# NEWTON'S LAWS OF MOTION

Force :

Newton's law of Motion (NLM) Pg - 1

Any push or pull which either changes or tends to change the state of rest or of uniform motion ( constant velocity) of a body is known as force.

Effect of resultant force :

- change in speed of a body
- change the direction of motion
- change the speed and direction both
- change the size and shape of the body

Units for measurement of force :

(NLM) Pg - 1

| Absolute units | Gravitational units |
|---|---|
| N (MKS) | Kg - wt or kg - f |
| dyne ( C.G.S) | g - wt or g - f |

☆ Relation between above units :

1 Kg - wt = 9.8 N

1 g - wt = 980 dyne

$1 N = 10^5$ dyne

$$1\ \text{kg-wt} \underset{\div g}{\overset{\times g}{\rightleftharpoons}} N$$

$$1\ \text{g-wt} \underset{\div g}{\overset{\times g}{\rightleftharpoons}} \text{dyne}$$

Aristotle's law :

a constant force is required to keep a body in uniform motion. also known as Aristotle's fallacy.

Galileo's law :

No force is required to maintain the uniform motion of a body. It defines the property of inertia and also known as Galileo's law of inertia.

Inertia:

Inertia is a property due to which a body tries to maintain its state of rest or of uniform motion.

$\therefore$ Inertia $\propto$ mass.

Newton's first law of motion:
(NLM) Pg-2

According to Newton, a body continues to be in the state of rest or of uniform motion along a straight line unless it is compelled by some external force. It defines force, It tells about qualitative property of force.

• It defines the property of inertia. hence, it is also known as 'Law of inertia'

Types of inertia:

i) Inertia of rest: A body at rest cannot change its state of rest by itself.

ii) Inertia of Motion: A body at motion cannot change its state of motion by itself

iii) Inertia of direction: A moving body cannot change its direction of motion by itself.

Momentum:
(NLM) Pg-2

The product of mass and velocity of an body is called its momentum.

$\vec{p} = m\vec{v}$

Unit: kg m/s

Dimensions: $[M^1 L^1 T^{-1}]$

Newton's second law of motion:
(NLM) Pg-3

According to Newton, the rate of change of momentum of any system is directly proportional to the applied external force. and this change of momentum takes place in the direction of applied force.

Case I : $\vec{F} = \frac{m d\vec{V}}{dt} + \frac{\vec{V} dm}{dt}$

Case II : $\vec{F} = m\vec{a}$

Case III : $\vec{F} = \frac{\vec{V} dm}{dt}$

~~case~~

Impulse:

when a large force is applied on a body for a very short interval of time, then impulse is the product of force and time interval

case I : $\vec{I} = \int_{t_1}^{t_2} \vec{F} dt = \int_{\vec{p_1}}^{\vec{p_2}} d\vec{p}$

Case II : $\vec{I} = \vec{F}_{avg} \Delta t = \Delta \vec{p}$

Impulse Momentum Theorem :

(NLM) Pg - 4

The impulse of force is equal to change in momentum of a body

Units : N-s or kg - m/s

dimensions : $[M^1 L^1 T^{-1}]$

Q. 2 (NLM) Pg - 4

$\because \vec{I} = \int F dt$

$$= \int (10t - 20)\, dt$$

$$= \frac{10t^2}{2} - 20t + c \quad \text{units}$$

$$= (5t^2 - 20t + c) \text{ units}$$

Q.3 (NLM) Pg-4

$$\because \vec{I} = \int_{t_1}^{t_2} \vec{F}\, dt$$

$$= \int_0^2 (3t^2 - 2t + 10)\, dt$$

$$= \left| \frac{3t^3}{3} - \frac{2t^2}{2} + 10t \right|_0^2$$

$$= \left| t^3 - t^2 + 10t \right|_0^2$$

$$= 8 - 4 + 20 - 0$$

$$= 28 - 4 = 24 \text{ Ns}$$

Q.4 (NLM) Pg-4

$$\because \vec{I} = \int_{t_1}^{t_2} \vec{F}\, dt$$

$$= \int_1^3 (12t + 3t^2)\, dt$$

$$= \left| \frac{12t^2}{2} + \frac{3t^3}{3} \right|_1^3$$

$$= \left| 6t^2 + t^3 \right|_1^3$$

$$= \left[ 6(3)^2 + (3)^3 \right] - \left[ 6(1)^2 + (1)^3 \right]$$

$$= (6 \times 9 + 27) - (6 + 1)$$

$$= (54 + 27) - 7$$

$$\cancel{63} \cdot (81 - 7) \text{ Ns}$$

$$= 74 \text{ N-s}$$

Q.5 (NLM) Pg - 4

$$\because \quad p = at - bt^2$$

$$F = \frac{dp}{dt}$$

$$= \frac{d(at - bt^2)}{dt}$$

$$= a - 2bt$$

Acc to que, $F = 0$

$$\therefore a - 2bt = 0$$

$$\therefore a = 2bt$$

$$\therefore t = \frac{a}{2b}$$

Important points about Newton's second law of Motion :

(NLM) Pg - 4

i) Newton's first law of motion defines force and second law of motion measures force. It gives units, dimensions and magnitude of force

ii) In the absence of external force, a partical moves uniformly

iii) Accelerated Motion is always due to external force

iv) If external force on any system is zero then its linear momentum will be conserved. This is known as laws of conservation of linear momentum (COLM)

* It is applicable in the direction in which applied force is zero.

v) The slope of momentum - time graph is equal to force on the particles.

$$F = \frac{dp}{dt} = \text{slope} = \tan\theta$$

vi) The area under the force - time graph represent impulse or change in momentum

$$I \text{ or } \Delta p = \int F\,dt = \text{area under graph}$$

Q.6 (NLM) Pg - 5

i) $$\frac{F_A}{F_B} = \frac{\text{slope } A}{\text{slope } B} = \frac{\tan\theta_A}{\tan\theta_B}$$

$$= \frac{\tan 30^\circ}{\tan 60^\circ}$$

$$= \frac{1}{\sqrt{3}} \times \frac{1}{\sqrt{3}} = \frac{1}{3}$$

$$\therefore \frac{F_A}{F_B} = \frac{1}{3} = 1:3$$

ii) $$\frac{F_A}{F_B} = \frac{\text{Slope } A}{\text{Slope } B} = \frac{\tan\theta_A}{\tan\theta_B}$$

$$= \frac{\tan 30^\circ}{\tan 45^\circ}$$

$$= \frac{1}{\sqrt{3}} = \frac{F_A}{F_B} = 1:\sqrt{3}$$

iii) $\frac{F_A}{F_B} = \frac{\text{Slope A}}{\text{Slope B}}$

$= \frac{\tan \theta_A}{\tan \theta_B} = \frac{\tan(90-45)^\circ}{\tan(90-30)^\circ}$

$= \frac{\tan 45^\circ}{\tan 60^\circ}$

$\therefore \frac{F_A}{F_B} = \frac{1}{\sqrt{3}} = 1 : \sqrt{3}$

Q.7 (NLM) Pg-5

Impulse = Area covered in F-t graph.

$= \frac{1}{2} \times 2 \times 100 - \frac{1}{2} \times 1 \times 100$

$= 100 - 50$

$= 50$ Ns

Q.8 (NLM) Pg-5

change in momentum = Area covered by F-t graph.

$= 1 \times 10 + 2 \times 20 - 1 \times 10$

$= 10 + 40 - 10$

$= 40$ Ns

Q.9 (NLM) Pg-6

$\frac{dm}{dt} = 40$ kg/s

here, $\frac{dm}{dt}$ = rate of consumption.

$v = 50$ m/s (velocity of gas w.r.t rocket)

$\therefore$ Force on rocket $= \frac{v\,dm}{dt}$

$= 50 \times 40$

$\therefore F = 2000\ N$

Q.10 (NLM) Pg - 6

$m = 1000\ kg$

$\frac{dm}{dt} = 60\ \cancel{m/s}\ kg/s$

$v = 20\ m/s.$

$F = \frac{v\,dm}{dt} = 20 \times 60$

$= 1200\ N$

$\because F = ma$

$\therefore a = \frac{F}{m}$

$= \frac{1200}{1000} = \frac{12}{10} = 1.2\ m/s^2$

Q.11 (NLM) Pg - 6

$m = 2000\ kg$

$\frac{dm}{dt} = 50\ kg/s$

$v = 20\ m/s$

$\therefore F = \frac{v\,dm}{dt} = 20 \times 50$

$= 1000\ N$

$\because$ loss of mass of rocket in 1 sec = 50 kg

$\therefore$ loss of mass of rocket in 20 sec = $(50 \times 20)$ kg

$= 1000$ kg

Air

$\because$ $F = ma$

$\therefore$ $a = \dfrac{F}{m_{\text{after 20 sec}}}$

$= \dfrac{1000}{1000} = 1\ m/s^2$

$\because$ Mass ~~of~~ after 20 sec $= (2000 - 1000)$ kg

$= 1000$ kg

Q.12 (NLM) Pg - 6

$\dfrac{dm}{dt} = 6\cancel{0}$ kg/s

$v = 4$ m/s

mass of block $= 10$ kg

$\because$ $F = V\dfrac{dm}{dt}$

$= 4 \times 6\cancel{0} = 24\cancel{00}$ N

$\because$ $F = ma$

$\therefore$ $a = \dfrac{F}{m}$

$= \cancel{\dfrac{24}{4}}\ \dfrac{24}{10} = 2.4\ m/s^2$

Q.13 (NLM) Pg - 6

$m = 200$ kg

$V_1 = 20$ m/s

$V_2 = 0$ m/s

$t = 5$ sec

$\because$ $\Delta p = m(V_2 - V_1)$

$= 200(0 - 20)$

$= -4000$ kg m/s

$\because \ \vec{\Delta p} = \vec{F} \times \Delta t$

$\therefore \ \vec{F} = \dfrac{\vec{\Delta p}}{\Delta t} = \dfrac{-4000}{5} = -800 \text{ N}$

$\therefore$ retarding force = 800 N.

~~OR~~

$\because \ \cancel{F = m \times a}$

$\therefore \ \cancel{a = \dfrac{F}{m} = \dfrac{-4000}{200} = -8 \text{ m/s}^2}$

Q.14 (NLM) Pg - 6

$m = 500 \text{ kg}$

$v_1 = 72 \text{ km/h} = 72 \times \dfrac{5}{18} = 4 \times 5 = 20 \text{ m/s}$

$v_2 = 0$

$t = 5 \text{ sec.}$

$\because \ \Delta p = m(v_2 - v_1)$

$= 500 \ (0 - 20)$

$= -10{,}000 \text{ kg m/s}$

$\because \ \vec{\Delta p} = \vec{F} \times \Delta t$

$\therefore \ \vec{F} = \dfrac{\vec{\Delta P}}{\Delta t} = \dfrac{-10{,}000}{5}$

$= -2000 \text{ N}$

$\therefore$ retarding force = 2000 N

Q.15 (NLM) Pg - 6

$m = 50 \text{ gm} = 0.05 \text{ kg}$

$v_1 = 400 \text{ m/s}, \ v_2 = 0$

$t = 1 \mu s = 10^{-6} \text{ sec}$

$\because \ F_{avg} = m a_{avg} = m \left( \dfrac{v_2 - v_1}{t} \right)$

$$= 0.05 \left( \frac{0 - 400}{10^{-6}} \right)$$

$$= \frac{0.05 \times (-400)}{10^{-6}}$$

$$= -20 \times 10^{6} \text{ N}$$

$$= -2 \times 10^{7} \text{ N}$$

$\therefore$ Retarding force $= 2 \times 10^{7}$ N

Q.16

$m = 50 \text{ gm} = 0.05 \text{ kg}$

$V_1 = 200 \text{ m/s}, \quad V_2 = 0$

$s = 50 \text{ cm} = 0.5 \text{ m}$.

