1(a) It states, "The total momentum of two bodies remains constant after their collision or any other mutual action." mathematically $\boxed{m_1u_1 + m_2u_2 = m_1V_1 + m_2V_2}$

(e) The forces, which meet at one point and their lines of action also lie on the same plane, are known as Coplanar Concurrent forces.

(f) Newton's 1st Law of motion states, "Everybody continues in its state of rest or of uniform motion, in a straight line, unless it is acted upon by some external force."

IIND SEM ./COMMON / 2022(S)

Th4(a) - Engineering Mechanics

Full Marks: 80 Time- 3 Hrs

Answer any five Questions including Q No.1& 2

Figures in the right hand margin indicates marks

1. Answer **All** questions 2 x 10

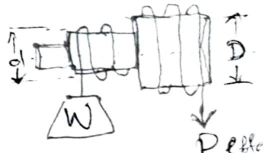
(a) State the Law of Conservation of Linear momentum.

b. What is fundamental unit and derived units with examples? ⇒ Units of area, velocity, Pressure, acceleration

Length, Mass, Time ⇐

c. What is coefficient of friction? $\mu = \frac{F}{R_N} = \tan\phi$

d. Write down the expression for Velocity Ratio of a Simple wheel and Axle. $VR = \frac{D}{d} = \frac{\text{Distance moved by Effort}}{\text{Distance moved by Load}} = \frac{\pi D}{\pi d} = \frac{D}{d}$

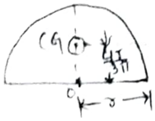


(e) What is Coplanar Concurrent Forces?

(f) State Newton's 1st law of motion.

g. What is Self Locking machine? A machine not capable of doing any work in the reversed direction, after the effort is removed. Also known as non-reversible machine. efficiency $= \eta < 50\%$

h. What is the distance of centroid of a semi circular area from the base? $\frac{4r}{3\pi}$



(i) Define Force and its unit in S.I system.

(j) Define Couple and its unit.

2. Answer **Any Six** Questions 6 x 5

a. Derive the relation between Mechanical Advantage, Velocity Ratio and Efficiency of a Lifting machine. $\eta = \frac{MA}{VR} \times 100 = (\ )\%$

b. In a lifting machine, an effort of 15N can lift a load of 300N and an effort of 20N can lift a load of 500N. Find the law of machine. Also find the effort required to lift a load of 880N. ↳ $P = 0.025W + 7.5$ Effort = 29.5 N

c. What is Gear Train .Derive its velocity ratio of a Simple Gear Train.

d. State and Proof the Polygon Law of Forces.

e. Find the angle between two equal forces p, when their resultant is equal to (i) p and (ii) p/2 (i) $\theta = 120°$ (ii) $\theta = 151°$

f. State and prove Lami's theorem.

g The following forces act at a point $\Sigma H = 20\cos 30° + 25\cos 90° + 30\cos 135° + 35\cos 220°$

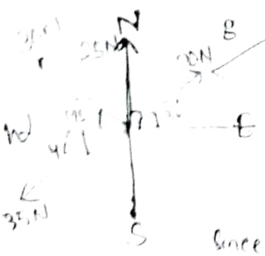
(i) 20N inclined at 30° towards North to East. $\Sigma H = -30.7\ N$

(ii) 25N towards North $\Sigma V = 20\sin 30° + 25\sin 90° + 30\sin 135° + 35\sin 220°$

(iii) 30N towards North west, and $\Sigma V = 33.7\ N$

(iv) 35N inclined at 40°towards south of west. $R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2} = 45.6N$

Find the magnitude and direction of the resultant force. $\tan\theta = \frac{\Sigma V}{\Sigma H} = \frac{33.7}{-30.7} = -1.098 \Rightarrow \theta = 47.7$

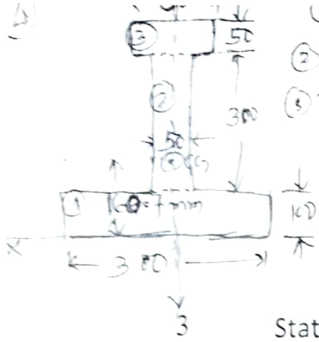


Since ΣH(-ve) & ΣV(+ve), therefore resultant lies in 2nd Quadrant.

Thus actual angle of resultant = 180 − 47.7 = 132.3°

1(i) Force = defined as an agent which produces or tends to produce, destroy or tends to destroy motion. Unit - Newton (N).

(j) Couple - A pair of two equal and unlike parallel forces (i.e. forces are equal in magnitude with lines of action parallel to each other and acting in opposite directions) is known as a couple. Unit = moment of couple = P×L (N-m)



(1) Bottom flange : $a_1 = 300 \times 100 = 30,000\ mm^2$, $y_1 = \frac{100}{2} = 50\ mm$, $x_1 = 0$

(2) Web : $a_2 = 300 \times 50 = 15,000\ mm^2$, $y_2 = 100 + \frac{300}{2} = 250\ mm$, $x_2 = 0$

(3) Top flange : $a_3 = 150 \times 50 = 7500\ mm^2$, $y_3 = 100 + 300 + \frac{50}{2} = 425\ mm$, $x_3 = 0$

$$\bar{y} = \frac{a_1 y_1 + a_2 y_2 + a_3 y_3}{a_1 + a_2 + a_3} = 160.7\ mm, \quad \bar{x} = 0. \quad \text{Ans}$$

Centroid - The plane figure (like triangle, quadrilateral, circle etc) have only areas, but no mass. The centre of area of such figures is known as centroid.

