformation of the spring where K = spring constant.

$K \times l$ = constant

where $l$ = Natural length of spring

Note: If spring is cut into two in the ratio $m : n$ then spring constant is given by

$$\ell_1 = \frac{m\ell}{m+n}; \ell_2 = \frac{n\ell}{m+n}$$

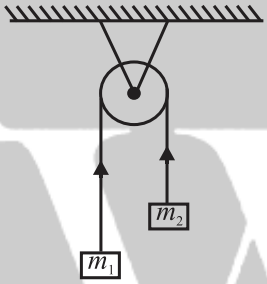
$$k\ell = k_1\ell_1 = k_2\ell_2$$

For series combination of springs. $\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + \ldots$

For parallel combination of spring $k_{eq} = k_1 + k_2 + k_3 \ldots$

**MOTION OF CONNECTED BODIES**

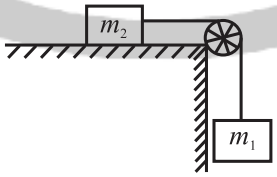
**1.** When two bodies of masses $m_1$ and $m_2$ are tied at the ends of an inextensible string that passes over a light frictionless pulley.




Acceleration of the block (a) $= \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g$

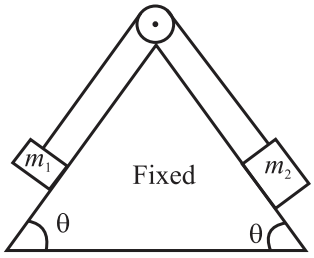
Tension in the string $(T) = \left(\frac{2m_1m_2}{m_1 + m_2}\right) g$

**2.** Acceleration of the system when blocks connected by a string which passes over a light frictionless pulley.



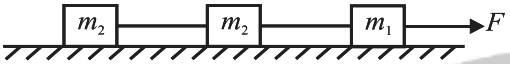

$$a = \left(\frac{m_1 g}{m_1 + m_2}\right)$$

**3.** In the system shown below if $m_1 > m_2$, then acceleration of the blocks is given by (All surfaces are smooth)




$$a = \frac{(m_1 - m_2) g \sin\theta}{m_1 + m_2}$$

[a is the acceleration of the block tension in the string is given by $\frac{2m_1 m_2 g \sin\theta}{m_1 + m_2}$

4. 


Equation of motion of first body is $F - T_1 = m_1 a$
Equation of motion of second body is $T_1 - T_2 = m_2 a$
Equation of motion of 3rd body is $T_2 = m_3 a$
Common acceleration, (a is the common acceleration)

$$a = \frac{F}{m_1 + m_2 + m_3}$$

$$T_1 = \left(\frac{m_2 + m_3}{m_1 + m_2 + m_3}\right) F$$

$$T_2 = \frac{m_3 F}{m_1 + m_2 + m_3}$$

**Frame of Reference**

**Inertial frames of reference:** A reference frame which is either at rest or in uniform motion along the straight line. A non-accelerating frame reference is called an inertial frame of reference. All the fundamental laws of physics have been formulates in respect of inertial frame of reference.

**Non-inertial frame of reference:** An accelerating frame of reference is called a non-inertial frame of reference. Newton's laws of motion are not directly applicable in such frames, before application we must add pseudo force.

**Pseudo force:** The force on a body due to acceleration of noninitial frame is called fictitious or apparent or pseudo force and is $-m\vec{a}_0$ given by where $\vec{a}$ is acceleration of non-inertial frame with respect to an inertial frame and m is mass of the particle or body. The direction of pseudo force must be opposite to the direction of acceleration of the non-inertial frame.

**Time of flight**

Friction is a force which resist the relative motion of two contact bodies.
Friction force is of two types– (1) Static, (2) Kinetic.

**Static Friction**

It exists between the two surfaces when there is tendency of relative motion but no relative motion along the two contact surfaces. This means static friction is a variable and self adjusting force. However it has a maximum value called limiting friction.

$f_{max} = \mu_s \times N$ $\qquad$ $0 < f_s < f_{s\max}$

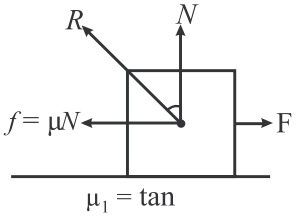
**Kinetic Friction**

$f_k = \mu_k \times N$

The proportionality constant $\mu_k$ is called the coefficient of kinetic friction a

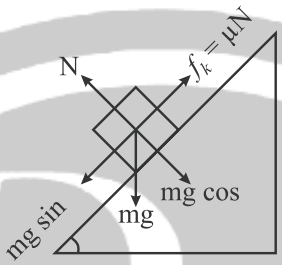
**Angle of Friction**

It is the angle which the resultant of the force of limiting friction and the normal reaction (N) makes with the normal reaction.




**Angle of Repose or Angle of Sliding**

It is the minimum angle of inclination of a plane with the horizontal, such that a body placed on it, just begins to slide down.




If angle of repose is $\alpha$ and coefficient of limiting friction is $\mu_l$ then $\mu = \tan\alpha$

**Note:** Pulling (Fig. I) is easier than pushing (fig. II) on a rough horizontal surface beacuse normal reaction is less in pulling than in pushing.




Fig.-I Fig.-II

**Dynamics of Circular Motion**

**Centripetal Force: (FC):** It is a force which required to move a body in circular path. Direction of centripetal force is always perpendicular to direction of linear velocity.

$$\text{Centripetal Force } (F_C) = \frac{mv^2}{r}$$

Centrifugal Force: It is a pseudo force experienced radially outward by an object of mass m relative to the object, moving in a circular path of radius r, relative to an inertial frame. the centrifugal force is given by $mv^2/r$

($v$ = speed of object relative to inertial frame)

$$\frac{H}{R} = \frac{1}{4}\tan\theta$$

**Circular turning of roads:**

**(i) Friction only:** Friction provides the necessary centripetal force for turning of vehicle.

$$v_{max} = \sqrt{\mu_s rg}$$

$v_{max}$ = Maximum safe velocity for turning.

**(ii) Banking of roads only:** Centripetal force provides by banking of road only:

$$v_{max} = \sqrt{\tan\theta rg}$$

**(iii) Both friction and banking of roads:** To avoid the risk factor and reduce the wear of tyres, both friction and banking of rods are used to provide the necessary centripetal force. Maximum safe speed without skidding:

$$v_{max} = \frac{rg(\tan\theta + \mu_s)}{1 - \mu_s \tan\theta}$$

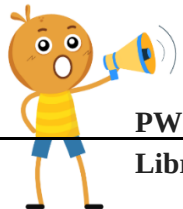
**Note :** In condition of both banking of rod and friction, the direction of frictional force is determined by the velocity of vehicle $v$ for a given banking angle $\theta$:

(a) It $v = 0$ then frictional force is outward.

(b) It $v > \sqrt{gr\tan\theta}$, then frictional force is inwards.

(c) It $v = \sqrt{gr\tan\theta}$ then frictional force f = 0.

(d) It $v < \sqrt{gr\tan\theta}$ then frictional force f is outwards.



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