$\because \; v^2 = u^2 + 2as$

$$\therefore \; a = \frac{v^2 - u^2}{2s} = \frac{V_2^{\,2} - V_1^{\,2}}{2s}$$

$$= \frac{0 - (200 \times 200)}{2 \times 0.5}$$

$$= -\frac{40000}{1}$$

$$= -40{,}000 \text{ m/s}^2$$

$\because \; F_{avg} = m a_{avg} = \cancel{50 \times}$

$= 0.05 \times (-40{,}000)$

$= -2000$ N

$\therefore$ Retarding force $= 2000$ N

Q.17 ★ (NLM) Pg-6

$\cancel{V_1 = 0, \; V_2 =} \; V = V$

$m = m, \quad F_{avg} = F$

$t = 1 \text{ sec}$

$\Delta p$ of 1 bullet $= \cancel{m(V_2 - V_1)} = mV$

Let 'n' bullets be fired in 't' time

$\therefore \Delta p$ of $n$ bullets $= n(mv)$

$$\because F_{avg} = \frac{\Delta P}{\Delta t} = \frac{nmv}{t}$$

$\therefore$ no. of bullets fired per unit time $= \frac{n}{t}$

$$\because F = \frac{nmv}{t}$$

$$\star \quad \boxed{\therefore \frac{n}{t} = \frac{F}{mv}}$$

Q.18 (NLM) Pg-6

$m = 40 gm = 0.04 Kg$

$v_i = 1000 m/s$, $F = 400 N$

$\because$ no. of bullets per sec $= \frac{F}{mv}$

i.e. $\frac{400}{0.04 \times 1000} = 10$ bullets /sec

$\therefore$ no. of bullets per minutes $= 10 \times 60$

$= 600$ bullets/min

Q.19 (NLM) Pg-6

$m = 20$ kg (~~bullet~~) (machine gun)

$m = 35$ gm $= 0.035$ kg (bullet)

no. of bullets per minutes $= 300$

$V = 400$ m/s

$\cancel{\because \frac{n}{t} = \frac{F}{mv}}$

~~i.e. $\frac{300}{sec\ min} =$~~

n

$\because$ no. of bullets per min = 300

$\therefore$ no. of bullets per sec = $\frac{300}{60}$ = 5 bullets.

i.e. $\frac{n}{t}$ = 5 bullets.

$\because \frac{n}{t} = \frac{F}{mv}$

$\therefore F = \frac{nmv}{t} = 5 \times 0.035 \times 400$

$= 70$ N

Q.20

$m = 2$ kg

$v_1 = 20$ m/s

$t = 0.01$ sec

$\because$ it's a elastic collission,

$\therefore v_2 = -20$ m/s (reverse in direction)

$\Delta p = m(v_2 - v_1)$

$= 2(-20 - 20)$

$= 2 \times (-40)$

$= -80$ kg m/s

(here -ve indicates ↑ direction)

$F = \frac{\Delta p}{\Delta t} = \frac{-80}{0.01} = -8000$ N

(here -ve indicates ↑ direction)

Q.21 (NLM) Pg-6

$m = 5$ kg

$v_1 = 60$ m/s

$t = 0.02$ sec

$\because$ It's a elastic collission,

$\therefore v_2 = -60$ m/s. (reverse in direction)

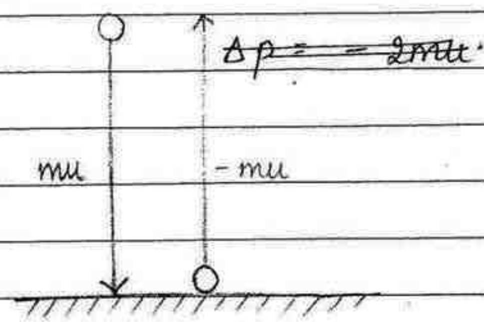
$$\Delta p = m(v_2 - v_1)$$
$$= 5(-60-60)$$
$$= 5 \times (-120)$$
$$= -600 \text{ kgm/s}$$ (-ve) indicates ↑ direction

$\because \Delta p = I = -600$ kg m/s or $-600$ N-s

$\because F = \dfrac{\Delta p}{\Delta t}$

$$= \frac{-600}{.02} = -30,000 \text{ N}$$

* when a ball falling downwards collides elastically from the ground such that its speed doesn't changes after the collission, only direction of motion reverses, then,




$\because \Delta p = p_f - p_i$
$$= -mu - mu$$
$$= -2mu$$

$\therefore \Delta p = -2mu$ and.
$$F = \frac{\Delta p}{\Delta t} = \frac{-2mu}{t}$$

Q.22 (NLM) Pg -6

$m = 1$ kg

$v_1 = 72\ km/h = 72 \times \frac{5}{18} = 20\ m/s$

$v_2 = 36\ km/h = 36 \times \frac{5}{18} = 10\ m/s$

$v_2 = -10\ m/s$, it is because the direction reverses from $v_1$ to $v_2$

$t = 1$ mili sec $= 1 \times 10^{-3}$ sec

$\therefore \Delta p = m(v_2 - v_1)$

$= 1(-10 - 20)$

$= -30\ kg\,m/s.$

$\because F = \frac{\Delta p}{\Delta t} = \frac{-30}{10^{-3}}$

$= -30 \times 10^{3} = -30{,}000\ N$

Q.23 (NLM) Pg-6

$m = 2\ Kg$

$v_1 = 108\ km/h = 108 \times \frac{5}{18} = 30\ m/s$

$v_2 = 36\ km/h = 36 \times \frac{5}{18} = 10\ m/s.$

$v_2 = -10\ m/s$, it is because the direction reverses from $v_1$ to $v_2$

$t = 1$ microsec $= 1 \times 10^{-6}$ sec.

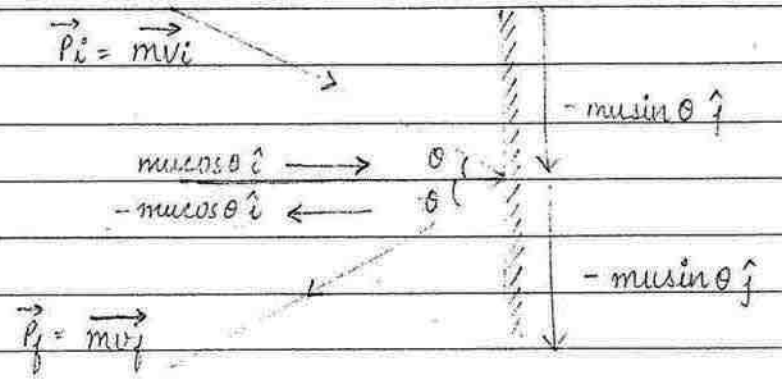
$\therefore F = \frac{\Delta p}{\Delta t}$

$= \frac{m(v_2 - v_1)}{t}$

$= \frac{2(-10 - 30)}{10^{-6}} = \frac{2 \times (-40)}{10^{-6}}$

$\therefore F = -80 \times 10^{6} = -8 \times 10^{7}\ N$

Q.24




$$\vec{P_i} = mu\cos\theta\,\hat{i} - mu\sin\theta\,\hat{j}$$

$$\vec{P_f} = -mu\cos\theta\,\hat{i} - mu\sin\theta\,\hat{j}$$

$$\therefore \vec{\Delta P} = \vec{P_f} - \vec{P_i}$$

$$= (-mu\cos\theta\,\hat{i} - mu\sin\theta\,\hat{j}) - (mu\cos\theta\,\hat{i} - mu\sin\theta$$

$$= -mu\cos\theta\,\hat{i} - \cancel{mu\sin\theta\,\hat{j}} - mu\cos\theta\,\hat{i} + \cancel{mu\sin\theta}$$

$$= -2mu\cos\theta\,\hat{i}$$

$$\therefore |\vec{\Delta P}| = |-2mu\cos\theta\,\hat{i}| = 2mu\cos\theta$$

$$\because \vec{F} = \frac{\vec{\Delta P}}{\Delta t} = \frac{-2mu\cos\theta\,\hat{i}}{t}$$

$$\therefore |\vec{F}| = \frac{2mu\cos\theta}{t}$$

* Special cases :

i) If ball is thrown perpendicular to the surface

i.e. $\theta = 0^\circ$

$$\vec{\Delta P} = -2mu\cos\theta\,\hat{i}$$

$$= -2mu\cos 0^\circ\,\hat{i} = -2mu\,\hat{i} \quad (\because \cos 0^\circ = 1)$$

$$\vec{F} = \frac{\vec{\Delta P}}{\Delta t} = \frac{-2mu\,\hat{i}}{t}$$

ii) If $\theta$ is made from the surface. ~~ie. $\theta$=~~

$$\vec{\Delta P} = -2mu\sin\theta\,\hat{i}$$

$$|\vec{\Delta P}| = 2mu\sin\theta$$

$$\vec{F} = \frac{\vec{\Delta P}}{\Delta t} = \frac{-2mu\sin\theta\,\hat{i}}{t} \quad \therefore |\vec{F}| = \frac{2mu\sin\theta\,\hat{i}}{t}$$

Q.25 (NLM) Pg - 7

$$|\vec{\Delta P}| = 2mu\cos\theta$$
$$= 2 \times 1 \times 20 \times \cos 60^\circ$$
$$= 2 \times 1 \times 20 \times \frac{1}{2}$$
$$= 20 \text{ kg m/s}$$
$$|\vec{F}| = \frac{2mu\cos\theta}{t}$$
$$= \frac{2 \times 1 \times 20 \times \frac{1}{2}}{0.01}$$
$$= \frac{20}{0.01} = 2000 \text{ N}$$

OR

~~Q.26~~

$$\vec{P_i} = mu\cos\theta\,\hat{i} - mu\sin\theta\,\hat{j}$$
$$\vec{P_f} = -mu\cos\theta\,\hat{i} - mu\sin\theta\,\hat{j}$$
$$\because \vec{\Delta P} = P_f - P_i$$
$$= -mu\cos\theta\,\hat{i} - mu\sin\theta\,\hat{j} - mu\cos\theta\,\hat{i} + mu\sin\theta\,\hat{j}$$
$$= -2mu\cos\theta\,\hat{i}$$
$$\therefore |\vec{\Delta P}| = 2mu\cos\theta$$
$$= 2 \times 1 \times 20 \times \cos 60^\circ$$
$$= 2 \times 1 \times 20 \times \frac{1}{2} = 20 \text{ kg m/s}$$
$$|\vec{F}| = \frac{|\vec{\Delta P}|}{\Delta t} = \frac{2mu\cos\theta}{t}$$
$$= \frac{2 \times 1 \times 20 \times \cos 60^\circ}{t}$$
$$= \frac{2 \times 1 \times 20 \times \frac{1}{2}}{0.01}$$
$$= 2000 \text{ N}$$

Q-26 (NLM) Pg - 7

∵ the angle is from the surface.