3 State Triangle Law of force and proof Parallelogram Law of Force. 10

4 Define Centroid. 10

An I- section has the following dimensions in mm units.

Bottom flange= 300x100 $\bar{x} = 0$

Top flange= 150x50

Web= 300x50 $\bar{y} = 160.7\ mm$

Determine mathematically the position of centre of gravity of the section.

5 Define Angle of repose. 10

A body of weight 500N is pulled up an inclined plane, by a force of 350N. The inclination of the plane is 30^0 to the horizontal and the force is applied parallel to the plane.

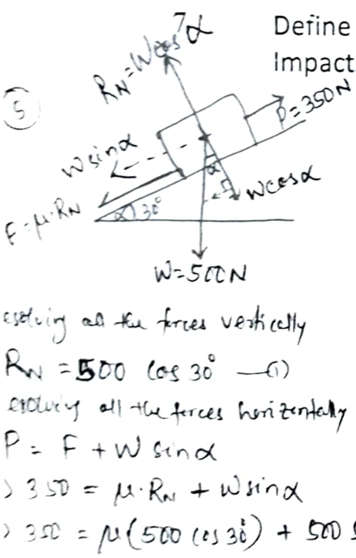
Determine the co-efficient of friction. $\mu = 0.23$

6 A body of weight 70KN is suspended by two strings whose lengths are 6cm and 8cm from two points in the same horizontal level. The horizontal distance between the two points is 10cm. 10

Determine the tensions of the strings. $T_1 = 42\ KN$, $T_2 = 56\ KN$

7 Define Coefficient of Restitution. What are various types of Impacts? Discuss any one of them. 10

(5)



resolving all the forces vertically

$R_N = 500 \cos 30°$ —(1)

resolving all the forces horizontally

$P = F + W \sin\alpha$

$\Rightarrow 350 = \mu \cdot R_N + W \sin\alpha$

$\Rightarrow 350 = \mu (500 \cos 30°) + 500 \sin 30°$

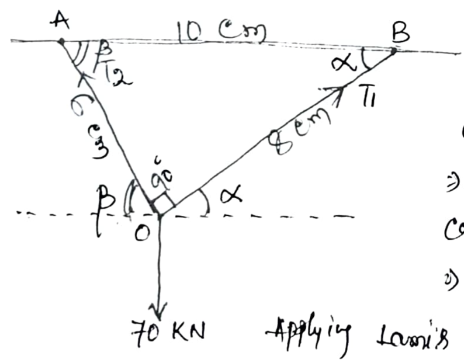
$\Rightarrow 350 = \mu \times (500 \times 0.866) + (500 \times 0.5)$

$\Rightarrow 350 = \mu \times 433 + 250$

$\Rightarrow \mu (433) = 350 - 250 = 100$

$\Rightarrow \mu = \frac{100}{433} = 0.23$ Ans

(6)



Δ AOB is a right angle triangle.

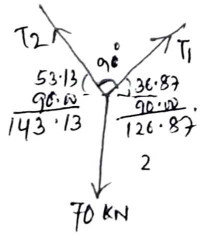
$\cos\alpha = \frac{8}{10} = 0.8$

$\Rightarrow \alpha = \cos^{-1}(0.8) = 36.87°$

$\cos\beta = \frac{6}{10} = 0.6$

$\Rightarrow \beta = \cos^{-1}(0.6) = 53.13°$

Applying Lami's theorem at point 'O'



$$\frac{T_2}{\sin 126.87} = \frac{70}{\sin 90°} = \frac{T_1}{\sin 143.13}$$

$$\Rightarrow T_1 = \frac{70 \times \sin 143.13}{\sin 90} = 70 \times 0.6 = 42\ KN$$

$$\Rightarrow T_2 = \frac{70 \times \sin 126.87}{\sin 90} = 70 \times 0.8 = 56\ KN$$

SOLUTION 2nd Sem - TH-4(a) Engineering Mechanics 202(

Q.2(a) We know that $MA = \frac{W \text{ (load)}}{P \text{ (effort)}}$ & $VR = \frac{y \text{ (distance moved by effort)}}{x \text{ (distance moved by load)}}$

Also know that Input of a machine = Effort applied × Distance through which the effort has moved

$\Rightarrow$ Input $= P \times y$

Similarly Output of a machine = Load lifted × Distance through which the load has moved

$\Rightarrow$ Output $= W \times x$

$$\therefore \text{Efficiency} = \eta = \frac{\text{Output}}{\text{Input}} = \frac{W \times x}{P \times y} = \frac{\left(\frac{W}{P}\right)}{\left(\frac{y}{x}\right)} = \frac{MA}{VR}$$

Q.2(b) Given Data

case(i) $P = 15\ N$, $W = 300\ N$

case(ii) $P = 20\ N$, $W = 500\ N$

$\mapsto$ find Law of machine = ?

