UNIT-3 LAWS OF MOTION

MY REVISION TIMELINE:-

SUMMARY:-

- Aristotle's idea of motion: To maintain motion, a force is required.
- Galileo's idea of motion: To maintain motion, a force is not required.
- Newton's first law states that under no external force, the object continues its state of motion or state of rest.
- Newton's second law states that to change the momentum of the body, external force is required. Mathematically it is defined as $\vec{F} = \frac{d\vec{p}}{dt}$.
- Both Newton's first and second laws are valid only in inertial frames.
- Newton's third law states that for an every force there is an equivalent and opposite force and such pair of forces is called action and reaction pair.
- Internal forces acting on the system cannot change the total momentum of the system.
- The origin of friction is electromagnetic interaction between the atoms of two surfaces which are touching each other.

FORMULAS:-

- $\vec{F} = m\vec{a}$
- T = mg
- v = $\sqrt{2sgsin\theta}$
- Two bodies in contact on horizontal body,

  $\vec{f}_{12} = \frac{-Fm_2}{m_1 + m_2}$

  $\vec{f}_{21} = \frac{Fm_2}{m_1 + m_2}$
- Tension of a vertical motion,

  T = $(\frac{2m_1m_2}{m_1+m_2})$g
- Tension of a horizontal motion,

  T = $(\frac{m_1m_2}{m_1+m_2})$g
- Lami's theorem, constant = $\frac{\overrightarrow{F_1}}{sin\alpha} = \frac{\overrightarrow{F_2}}{sin\beta} = \frac{\overrightarrow{F_3}}{sin\gamma}$
- Impulse, $F_{avg} = \frac{\Delta p}{\Delta t}$ or $J = F_{avg}\Delta t$
- Kinetic friction, $f_k = \mu_k N$
- Angle of friction, $\mu_s = \tan\theta$
- Angle of repose, $\mu_s = \tan\theta$

- Centripetal force, F = $\frac{mv^2}{r}$
- Banking of road, v = $\sqrt{rgtan\theta}$

MULTIPLE CHOICE QUESTIONS:-

1. **When car takes a sudden left turn in the curved road, passengers are pushed towards the right due to**
   a) Inertia of direction
2. **An object of mass m held against a vertical wall by applying horizontal force F. The minimum value of force is**
   c) Greater than mg
   Solution:
   F = mg
   f = μN =μF
   mg = μF

   $\boldsymbol{F = \frac{mg}{\mu}}$

   The minimum value of force F is greater than mg.
3. **A vehicle is moving along the positive x direction, if sudden brake is applied, then**
   a) Frictional force acting on the vehicle is along negative x direction
4. **A book is at rest on the table which exerts a normal force on the block. If this force is considered as reaction force, what is the action force according to Newton's third law?**
   b) Normal force exerted by the book on the table
5. **Two masses m_1 and m_2 experiencing the same force where $m_1<m_2$. The ratio of their acceleration $\frac{a_1}{a_2}$ is**
   c) Greater than 1

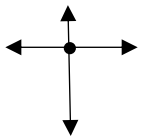
   Solution:

   $m_1a_1 = m_2a_2$

   $\frac{m_1}{m_2} = \frac{a_2}{a_1}$

   $\frac{a_2}{a_1} <; \frac{m_1}{m_2} <1$

   $\Rightarrow \frac{a_1}{a_2} > 1$
6. **Choose appropriate free body diagram for the particle experiencing net acceleration along negative y direction.**
   c)

7. **A particle of mass m sliding on the smooth double inclined plane**
   b) Greater acceleration along the path AC
8. **Two blocks of masses m and 2m are placed on a smooth horizontal surface. In the first case only a force F_1 is applied from the left. Later only a force F_2 is applied**

from the right. If the force acting to the interface of the two blocks in the two cases is same then F_1:F_2 is

c) 2:1

Solution:

Case i) $a_1 = \frac{F_1}{3m}$ → *acceleration of Block 1*

$\mu_1 = ma_1 = \frac{F_1}{3}$

Case ii) $a_2 = \frac{F_2}{3m}$ → *acceleration of Block 2*

$\mu_2 = 2ma_2 = \frac{2F_2}{3}$

$\mu_1 = \mu_2$

$\frac{F_1}{3} = \frac{2F_2}{3}$

$\frac{F_1}{F_2} = \frac{2}{1}$

$F_1 : F_2 = 2:1$

9. Force acting on the particle moving with constant speed is
b) need not be zero

10. An object of mass m begins to move on a plane inclined at an angle θ. The coefficient of static friction of inclined surface is μ_s. The maximum static friction experienced by the mass m
d) $\mu_s mg\cos\theta$

11. When the object at moving at constant velocity the rough surface.
a) Net force on the object is zero.

12. When an object is at rest on the inclined rough surface
c) static friction is not zero and kinetic friction is zero.

13. The centrifugal force appears to exist _____
b) only in rotating frame

14. Choose the correct statement from the following
c) Centripetal force acts towards the centre and centripetal force appears to act away from the centre in circular motion.

15. If a person moving from pole to equator, the centrifugal force acting on him ____
a) increases

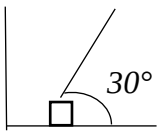
NUMERICAL PROBLEMS:-

1. Given:

F = 50N

m = 20kg

a_x = ? a_y = ?



Formula used:

$F_y = ma_y = mg\sin\theta$

$F_x = ma_x = mg\cos\theta$

Solution:

$F_y = mg\sin\theta$

$= 50 \times \sin 30°$

$= 50 \times \frac{1}{2}$

$= 25N$

$F_y = ma_y$

$25 = (20)\, a_y$

$\boxed{a_y = 1.25ms^{-2}}$

$F_x = mg\cos\theta$

$= 50 \times \cos 30°$

$= 50 \times \frac{\sqrt{3}}{2}$

$= 25\sqrt{3}N$

$F_x = ma_x$

$25\sqrt{3} = (20)\, a_y$

$\boxed{a_x = 2.165ms^{-2}}$

2. Given:

Mass = 50g = 50 × 10^{-3}kg

Tension = ?

Formula used:

$T = mg$

Solution:

$T = mg$

$= 50 \times 10^{-3} \times 9.8$

$\boxed{= 0.49N}$

3. Given:

m = 2kg

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$\theta = 30°$

Formula used:

$F_y = mg\sin\theta$

Solution:

a) Zero

b) $F_y = mg\sin\theta$

$= 2\times9.8\times\sin30°$

$= 2\times9.8\times\frac{1}{2}$

$= 9.8N$

4. Solution:

Assume that +1 volume 1 and 2 and +2 volume 1 and 2 stacked in a sequence one above the other solution is given.

Stacked books which acts vertically upwards.

+2 Volume 2 A

+2 Volume 1 B

+1 Volume 2 C

+1 Volume 1 D

Force on book A:

i) Downward gravitational force.

ii) Upward normal force(N_b) exert by (N_a)

Force on book B:

i) Downward gravitational force.

ii) Upward normal force exert by book C.

iii) Downward force exerted by the book D.

Force on book C:

i) Downward gravitational force.

ii) Downward force exerted by book B.

5. Solution:

The gravitational force(mg) acting downward can be resolved into two components as $mg\cos\theta$ and $mg\sin\theta$.

T – tension exerted by the string.

Tangential force $F_T = ma_T = mg\sin\theta$

∴ Tangential acceleration $a_T = g\sin\theta$

Centripetal force $F_c = ma_c = T - mg\cos\theta$

$a_c = \frac{T-mg\cos\theta}{m}$

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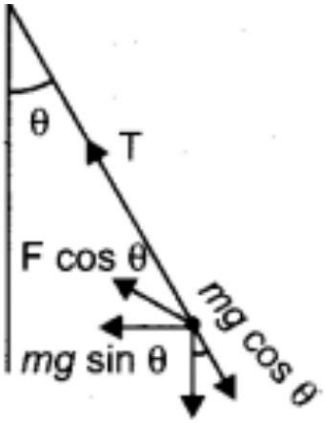

6. Given:

$\mu = 0.2$

$m_1 = 15kg$

$m_2 = 10kg$

$m_3 = ?$

Solution:

$Tension(T) = \mu(m_1+m_3)g$

$\mu(m_1+m_3)g = m_2g$

$\mu m_1g+\mu m_3g = m_2g$

$\mu m_3g = m_2g - \mu m_1g$

$\mu m_3g = g(m_2 - \mu m_1)$

$m_3 = \frac{m_2}{\mu} - m_1$

The minimum mass m_3 to be placed on m_1 to prevent it from sliding is $m_3 = \frac{m_2}{\mu} - m_1$

⇨ $m_3 = \frac{m_2}{\mu} - m_1$

$m_3 = \frac{10}{0.2} - 15$

$m_3 = 35kg$

The combined mass of m_1 and m_3 = 35 + 15 = 50kg

7. Given:

Mass = 25kg

Solution:

Figure 1:

(500-400)N = 100N = F

We know that, F = ma

100 = 25(a)

$a = 4ms^{-2}$

Figure 2:

(400-400)N = F

F = 0

$\therefore a = 0$

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8. Given:

F = 50N

θ = 30°

T = ?

Formula used:

The tension acting along each string is $T = \frac{mg}{2cos\theta}$

Solution:

$T = \frac{mg}{2cos\theta}$

$T = \frac{50 \times 9.8}{2(cos30°)}$

T = 282.91N

9. Given:

m = 0.8kg

v = 12ms^{-1}

$t = \frac{1}{60} s$

Formula used:

$a = \frac{v}{t}$

F = ma

Solution:

$a = \frac{v}{t}$

$= \frac{12}{\frac{1}{60}} = 720$

$F = ma$

$= 0.8 \times 720$

$= 576N$

Kicking force is 576N

10. Given:

m = 2kg

l = 1m

T = 200N

Maximum speed = ?

Formula used:

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

Solution:

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

$200 = \frac{2v^2}{1}$

v = 100ms^{-1}

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11. Given:

Mass of the Moon = 7.34 ×10^{22}kg

Distance between the Moon and the Earth = 3.84 × 10^{8}m

Formula used:

Centripetal force T = $\frac{mv^2}{r}$

Solution:

$v = \frac{D}{T}$

$v = \frac{2\pi r}{T}$

T = 27.3 days

$v = \frac{2\times3.14\times3.84\times10^8}{27.3\times24\times3600}$

v = 1.022 × $10^{3}$$ms^{-1}$

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

$T = \frac{7.34\times10^{22}\times(1.022\times10^3)^2}{3.84\times10^8}$

$T = \frac{7.6665\times10^{28}}{3.84\times10^8}$ *= 1.9965 × 10^{20}N*

$\boxed{T \approx 2 \times 10^{20}N}$

12. Given:

m_1 *= 15kg*

m_2 *= 10kg*

F = 500N

T = ?

Formula used:

$T = m_2a \rightarrow 1$

$F-T = m_1a \rightarrow 2$

Substitute 2 in 1

$F - m_1a = m_2a$

$F = (m_1 + m_2)a$

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

$\boldsymbol{T = m_2a}$

Solution:

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

$a = \frac{500}{15+10} = \frac{500}{25}$

$a = 20ms^{-2}$

$T = m_2a$

$T = 10\times20$

$\boxed{T = 200N}$

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13. Solution:

Newton's third law is applicable to only human's action which involves physical force. Third law is not applicable to human's psychological action or thoughts.

14. Given:

$v = 50ms^{-1}$

$r = 10m$

$m = 60kg$

Centrifugal force = ?

Formula used:

$$\text{Centrifugal force} = \frac{mv^2}{r}$$

$$= \frac{60\times(50)^2}{10}$$

$$= 15000\ N$$

15. Given:

$\mu = 0.7$

$l = 10m$

Minimum speed = ?

Formula used:

$F = \mu_k Mg$, $a = \mu_k g$

Here 'a' retardation. So,

$v^2 = u^2 - 2al$

Since object comes at rest, $v = 0$

$u^2 - 2al = 0$

$u^2 = 2al$

$u^2 = 2\mu_k gl$

$u = \sqrt{2\mu kgl}$

$u = \sqrt{2 \times 0.7 \times 9.8 \times 10}$

$$u = 11.71ms^{-1}$$

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