$\therefore |\vec{\Delta P}| = 2mu \sin\theta$

$u = 36 \text{ km/h} = \frac{36 \times 5}{18} = 5 \times 2 = 10 \text{ m/s.}$

$\therefore |\vec{\Delta P}| = 2 \times 4 \times 10 \times \sin 30^\circ$ or $2 \times 4 \times 10 \times \cos(90-30^\circ)$

$= 2 \times 4 \times 10 \times \frac{1}{2}$ $= 2 \times 4 \times 10 \times \cos 60^\circ$

$= 2 \times 4 \times 10 \times \frac{1}{2}$

$= 40 \text{ kg m/s}$ $= 40 \text{ kgm/s}$

$|\vec{F}| = \frac{\Delta P}{\Delta t} = \frac{40}{0.05}$

$= \frac{4000}{5} = 800 \text{ N}$

Q.27 (NLM) Pg - 7

$\because F = ma$

$\therefore a = \frac{F}{m} = \frac{F\cos\theta}{M.}$

$= \frac{F\cos 60^\circ}{M} = \frac{100 \times \frac{1}{2}}{10}$

$= \frac{50}{10} = 5 \text{ m/s}^2$

Q.28 (NLM) Pg - 7

$\because a = \frac{F}{M} = \frac{F\sin\theta}{M} = \frac{F\sin 30^\circ}{m}$

$\frac{50}{2} \times \frac{1}{2} = 12.5 \text{ m/s}^2$

* $\because F_{avg} = \frac{\Delta p}{\Delta t}$

$\therefore$ For a particular momentum change, if time interval is increased, then the average force on the body will decrease

$\because F_{avg} \propto \frac{1}{\Delta t}$

Newton's third law of motion:

(NLM) Pg-8

According to Newton's third law, to every action, there is always an equal and opposite reaction. It is also known as action reaction law.

$\therefore \vec{F}_{12} = -\vec{F}_{21}$

$\begin{pmatrix}\text{force on 1st body}\\ \text{due to second body}\end{pmatrix} = -\begin{pmatrix}\text{Force on 2nd body}\\ \text{due to 1st body}\end{pmatrix}$

Important point about action and reaction law:

i) We cannot produce a single isolated force in the nature. They are always produced in action - reaction pair.

ii) There is no time gap in between action and reaction. hence, we can't say that action is the cause and reaction is the effect. Any force can be action and other can be reaction.

iii) Action - reaction law is applicable on both the states either in rest or in motion.

iv) Action - reaction are also possible for a body which are not in physical contact.

v) This law is applicable for all the interaction forces eg: gravitational force, electrostatic force, electromagnetic force, tension, friction, viscous forces etc.

vi) They always act on two different bodies.

vii) They never cancel each other because they are exerted on two different bodies.

eg: Swimming, walking, recoiling of gun when a bullet is fired from it, Rocket propulsion.

Q. 29 (NLM) Pg - 8

Rocket Propulsion:

Case I: If rocket is accelerating upwards.

$$F_{net} = ma$$

$$\frac{vdm}{dt} - mg = ma$$

Case II: If rocket is moving with constant velocity then $a = 0$

$$\therefore \frac{vdm}{dt} - mg = ma$$

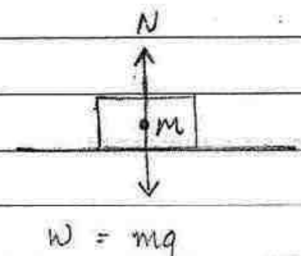
$$\therefore \frac{v\,dm}{dt} - mg = 0$$

$$\frac{v\,dm}{dt} = mg$$

## Normal Reaction:

(NLM) Pg-9

It is a constant force exerted by the surface on the body which is perpendicular to the surface and towards the body.




$\because$ the body is in equilibrium,

$$\therefore \vec{w} + \vec{N} = \vec{0}$$

$$\vec{N} = -\vec{w}$$

$$N = w \quad [\because |\vec{N}| = |-\vec{w}|]$$

$$\therefore N = mg \quad (\because w = mg)$$

## Effective or apparant weight of a man in lift.

(NLM) Pg-9

It is caused due to normal reaction

Case I: If the lift is at rest or moving uniformly $(a=0)$

$$\because N = mg$$

$$\therefore W_{app} = W_{actual}$$

where $N = W_{app}$ and $W = mg = W_{actual}$

Case II : If the lift is accelerated upwards,

$$W_{app} \text{ or } N = m(g+a)$$

$$W_{app} > W_{actual}$$

Case III : If the lift is retarding upwards,

$$W_{app} \text{ or } N = m(g-a)$$

$$W_{app} < W_{actual}$$

Case IV : If the lift is accelerated downwards,

$$W_{app} \text{ or } N = \cancel{m(g+a)}\ m(g-a)$$

$$W_{app} < W_{actual}$$

Case V : If the lift is retarding downwards,

$$W_{app} \text{ or } N = m(g+a)$$

$$W_{app} > W_{actual}$$

Two special cases of downward acceleration: (case IV)

* Special case I : If the lift is falling freely, means its acceleration is in the vertically downward direction equal to acceleration due to gravity. i.e. $a = g$.

$$W_{app} = m(g-a) = m(g-g)$$
$$= m \times 0 = 0$$

This condition is known as condition of weightlessness.

* Special case II : If the lift is accelerating downwards with an acceleration which is greater than 'g'. The man will move up with respect to the lift and he will stick to the ceiling.

Q.30 (NLM) Pg-10

∵ the lift is accelerating upward.

$$\therefore W_{app} = m(g+a)$$
$$= 60(10+2)$$
$$= 60 \times 12 = 720\ N$$

Q.31 (NLM) Pg-10

∵ the lift is accelerating downwards.

$$\therefore W_{app} = m(g-a)$$
$$= 80(10-5)$$
$$= 80 \times 5 = 400\ N$$

.32 (NLM) Pg-10

∵ the lift is accelerating upwards.

$$\therefore W_{app} = m(g+a)$$
$$1000 = 50(10+a)$$
$$= 500 + 50a$$
$$\therefore 50a = 1000 - 500$$
$$a = \frac{500}{50} = 10\ m/s^2$$

.33 ∵ the lift is accelerating downwards.

$$\therefore W_{app} = m(g-a)$$
$$600 = 80(10-a)$$
$$600 = 800 - 80a$$
$$\therefore -80a = 600 - 800$$
$$a = \frac{-200}{-80}$$
$$= 2.5\ m/s^2$$

Q.34 (NLM) Pg - 10

$\because$ the lift is accelerating upward.
acc to que,

$$W_{app} = 3\, W_{actual}$$
$$m(g+a) = 3mg$$
$$g + a = 3g$$
$$\therefore a = 3g - g = 2g$$
$$= 2 \times 10 = 20\ m/s^2$$

Q.35 (NLM) Pg-10

$$W_{app} = \frac{1}{3} W_{actual}$$

$\because$ the lift is accelerating downward.

$$\therefore m(g-a) = \frac{1}{3} mg$$

$$g - a = \frac{g}{3}$$

$$-a = \frac{10-30}{3} = \frac{-20}{3} = -6.67\ m/s^2$$

$$\therefore a = 6.67\ m/s^2$$

Q.36 (NLM) Pg-10

$$W_{app} = \frac{5}{4} W_{actual}$$

$\because$ the lift is accelerating upward

$$\therefore m(g+a) = \frac{5}{4} mg$$

$$10 + a = \frac{5}{4} \times 10$$

$\therefore \quad a = \frac{25}{2} - \frac{20}{2} = \frac{5}{2}$

$= 2.5 \ m/s^2$

Q.37 (NLM) Pg- 10

$\because$ the monkey is accelerating downward

$\therefore$ Wapp $\leq$ Wactual.

$m(g-a) \leq \frac{50}{100} mg$

$g - a \leq \frac{1}{2} g$

$-a \leq \frac{10}{2} - 10$

$-a \leq -5$

$\therefore a \geq 5 \ m/s^2$

Hence, minimum acceleration of the monkey = $5 \ m/s^2$

Q.38 (NLM) Pg - 10

$\because$ the man is moving with upward acceleration

$\therefore$ Wapp = $m(g+a)$ and.

now the man is moving with downward acceleration. $\therefore$ Wapp = $m(g-a)$

$\therefore \frac{(Wapp)\, a\uparrow}{(Wapp)\, a\downarrow} = \frac{m(g+a)}{m(g-a)} = \cancel{\frac{1}{3}} \ \frac{3}{1}$

$\therefore \frac{g+a}{g-a} = \cancel{\frac{1}{8}} \ \frac{3}{1}$

$\therefore$ ~~$g - a = 3g + 3a$~~

$3g - 3a = g + a$

$3g - g = 3a + a$

$2g = 4a$

$\therefore \; g = 2a$

$$\therefore \; a = \frac{g}{2} = \frac{10}{2} = 5 \; m/s^2$$

Q.39. (NLM) Pg-10

$\because$ the body is moving uniformly $(a = 0)$

$\therefore \; W_{app} = mg$ and

now the body is moving with downward acceleration $\therefore \; W_{app} = m(g-a)$

$$\therefore \; \frac{mg}{m(g-a)} = \frac{5}{3}$$

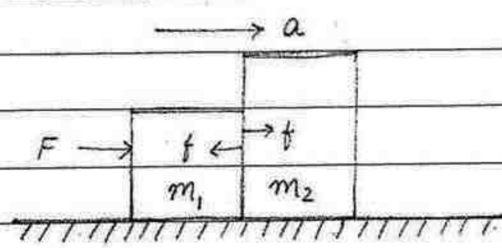
$$\therefore \; 3g = 5g - 5a$$

$$5a = 5g - 3g = 2g$$

$$\therefore \; a = \frac{2 \times 10}{5} = 4 \; m/s^2$$

Motion of bodies in contact (contact forces)

For two bodies in contact:

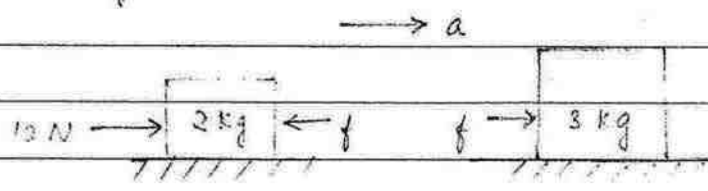



$$a = \frac{F}{m_1 + m_2} = \frac{F_{net}}{m_{net}}$$

$$\therefore \text{contact force, } f = \frac{m_2 F}{m_1 + m_2}$$

$f = a \times$ total mass of the body ahead.

Q.40 (NLM) Pg-11




$\because \quad F - f = m_1 a \quad \text{—(I)}$

$f = m_2 a \quad \text{—(II)}$

On adding (I) and (II)

$F = m_1 a + m_2 a$

$= a(m_1 + m_2)$

$\therefore \quad a = \dfrac{F}{m_1 + m_2} = \dfrac{10}{2+3}$

$= \dfrac{10}{5} = 2\ m/s^2$

$\therefore \quad f = 3 \times 2 = 6\ N$

**OR**

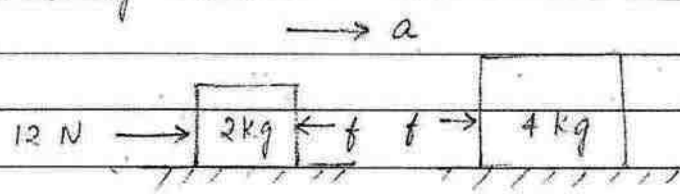
Using short Trick:

$a = \dfrac{F_{net}}{M_{net}} = \dfrac{10}{5} = 2\ m/s^2$

$f = a \times$ total mass of the bodies ahead

$= 2 \times 3 = 6\ N$

Q.41 (NLM) Pg-11




$\because \quad 12 - f = 2a \quad \text{—(I)}$

$f = 4a \quad \text{—(II)}$

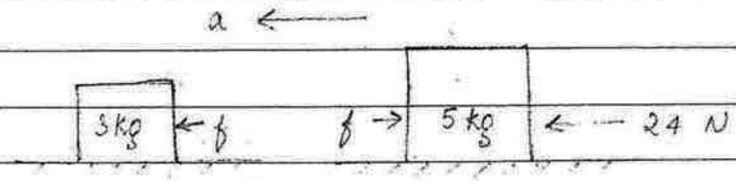
On adding (I) and (II)

$12 = 2a + 4a = 6a$

$\therefore \quad a = 2\ m/s^2$

$\therefore \; f = 4 \times 2 = 8 N$

Q.42 (NLM) Pg-11




$\because \; f = 3a$ —— (I)

$\therefore 24 - f = 5a$ —— (II)

on adding (I) and (II)

$24 = 8a$

$\therefore \; a = \frac{24}{8} = 3 m/s^2$

$\therefore \; f = 3 \times a = 3 \times 3 = 9 N$

OR

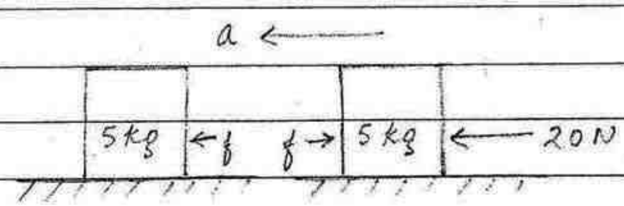
Using short Trick:

$a = \frac{F_{net}}{M_{net}} = \frac{24}{8} = 3 m/s^2$

$\therefore f = a \times$ total mass of the body ahead

$= 3 \times 3 = 9N$

Q.43 (NLM) Pg-11




$\because \; f = 5a$ —— (I)

$\therefore \; 20 - f = 5a$ —— (II)

On adding (I) and (II)

$20 = 10a$

$\therefore \; a = \frac{20}{10} = 2 m/s^2$

$\therefore f = 5 \times a = 5 \times 2 = 10N$

OR

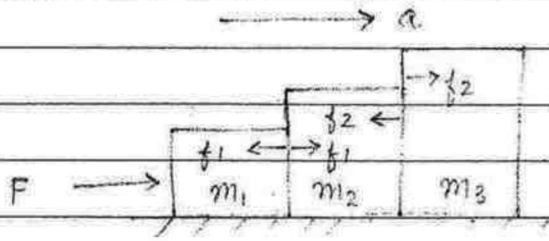
Using short trick :

$$a = \frac{F_{net}}{M_{net}} = \frac{20}{10} = 2 m/s^2$$

$\therefore f = a \times$ total mass ahead

$= 2 \times 5 = 10\ N$

Three bodies in contact :



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

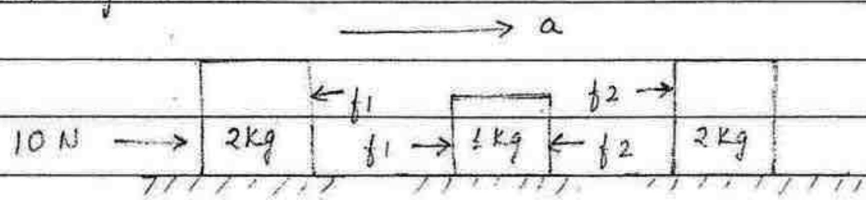
$\therefore$ contact force, $f_1 = \dfrac{(m_2 + m_3) F}{m_1 + m_2 + m_3}$ and

contact force, $f_2 = \dfrac{F m_3}{m_1 + m_2 + m_3}$

Short trick :

$f = a \times$ total mass of the body ahead

Q.44 (NLM) Pg-12



$\because \quad 10 - f_1 = 2a$ —— (I)

$f_1 - f_2 = a$ —— (II)

$f_2 = 2a$ —— (III)

On adding (I), (II) and (III)

$$10 = 5a$$

$$\therefore a = \frac{10}{5} = 2 m/s^2$$

$$f_1 = 10 - 2a$$
$$= 10 - 2\times2 = 10 - 4 = 6\ N \quad \text{and}$$
$$f_2 = 2a = 2\times2 = 4N$$

OR

Using short trick :

$$a = \frac{F_{net}}{m_{net}} = \frac{10}{5} = 2 m/s^2$$

$$f_1 = 2\times3 = 6N \quad \text{and}$$
$$f_2 = 2\times2 = 4N$$

Q.45 (NLM) Pg - 12


$$\because \quad f_1 = 2a \quad \text{— (I)}$$
$$f_2 - f_1 = 3a \quad \text{— (II)}$$
$$100 - f_2 = 5a \quad \text{— (III)}$$

On adding (I) (II) and (III)

$$100 = 10a$$

$$\therefore a = \frac{100}{10} = 10 m/s^2$$

$$\therefore f_1 = 2\times a = 2\times10 = 20\ N$$
$$f_2 = 100 - 5a = 100 - 50 = 50\ N$$

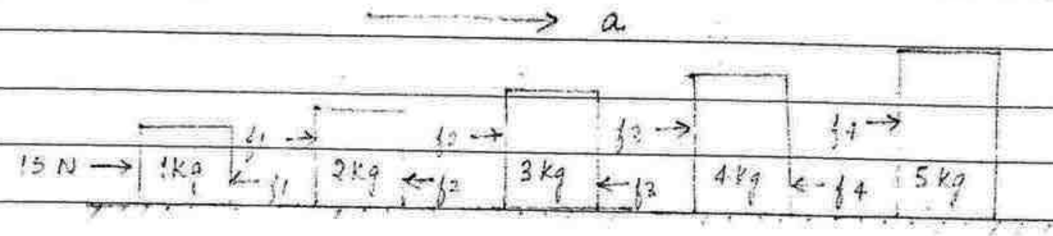
Using short trick,

$$a = \frac{F_{net}}{M_{net}} = \frac{100}{10} = 10 m/s^2$$

$\therefore f_1 = 10 \times 2 = 20\,N$ and

$f_2 = 10 \times 5 = 50\,N$

Q. 46 (NLM Pg - 12.




$$\because \quad 15 - f_1 = a \quad \text{—— (I)}$$
$$f_1 - f_2 = 2a \quad \text{—— (II)}$$
$$f_2 - f_3 = 3a \quad \text{—— (III)}$$
$$f_3 - f_4 = 4a \quad \text{—— (IV)}$$
$$f_4 = 5a \quad \text{—— (V)}$$

On adding (I) (II) (III) (IV) and (V)

$$15 = 15a$$
$$\therefore a = \frac{15}{15} = 1\,m/s^2$$

$$f_1 = 15 - a = 15 - 1 = 14\,N$$
$$f_2 = f_1 - 2a = 14 - 2 = 12\,N$$
$$f_3 = f_2 - 3a = 12 - 3 = 9\,N$$
$$f_4 = f_3 - 4a = 9 - 4 = 5\,N$$

**OR**

Using short trick,

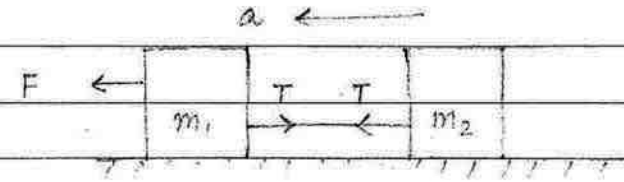
$$a = \frac{F_{net}}{M_{net}} = \frac{15}{15} = 1\,m/s^2$$

$$f_1 = 1 \times 14 = 14N$$
$$f_2 = 1 \times 12 = 12N$$
$$f_3 = 1 \times 9 = 9N$$
$$f_4 = 1 \times 5 = 5N$$

## Motion of connected bodies :

(NLM) Pg - 12.

Two connected bodies :

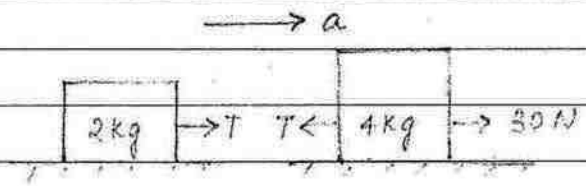



$$a = \frac{F}{m_1 + m_2} = \frac{F_{net}}{M_{net}}$$

Tension, $T = \dfrac{m_2 F}{m_1 + m_2}$

$T = a \times$ total mass behind that body.

Q.47 (NLM) Pg-12




$\because \quad T = 2a$ —— (I)

$30 - T = 4a$ —— (II)

On adding (I) and (II)

$30 = 6a$

$\therefore \quad a = \dfrac{30}{6} = 5 \ m/s^2$

$\therefore \ T = 2 \times 5 = 10 \ N$

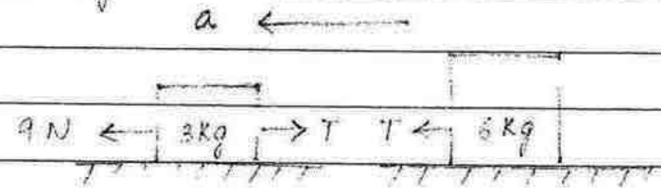
OR

Using short trick,

$a = \dfrac{F_{net}}{M_{net}} = \dfrac{30}{6} = 5 \ m/s^2$

$\therefore \ T = 2 \times 5 = 10 \ N$

Q-48 (NLM) Pg - 12




$$\because \quad 9 - T = 3a \quad \text{—(I)}$$

$$T = 6a \quad \text{—(II)}$$

On adding (I) and (II)

$$9 = 9a$$

$$\therefore \quad a = \frac{9}{9} = 1 \, m/s^2$$

$$T = 6 \times 1 = 6 \, N$$

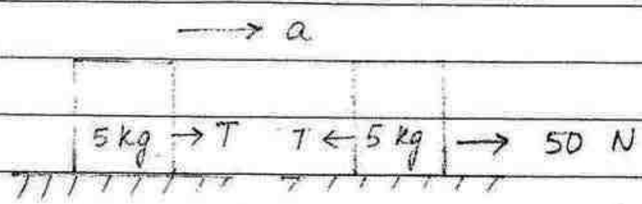
OR

Using short trick,

$$a = \frac{F_{net}}{M_{net}} = \frac{9}{9} = 1 \, m/s^2$$

$$T = 1 \times 6 = 6 \, N$$

Q. 49 (NLM) Pg - 12




$$\because \quad T = 5a \quad \text{—(I)}$$

$$50 - T = 5a \quad \text{—(II)}$$

$\therefore$ On adding (I) and (II)

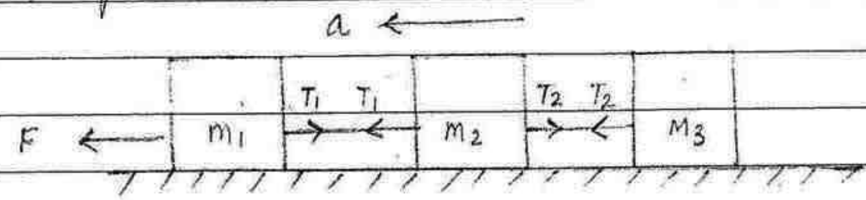
$$50 = 10a$$

$$\therefore \quad a = \frac{50}{10} = 5 \, m/s^2$$

$$T = 5 \times 5 = 25 \, N$$

Three connected bodies:

(NLM) Pg-12




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

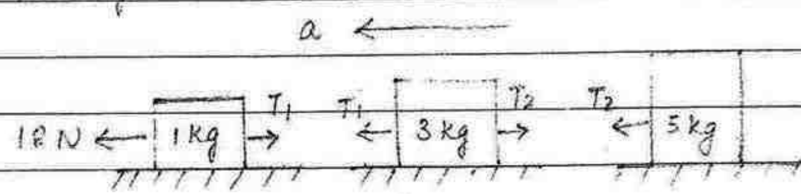
$$T_1 = \frac{(m_2 + m_3)\,F}{m_1 + m_2 + M_3} \quad \text{and}$$

$$T_2 = \frac{m_3 F}{m_1 + M_2 + M_3}$$

OR

Tension, T = a x total mass behind the body

Q.50 (NLM) Pg-13




$18 - T_1 = a$ —(I)

$T_1 - T_2 = 3a$ —(II)

$T_2 = 5a$ —(III)

On adding (I) (II) and (III)

$18 = 9a$

$\therefore a = \frac{18}{9} = 2\ m/s^2$

$T_1 = 18 - a = 18 - 2 = 16\ N$

$T_2 = 5 \times a = 5 \times 2 = 10\ N$

OR

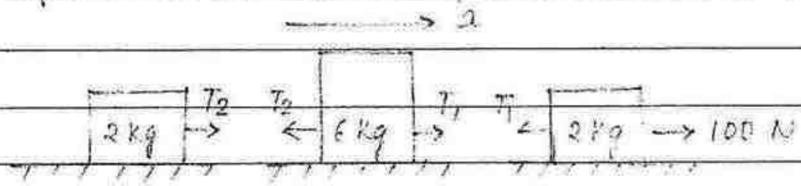
using short trick:

$$a = \frac{F_{net}}{M_{net}} = \frac{18}{9} = 2\ m/s^2$$

$$T_1 = 2 \times 8 = 16\ N$$

$$T_2 = 2 \times 5 = 10\ N$$

Q.51 (NLM) Pg-13




$$\therefore\ T_2 = 2a \quad \text{—(I)}$$

$$T_1 - T_2 = 6a \quad \text{—(II)}$$

$$100 - T_1 = 2a \quad \text{—(III)}$$

On adding (I) (II) and (III)

$$100 = 10a$$

$$\therefore\ a = \frac{100}{10} = 10\ m/s^2$$

$$T_1 = 100 - 2a = 100 - 20 = 80\ N$$

$$T_2 = 2a = 2 \times 10 = 20\ N$$

OR

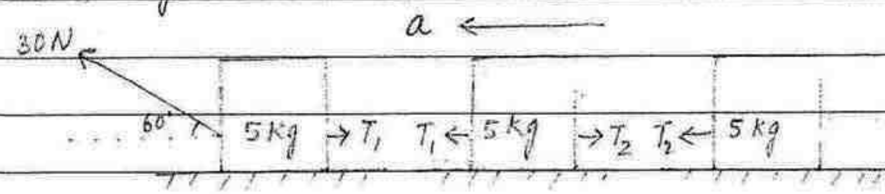
using short trick :

$$a = \frac{F_{net}}{M_{net}} = \frac{100}{10} = 10\ m/s^2$$

$T_1 = 10 \times 8 = 80\ N$ and

$T_2 = 10 \times 2 = 20\ N$

Q.52 (NLM) Pg-13



$\because \; F = F\cos\theta = F\cos 60^\circ = 30 \times \frac{1}{2} = 15N$

$\therefore \; 15 - T_1 = 5a$ — (I)

$T_1 - T_2 = 5a$ — (II)

$T_2 = 5a$ — (III)

On adding (I) (II) and (III)

$15 = 15a$

$\therefore \; a = \frac{15}{15} = 1\, m/s^2$

$T_1 = 15 - 5a = 15 - 5 = 10\,N$ and

$T_2 = 5a = 1 \times 5 = 5\,N$

**OR**

Using short trick :

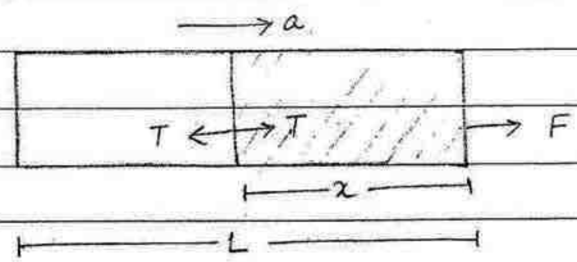
$a = \frac{F\cos\theta}{M_{net}} = \frac{F\cos 60^\circ}{15} = \frac{30}{15} \times \frac{1}{2} = 1\, m/s^2$

$T_1 = 1 \times 10 = 10\,N$ and

$T_2 = 1 \times 5 = 5\,N$

Tension in Rod :

(NLM) Pg - 13




$\because$ Mass of length 'L' = M

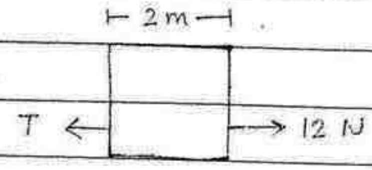
$\therefore$ Mass of unit length $= \frac{M}{L}$

Mass (m) of length 'x' $= \frac{M}{L} \times x$

$\therefore \; T = F\left(1 - \frac{x}{L}\right)$

$\therefore$ T decreases as we move away from the point of application of force and $x$ is the distance from the point of application of force

Q.53 (NLM) Pg - 14




$\because$ Mass of 6m = M

$\therefore$ Mass of 1m = $\frac{M}{6}$

Mass of 2m = $\frac{M}{6} \times 2 = \frac{M}{3}$

$\therefore \quad 12 - T = \frac{M}{3} \times \frac{F}{M} = \frac{12}{3} = 4$

$\therefore \quad T = 12 - 4 = 8\ N$

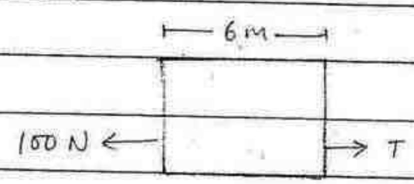
OR

$\because \quad T = F\left(1 - \frac{x}{L}\right)$

$= 12\left(1 - \frac{2}{6}\right)$

$= 12\left(\frac{3-1}{3}\right) = 12 \times \frac{2}{3} = 4 \times 2 = 8N$

Q.54 NLM (Pg-14)




$\because$ Mass of 10 m = M

Mass of 1 m = $\frac{M}{10}$

$\therefore$ Mass of $6m = \frac{M}{10} \times 6 = \frac{3M}{5}$

$\therefore 100 - T = \frac{3M}{5} \times \frac{100}{M}$

$= 3 \times 20 = 60.$

$\therefore T = 100 - 60 = 40\ N$

OR

$\because T = F\left(1 - \frac{x}{L}\right)$

$= 100\left(1 - \frac{6}{10}\right) = 100 \times \left(\frac{10-6}{10}\right)$

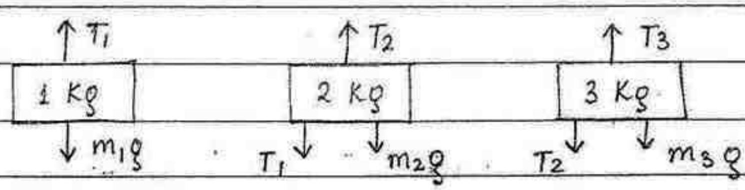
$= 10 \times 4 = 40\ N$

Bodies hanged vertically :

(NLM) Pg-14

Since the bodies are in equilibrium. therefore net force on all the bodies is 0.

Q.55 (NLM) Pg-14




$\because T_1 = m_1 g$

$= 1 \times 10 = 10\ N$

$\because T_2 = T_1 + m_2 g$

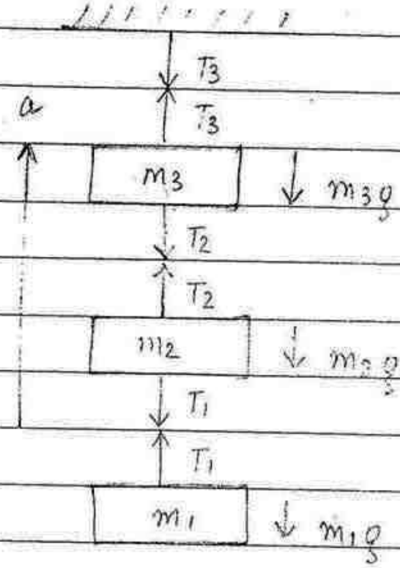
$= 10 + 2 \times 10 = 10 + 20 = 30\ N$

$\because T_3 = T_2 + m_3 g$

$= 30 + 3 \times 10 = 30 + 30$

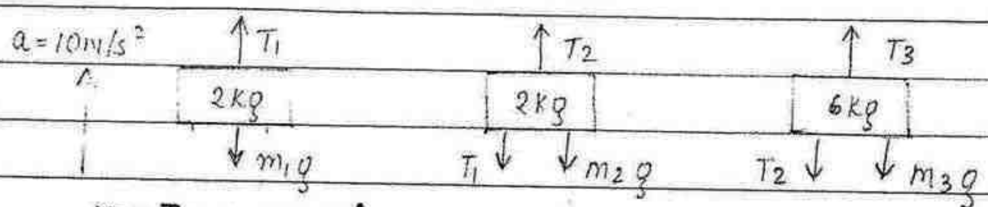
$= 60\ N$

Bodies accelerated vertically upwards:
(NLM) Pg-14




$$T_1 = m_1 (g+a)$$
$$T_2 = (m_1 + m_2)(g+a)$$
$$T_3 = (m_1 + m_2 + m_3)(g+a)$$

Q.56 (NLM) Pg-14




~~$\therefore T_1 = m_1($~~

$$T_1 - m_1 g = m_1 a$$
$$\therefore T_1 = m_1 a + m_1 g = m_1 (a+g)$$
$$= 2(10+10)$$
$$= 2 \times 20 = 40 N$$
$$T_2 - T_1 - m_2 g = m_2 a$$
$$\therefore T_2 = m_2 a + m_2 g + T_1$$
$$= m_2 (a+g) + T_1$$
$$= 2(10+10) + 40$$
$$= 2 \times 20 + 40 = 80 N$$

$$\therefore \quad T_3 - T_2 - m_3 g = m_3 a$$
$$T_3 = m_3 a + m_3 g + T_2$$
$$= m_3 (a+g) + T_2$$
$$= 6(10+10) + 80$$
$$= 6 \times 20 + 80 = 120 + 80 = 200\ N$$

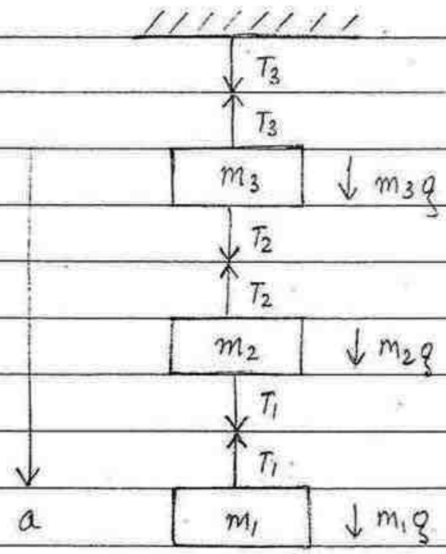
OR

using short trick:

$$T_1 = 2(g+a) = 2(10+10) = 40\ N$$
$$T_2 = (2+2)(g+a) = 4(10+10) = 80\ N$$
$$T_3 = (2+2+6)(g+a) = 10(10+10) = 200\ N$$

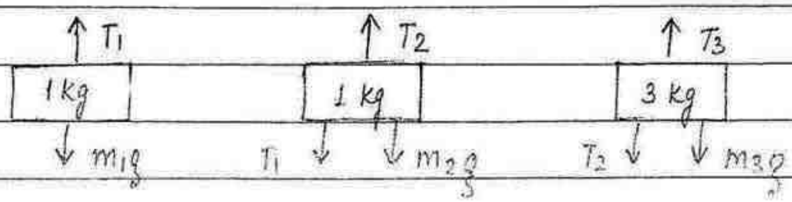
Bodies accelerating vertically downwards:

NLM (Pg-15)




$$T_1 = m_1(g-a)$$
$$T_2 = (m_1+m_2)(g-a)$$
$$T_3 = (m_1+m_2+m_3)(g-a)$$

Q.57 (NLM) Pg-14



i) Rest:

$T_1 = m_1 g$

$= 1 \times 10 = 10\,N$

$T_2 = m_2 g + T_1$

$= 1 \times 10 + 10 = 20\,N$

$T_3 = m_3 g + T_2$

$= 3 \times 10 + 20 = 30 + 20 = 50\,N$

ii) vertically upward acceleration:

$T_1 = m_1 (g + a)$

$= 1 (10 + 5) = 15\,N$

$T_2 = (m_1 + m_2)(g + a)$

$= (1 + 1)(10 + 5) = 30\,N$

$T_3 = (m_1 + m_2 + m_3)(g + a)$

$= (1 + 1 + 3)(10 + 5) = 5 \times 15 = 75$

iii) vertically downward ~~direction~~: acceleration:

$T_1 = m_1 (g - a)$

$= 1 (10 - 5) = 5\,N$

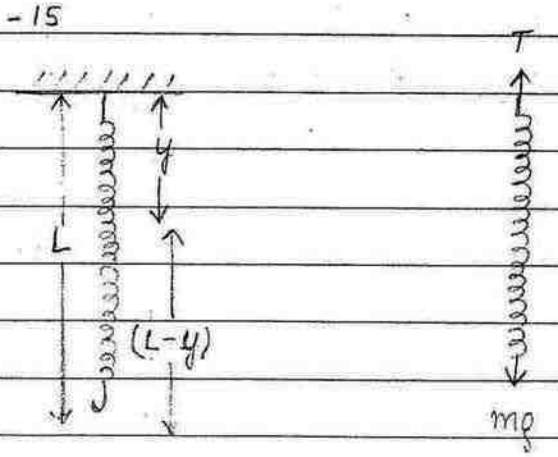
$T_2 = (m_1 + m_2)(g - a)$

$= (1 + 1)(10 - 5) = 10\,N$

$T_3 = (m_1 + m_2 + m_3)(g - a)$

$= (1 + 1 + 3)(10 - 5) = 5 \times 5 = 25\,N$

Q.58 (NLM) Pg - 15



* Tension at a point in a chain hanged vertically will balance the weight of chain below that point.

$$\because \text{Mass of } L \text{ 'm'} = M$$
$$\therefore \text{Mass of } 1 \text{ m} = \frac{M}{L}$$
$$\text{Mass of } (L-y)\text{ m} = \frac{M}{L}(L-y)$$
$$\therefore T = \frac{mg}{L}(L-y) \quad \left[\because M = mg\right]$$
$$= \boxed{mg\left(1 - \frac{y}{L}\right)}$$

* Horizontal tension: $F\left(1 - \frac{x}{L}\right)$
* Vertical tension: $mg\left(1 - \frac{y}{L}\right)$

- If spring balances are connected in series, then the reading of each balance is same and equal to the applied load provided the balances are massless.
- If spring balances are connected in parallel then the applied body is equally divided in all the balances so the reading of each balance will be $\frac{\text{applied load}}{\text{no. of balances}}$.

~~Eqa~~

Equilibrium :

i) Linear / Translatory equilibrium

$\vec{F}_{net} = \vec{0}$

$(\vec{F_x})_{net} = \vec{0}$

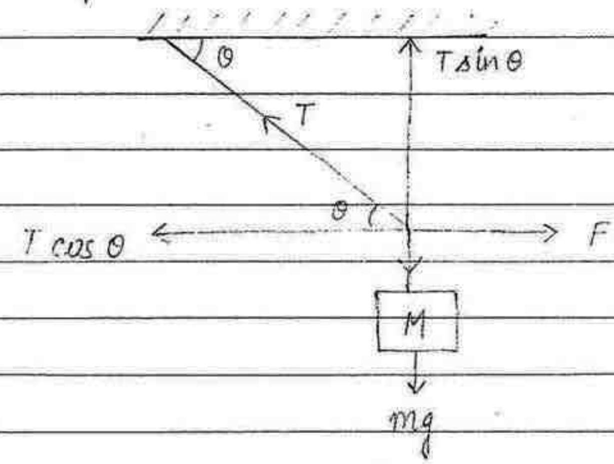
$(\vec{F_y})_{net} = \vec{0}$

$(\vec{F_z})_{net} = \vec{0}$

ii) Rotatory equilibrium

$\vec{\tau}_{net} = \vec{0}$

Q.59 (NLM) Pg - 16




For vertical equilibrium : $T\sin\theta = mg$ — (I)

For horizontal equilibrium : $T\cos\theta = F$ — (II)

On dividing (II) by (I)

$$\frac{T\sin\theta}{T\cos\theta} = \frac{mg}{F}$$

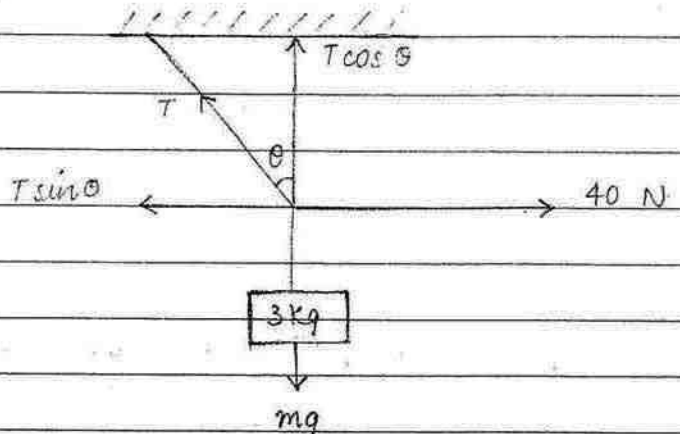
$$\tan\theta = \frac{mg}{F}$$

$$\therefore \quad \theta = \tan^{-1}\left(\frac{mg}{F}\right)$$

On squaring (I) and adding it to the square of (II)

$$T^2 \sin^2\theta + T^2 \cos^2\theta = M^2g^2 + F^2$$
$$T^2(\sin^2\theta + \cos^2\theta) = M^2g^2 + F^2$$
$$T^2 = M^2g^2 + F^2$$
$$\therefore T = \sqrt{M^2g^2 + F^2}$$

Q.60 (NLM) Pg-16




$\because T\cos\theta = mg$ (vertical equilibrium)

$T\sin\theta = 40\ N$ (horizontal equilibrium) — (I)

$\therefore T\cos\theta = 30\ N$ — (II)

On diving (II) ~~from~~ by (I)

$$\frac{T\sin\theta}{T\cos\theta} = \frac{40\ N}{30\ N}$$

$$\therefore \tan\theta = \frac{4}{3} = \tan 53^\circ$$

$$\therefore \theta = 53^\circ$$

$\because T\sin\theta = 40$

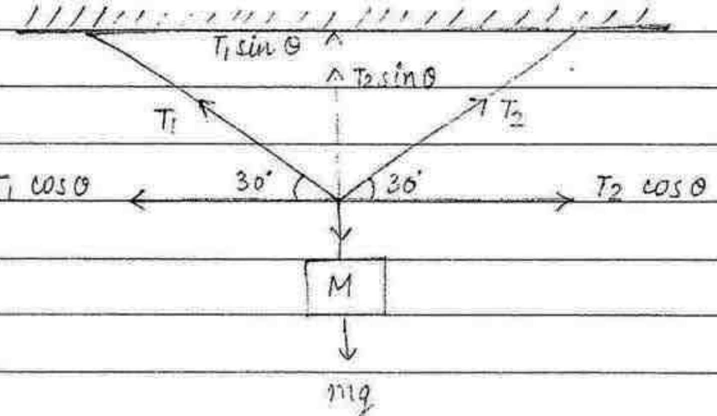
$$\therefore T = \frac{40}{\sin\theta} = \frac{40}{\sin 53^\circ}$$

$$= \frac{40}{4} \times 5$$

$$= 10 \times 5$$

$$= 50\ N$$

Q.61 (NLM) Pg - 16




For horizontal equilibrium :

$$T_1 \cos\theta = T_2 \cos\theta$$

$$\therefore T_1 = T_2$$

For vertical equilibrium :

$$T_1 \sin\theta + T_2 \sin\theta = mg$$

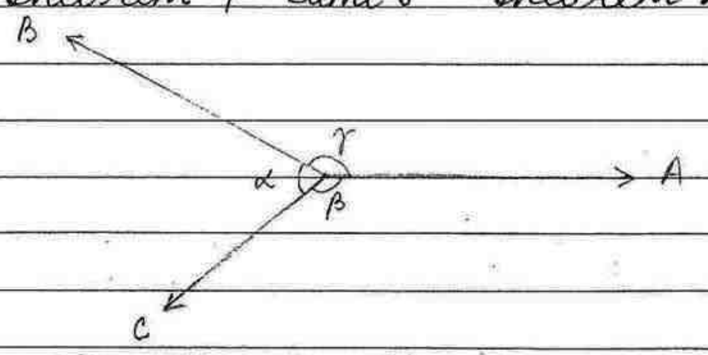
$$T_1 \sin 30^\circ + T_2 \sin 30^\circ = mg$$

$$\frac{T_1}{2} + \frac{T_2}{2} = Mg$$

$$\therefore T_1 + T_2 = 2Mg$$

$$T_1 = T_2 = Mg \quad (\because T_1 = T_2)$$

Sine Theorem / Lami's Theorem :




If $\vec{A} + \vec{B} + \vec{C} = \vec{0}$

$\because$ Its applicable for only equilibrium condition.

$$\therefore \frac{A}{\sin\alpha} = \frac{B}{\sin\beta} = \frac{C}{\sin\gamma}$$

Pulley System :
(NLM) Pg - 16

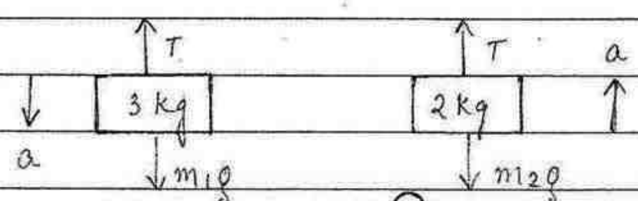
i) Fixed pulley
ii) Movable pulley

Fixed pulley :

i) equal masses on both sides :
- $a = 0$ ($\because$ net force $= 0$)
- $T = mg$
- $T' = 2T = 2mg$

ii) unequal masses on both sides :
- $a = \dfrac{(M_1 - M_2)g}{M_1 + M_2}$ $\quad (\because M_1 > M_2)$
- $a = \dfrac{F_{net}}{m_{net}}$ (net accelerating force)
- $T = \dfrac{2m_1m_2g}{m_1+m_2} = \dfrac{2w_1w_2}{w_1+w_2}$
- Thrust on pulley $(T') = \dfrac{4m_1m_2g}{m_1+m_2} = \dfrac{4w_1w_2}{w_1+w_2}$

Q.62 (NLM) Pg - 15

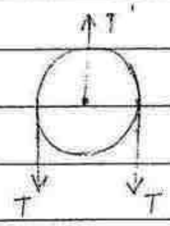



$\therefore m_1g - T = 3a$ —(I)
$T - m_2g = 2a$ —(II)
$(m_1 - m_2)g = 5a$ (on adding (I) and (II))
$(3-2)g = 5a$
$\therefore a = \dfrac{10}{5} = 2\ m/s^2$

$\therefore T = m_2 g + 2a$

$= 2 \times 10 + 2 \times 2$

$= 20 + 4 = 24\ N$




$\therefore T' = 2T = 2 \times 24 = 48\ N$

Using short trick,

$a = \dfrac{(m_1 - m_2)g}{m_1 + m_2} = \dfrac{(3-2)10}{3+2} = \dfrac{10}{5} = 2\ m/s^2$

$T = \dfrac{2 m_1 m_2 g}{m_1 + m_2} = \dfrac{2 \times 3 \times 2 \times 10}{3+2} = 24\ N$

$T' = \dfrac{4 m_1 m_2 g}{m_1 + m_2} = \dfrac{4 \times 3 \times 2 \times 10}{3+2} = 48\ N$

Q.63 (NLM) Pg - 15

$a = \dfrac{(m_1 - m_2)g}{m_1 + m_2} = \dfrac{(6-4)10}{6+4} = 2\ m/s^2$

$T = \dfrac{2 m_1 m_2 g}{m_1 + m_2} = \dfrac{2 \times 6 \times 4 \times 10}{6+4} = 48\ N$

$T' = \dfrac{4 \times m_1 m_2 g}{m_1 + m_2} = \dfrac{4 \times 6 \times 4 \times 10}{6+4} = 96\ N$

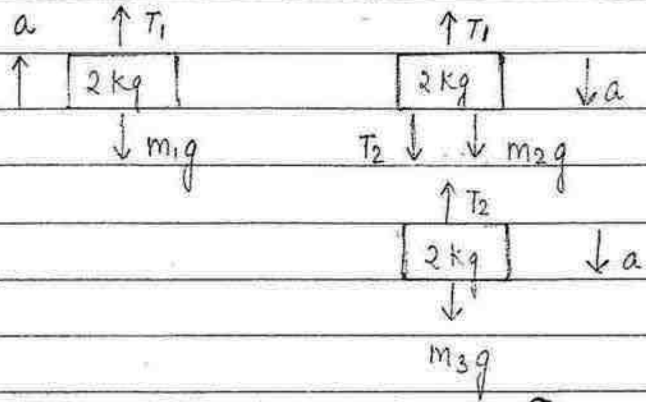
Q.64 (NLM) Pg - 19

$a = \dfrac{(m_1 - m_2)g}{m_1 + m_2} = \dfrac{(5-3)10}{5+3} = \dfrac{20}{8} = 2.5\ m/s^2$

$T = \dfrac{2 m_1 m_2 g}{m_1 + m_2} = \dfrac{2 \times 5 \times 3 \times 10}{5+3} = \dfrac{300}{8} = 37.5\ N$

$T' = 2T = 2 \times 37.5 = 75\ N$

Q.65 (NLM) Pg-18




$\therefore\ T_1 - m_1g = 2a$ —(I)

$T_2 + m_2g - T_1 = 2a$ —(II)

$m_3g - T_2 = 2a$ —(III)

$\therefore$ On adding (I) (II) and (III)

$(m_3 + m_2 - m_1)\, g = 6a$

$\therefore\ a = \frac{(2+2-2)10}{6} = \frac{2 \times 10}{6}$

$= \frac{10}{3}\ m/s^2$

$T_1 = 2a + m_1g = \frac{2 \times 10}{3} + 2 \times 10$

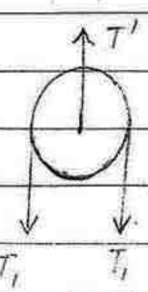
$= \frac{20}{3} + 20 = \frac{20+60}{3} = \frac{80}{3}\ N$

$T_2 = m_3g - 2a = 2 \times 10 - \frac{2 \times 10}{3}$

$= \frac{60-20}{3} = \frac{40}{3}\ N$

$T' = 2T_1 = \frac{2 \times 80}{3}$

$= \frac{160}{3}\ N$



OR

By using short trick,

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(2+2-2)10}{(2+2)+2}$$

$$= \frac{2 \times 10}{6} = \frac{10}{3}\ m/s^2$$

$$T_1 = \frac{2 \times m_1 \times m_2 g}{m_1 + m_2} = \frac{2 \times 4 \times 2 \times 10}{4+2} = \frac{80}{3}\ N$$

$T_2$ = $g_{eff}$ × mass below the point

$$= (g-a) \times 2$$

$$= \left(10 - \frac{10}{3}\right) \times 2 = \left(\frac{30-10}{3}\right) \times 2$$

$$= \frac{20}{3} \times 2 = \frac{40}{3}\ N$$

$$T' = 2T' = 2 \times \frac{80}{3} = \frac{160}{3}\ N$$

Q.66 (NLM) Pg-18

here, $m_1 = 3+3 = 6\ kg$ and $m_2 = 4\ kg$

$$\therefore a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(6-4)10}{6+4} = 2\ m/s^2$$

$$T_1 = \frac{2m_1 m_2 g}{m_1 + m_2} = \frac{2 \times 6 \times 4 \times 10}{6+4} = 48\ N$$

$T_2$ = $g_{eff}$ × mass below the point.

$$= (g-a) \times 3 = (10-2)\,3 = 24\ N$$

$$T' = 2T_1 = 2 \times 48 = 96\ N$$

Q.67 (NLM) Pg-18

here, $m_1 = 5+2 = 7\ kg$ and $m_2 = 3\ kg$

$\therefore a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(7-3)\,10}{7+3} = 4 m/s^2$

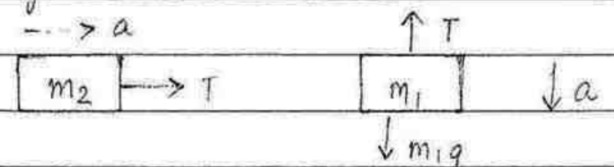
$T_1 = \frac{2 m_1 m_2 g}{m_1 + m_2} = \frac{2 \times 7 \times 3 \times 10}{7+3} = 42\ N$

$T_2 = g_{eff} \times$ mass below the point

$= (g-a) \times 2 = (10-4)\,2 = 12\ N$

$T' = 2T_1 = 2 \times 42 = 84\ N$

Q.68 (NLM) Pg-18




$\therefore m_1 g - T = m_1 a \quad —(I)$

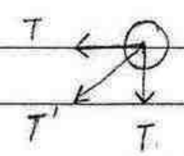
$T = m_2 a \quad —(II)$

On adding (I) and (II)

$m_1 g = (m_1 + m_2)\,a$

$\therefore a = \frac{m_1 g}{m_1 + m_2}$

$T = \frac{m_2 m_1 g}{m_1 + m_2}$




[Vector addition of equal magnitude] = 2T cos

$\therefore T' = 2T \cos\frac{\theta}{2} = 2T \cos\frac{90}{2} = 2T \cos 45^\circ$

$= 2T \frac{1}{\sqrt{2}} = \sqrt{2}\,T = \frac{\sqrt{2}\, m_1 m_2 g}{m_1 + m_2 g}$

Q.69 (NLM) Pg-18

$\because a = \frac{m_1 g}{m_1 + m_2} = \frac{3 \times 10}{3+2} = \frac{30}{5} = 6\ m/s^2$

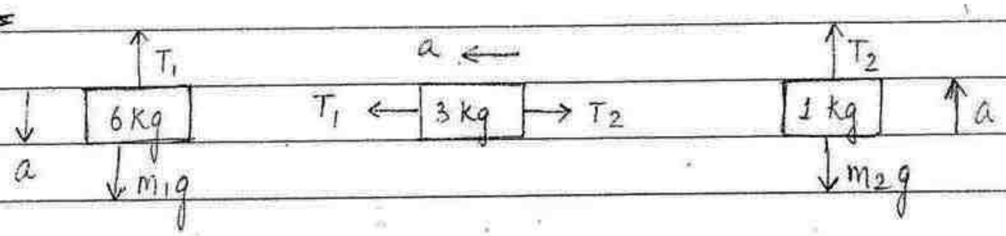
* $T = \dfrac{m_1 m_2 g}{m_1 + m_2} = \dfrac{3 \times 2 \times 10}{3 + \cancel{8}2} = 12\ N$

$T' = \sqrt{2}T = \sqrt{2} \times 12 = 12\sqrt{2}\ N$

Q. 70 (NLM) Pg - 18

$\cancel{\because a = \dfrac{F_{net}}{M_{net}} = \dfrac{(m_1 - m_2)g}{m_1 + m_2} = \dfrac{(6-1) \times 10}{6 + 3 + 1} = \dfrac{5 \times 10}{10} = 5\ m/s^2}$

~~$T_1 =$~~




$\because\ M_1 g - T_1 = 6a \quad \text{— (I)}$

$T_1 - T_2 = 3a \quad \text{— (II)}$

$T_2 - M_2 g = a \quad \text{— (III)}$

On adding (I) (II) and (III)

$(m_1 - m_2)g = 10a$

$\therefore\ a = \dfrac{(m_1 - m_2)}{10} g = \dfrac{(6-1)10}{10} = 5\ m/s^2$

~~$T_1 = 3a + T_2 = 3 \times 5 +$~~

$T_1 = -6a + M_1 g$

$= 6 \times 10 - 6 \times 5 = 60 - 30 = 30\ N$

$T_2 = T_1 - 3a = 30 - 3 \times 5 = 30 - 15 = 15\ N$

$\therefore\ T_1' = \sqrt{2}T_1 = \sqrt{2} \times 30 = 30\sqrt{2}\ N$

$T_2' = \sqrt{2}T_2 = \sqrt{2} \times 15 = 15\sqrt{2}\ N$

OR

Using short trick:

$a = \dfrac{F_{net}}{M_{net}} = \dfrac{(m_1 - m_2)g}{m_1 + m_2} = \dfrac{(6-1)10}{6 + 3 + 1} = 5\ m/s^2$

$T_1 = a \times$ mass below the point

$= 5 \times 6 = 30\,N$

$\cancel{T_2}$ or

$T_1 = g_{eff} \times mass$

$= (10-5) \times 6 = 5 \times 6 = 30\,N$

$\therefore T_2 = g_{eff} \times mass$

$= (g+a)\, m = (10+5)\, 1 = 15\,N$

$\therefore T_1' = \sqrt{2}\, T_1 = 30\sqrt{2}\,N$ and

$T_2' = \sqrt{2}\, T_2 = 15\sqrt{2}\,N$

Q-71 (NLM) Pg-18

Using short trick:

$$a = \frac{F_{net}}{M_{net}} = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(5-2)\,10}{5+2+3}$$

$$= \frac{3 \times 10}{10} = 3\,m/s^2$$

$T_1 = mass \times g_{eff}$

$= m(g+a) = 2(10+3) = 26\,N$

$T_2 = mass \times g_{eff}$

$= m(g-a) = 5\,(10-3) = 35\,N$

$\therefore T_1' = \sqrt{2}\, T_1 = 26\sqrt{2}\,N$ and

$T_2' = \sqrt{2}\, T_2 = 35\sqrt{2}\,N$

Q.72 (NLM) Pg-18

$$a = \frac{F_{net}}{M_{net}} = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(9-5) \times 10}{9+5+6}$$

$$= \frac{4 \times 10}{20} = 2\,m/s^2$$

$T_1 = g_{eff} \times mass$

$= m(g-a) = 9(10-2) = 72\,N$

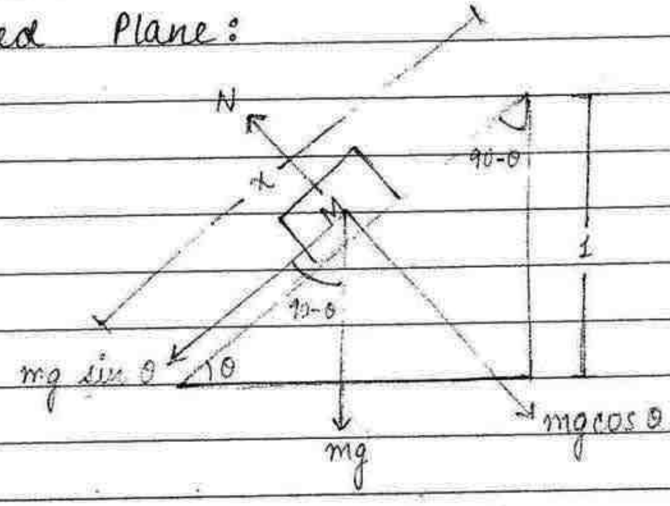
$T_2 =$ $g_{eff} \times$ mass

$= m(g+a) = 5\ (10+2) = 60\ N$

$\therefore T_1' = \sqrt{2}\,T_1 = 72\sqrt{2}\ N$ and

$T_2' = \sqrt{2}\,T_2 = 60\sqrt{2}\ N$

~~Q.73~~ Inclined Plane:




where, $\theta =$ angle of inclination from horizontal

OR

~~θ=~~ inclination is '1 sin x' $\Rightarrow \sin\theta = \frac{1}{x}$

Q.73 (NLM) Pg - 19

$\uparrow T$      $\uparrow T$

$a \downarrow$ $\boxed{m_1}$      $\boxed{m_2}$ $\uparrow a$

$\downarrow m_1 g$      $\downarrow m_2 g \sin\theta$

$\therefore\ m_1 g - T = m_1 a$ — (I)

$T - m_2 g \sin\theta = m_2 a$ — (II)

$\therefore\ g\,(m_1 - m_2 \sin\theta) = a\,(m_1 + m_2)$

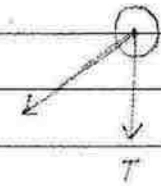
$\therefore\ a = \dfrac{(m_1 - m_2 \sin\theta)\,g}{m_1 + m_2}$

$T = m_1 g - m_1 a$

$= m_1 g - m_1 \left(\dfrac{m_1 - m_2 \sin\theta}{m_1 + m_2}\right) g$

$$T' = 2T\cos\left(\frac{90-\theta}{2}\right)$$

$$= 2T\cos\left(45^\circ - \frac{\theta}{2}\right)$$




vector addition of equal magnitude $= 2T\cos\frac{\theta}{2}$

where $\theta' = (90-\theta)$

Q.74 (NLM) Pg-19

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

$$= \frac{4\times10 - 6\times10\times\sin30}{6+4} = \frac{40 - 60\times\frac{1}{2}}{10}$$

$$= \frac{40-30}{10} = \frac{10}{10} = 1\,m/s^2$$

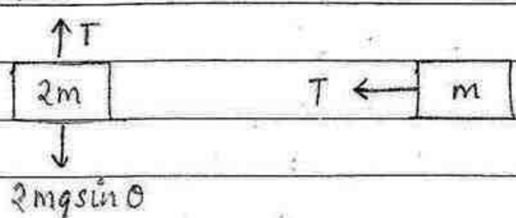
$T = m \times g_{eff} = 4\times(10-1) = 4\times9 = 36\,N$

$$T' = 2T\cos\left(\frac{90-\theta}{2}\right)$$

$$= 2\times36\cos\left(\frac{90-30^\circ}{2}\right) = 2\times36\times\cos30^\circ$$

$$= 2\times36\times\frac{\sqrt{3}}{2} = 36\sqrt{3}\,N.$$

Q.75 (NLM) Pg-19




$2mg\sin\theta - T = 2ma$ — (I)

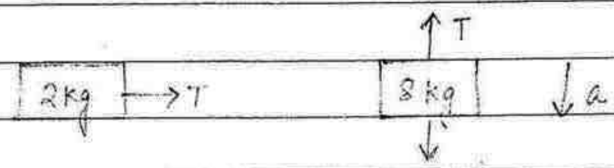
$T = ma$ — (II)

$\therefore 2mg\sin\theta = 3am$ (On adding ① and ⑪)

$$\therefore a = \frac{2g\sin\theta}{3} = \frac{20\sin\theta}{3}$$

$$T = ma = \frac{20m\sin\theta}{3}$$

Q.76 (NLM) Pg-19




$$\because T = 2a \quad \text{—①}$$

$$mg\sin\theta - T = 8a \quad \text{—⑪}$$

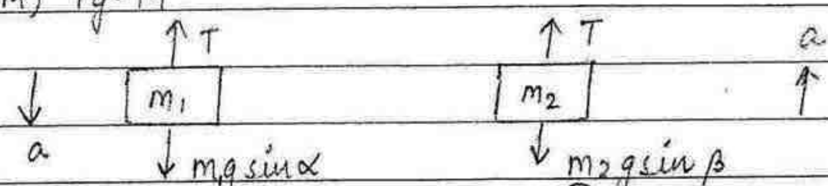
on adding ① and ⑪

$$mg\sin\theta = 10a$$

$$\therefore a = \frac{80 \times \sin 30^\circ}{10} = \frac{80}{10} \times \frac{1}{2} = 4\ m/s^2$$

$$\therefore T = 2a = 8\ N$$

Q.77 (NLM) Pg-19




$$\therefore m_1 g\sin\alpha - T = m_1 a \quad \text{—①}$$

$$T - m_2 g\sin\beta = m_2 a \quad \text{—⑪}$$

On adding ① and ⑪

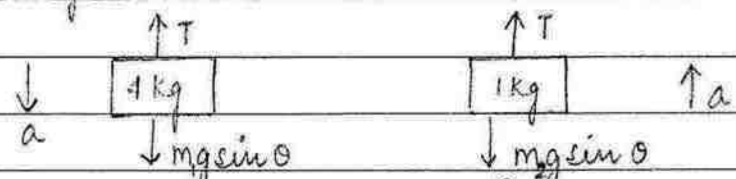
$$m_1 g\sin\alpha - m_2 g\sin\beta = (m_1+m_2)a$$

$$\therefore a = \frac{m_1 g\sin\alpha - m_2 g\sin\beta}{m_1+m_2}$$

$$\therefore T = m_2 a + m_2 g\sin\beta$$

$$= m_2\left(\frac{m_1 g\sin\alpha - m_2 g\sin\beta}{m_1+m_2}\right) + m_2 g\sin\beta$$

Q.78 (NLM) Pg-19




$\therefore \quad mg\sin\theta - T = 4a \quad \text{— (I)}$

$T - m_2 g\sin\theta = a \quad \text{— (II)}$

On adding (I) and (II)

$m_1 g\sin\theta \cancel{+} - m_2 g\sin\theta = 5a$

$40 \times \sin 30^\circ \cancel{+} - 10 \times \sin 30^\circ = 5a$

$\therefore \quad 40 \times \frac{1}{2} \cancel{+} - 10 \times \frac{1}{2} = 5a$

$\therefore \quad 5a = \cancel{20+5}\ 20 - 5$

$\therefore a = \frac{15}{5} = 3\,m/s^2$

$T = a + m_2 g\sin\theta$

$= 3 + 10 \times \frac{1}{2} = 3 + 5 = 8N$

Mechanical advantage:

~~M.A~~ (NLM) Pg-19

$M.A = \frac{\text{load}}{\text{effort}}$

Inertial and gravitational mass:

(NLM) Pg-19

- $m_i = \frac{F}{a}$
- $m_g = \frac{F_g}{g}$

$\therefore \quad m_i = m_g \qquad \text{Ratio} \Rightarrow m_i : m_g = 1 : 1$

* Bird in air tight cage:
- case I : when bird flies with constant velocity (weight remain unchanged)
- case II : when bird flies with upward acceleration (weight will increase)
- case III : when bird flies with downward acceleration (weight will decrease)

* Bird in wire ~~to~~ cage:
- weight will decrease in all the three cases.

Frame of Reference:
(NLM) Pg - 20

The system with respect to which position or motion of the particle is described.

i) Inertial frame of reference: The frame at rest or moving uniformly and law of inertia is applicable

ii) Non-inertial frame of reference: The frames are accelerating or rotating. and law of inertia is not applicable

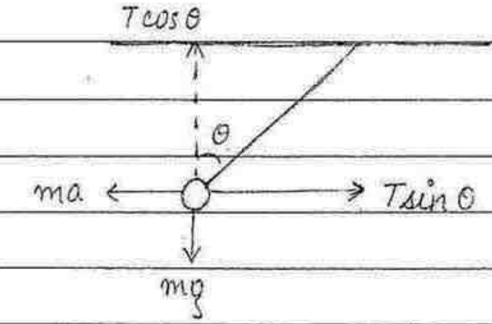
Pseudo force: The force always works in the direction opposite to that of accelerating frame and its magnitude is equal to the product of mass of body and the acceleration of non-inertial frame.

$$\vec{F} = -m\vec{a}$$

* Magnitude of the pseudo force acting away from the centre of the circular path is $\frac{mv^2}{r}$

* Pseudo force does not follow action-reaction law

Q.79 (NLM) Pg-20




$\therefore$ $T\cos\theta = mg$ — (I)

$T\sin\theta = ma$ — (II)

On dividing (I) by (II), we get

$$\frac{T\sin\theta}{T\cos\theta} = \frac{ma}{mg}$$

$$\tan\theta = \frac{a}{g}$$

$$\therefore \theta = \tan^{-1}\left(\frac{a}{g}\right)$$

On squaring and adding (I) and (II)

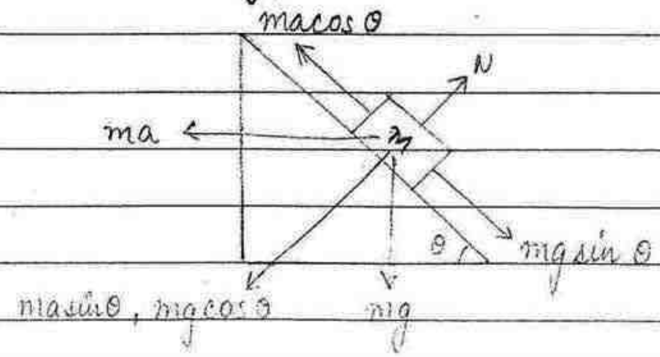
$$T^2\cos^2\theta + T^2\sin^2\theta = m^2g^2 + m^2a^2$$

$$T^2\underline{(\cos^2\theta + \sin^2\theta)} = m^2(g^2+a^2)$$

$$\therefore T = \sqrt{m^2(g^2+a^2)} \qquad (\because \cos^2\theta + \sin^2\theta = 1)$$

$$= m\sqrt{(g^2+a^2)}$$

Q.80



$\because$ the block is at rest.

$\therefore \quad ma\cos\theta = mg\sin\theta$

$$a = g\frac{\sin\theta}{\cos\theta}$$

$$\therefore a = g\tan\theta$$

* If inclination is "1 in x" then,

$P = 1$, $H = x$, $B = \sqrt{H^2 - P^2} = \sqrt{x^2 - 1}$

(using pythagoras)

$$\therefore a = g\tan\theta = \frac{g}{\sqrt{x^2-1}}$$

Force exerted by wedge on the body i.e. N

$$\therefore N = ma\sin\theta + mg\cos\theta$$

$$= mg\tan\theta\sin\theta + mg\cos\theta$$

$$= mg\left(\frac{\sin^2\theta}{\cos\theta} + \cos\theta\right)$$

$$= mg\left(\frac{\sin^2\theta + \cos^2\theta}{\cos\theta}\right)$$

$$= \frac{mg}{\cos\theta}$$

$$\therefore N = mg\sec\theta \quad \left(\because \frac{1}{\cos\theta} = \sec\theta\right)$$

# FRICTION

(NLM) Pg-21

It is a force which opposes tendency of motion or relative motion between surfaces

Types of Friction:

i Internal friction: The friction between layers of fluid

ii External friction: The friction between solid surface

- Static friction: The force which opposes Tendency of motion of surfaces. It is a self adjusting force and its numeric value is equal to external force applied on the body which causes motion.

- Dynamic / Kinetic friction: The force which opposes relative motion between surfaces.

Laws of limiting friction:
(NLM) Pg-22

coefficient of friction ($\mu$):
- coefficient of static friction ($\mu_s$)
- coefficient of kinetic friction ($\mu_k$)

$\because f_L \propto N$
$\therefore f_L = \mu_s \times N$

$\therefore \mu_s = \frac{f_L}{N}$ , unitless and dimensionless.

and. $\mu_k = \frac{f_k}{N}$

$\because f_L > f_k \quad \therefore \quad \mu_s > \mu_k$

coefficient of friction depends upon degree of smoothness, material and temperature of surface