$\mapsto$ Effort $= P = ?$ to lift load $W = 880\ N$

Soln $\boxed{P = mW + C}$

case (i) $15 = m(300) + C$ —(i)

case (ii) $20 = m(500) + C$ —(ii)

Substracting eq(ii) − eq(i)

$$20 = m(500) + \cancel{C}$$
$$(-)\ 15 = m(300) + \cancel{C}$$
$$5 = m(200)$$

$\Rightarrow m = \frac{5}{200} = 0.025$

Putting m value in eq(i)

$15 = 0.025(300) + C$

$\Rightarrow C = 15 - 7.5 = 7.5$

Putting 'm' value in eq(ii)

$20 = 0.025(500) + C$

$\Rightarrow C = 20 - 12.5 = 7.5$

Hence Law of machine $\Rightarrow \boxed{P = 0.025\,W + 7.5}$ Ans

case (iii) $P = ?$ When Load $(W) = 880\ N$

$\Rightarrow P = mW + C = (0.025 \times 880) + 7.5 = 22 + 7.5 = \boxed{29.5\ N = P}$ Ans

Q.2(c)

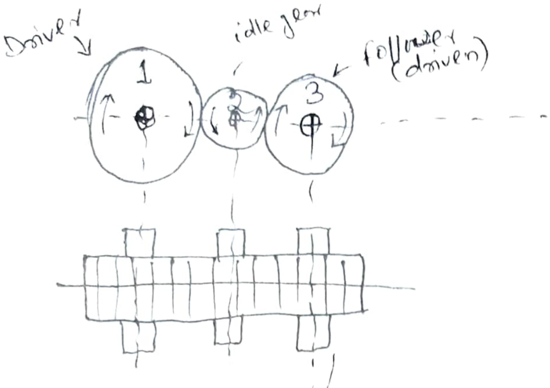
Gear Train – Gear train is any combination of gear wheels by means of which power and motion is transmitted from one shaft to another.

Various types of gear train → (1) Simple gear train (2) Compound gear train (3) Reverted gear train (4) Epicyclic gear train

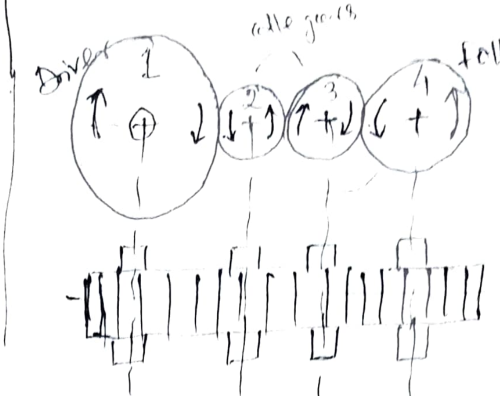
OR When two or more gears are made to mesh with each other, so as to operate as a single system, to transmit power from one shaft to another such combination is called Gear Train or Train of wheels.

(1) Simple Gear Train → in which each shaft carries one wheel only (or each shaft supports only one gear) & All the gears lie in the same plane.

When no. of intermediate wheel is odd
the motion of driver & follower (driven) is same (like) i.e. same direction.



When no. of intermediate wheel is even:
the motion of the follower (driven wheel) is the opposite direction of the driver.



N_1, N_2, N_3 & N_4 be the rotational speed of the gears 1, 2, 3 & 4

T_1, T_2, T_3 & T_4 be the number of teeth on the gears 1, 2, 3 & 4

Since gear 1 is meshed with gear 2

Hence $\frac{N_1}{N_2} = \frac{T_2}{T_1}$, similarly $\frac{N_2}{N_3} = \frac{T_3}{T_2}$, $\frac{N_3}{N_4} = \frac{T_4}{T_3}$

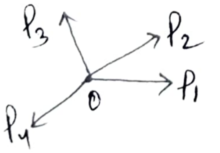
Speed (or) Velocity Ratio (VR) $= \frac{\text{Speed of the driving wheel}}{\text{Speed of the driven wheel}} = \frac{\text{No. of teeth on driven wheel}}{\text{No. of teeth on driving wheel}}$

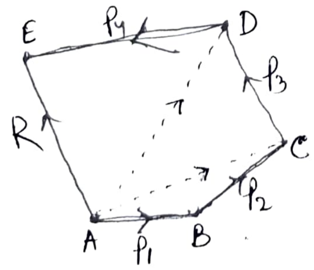
$$\frac{N_1}{\cancel{N_2}} \times \frac{\cancel{N_2}}{N_3} = \frac{\cancel{T_2}}{T_1} \times \frac{T_3}{\cancel{T_2}} \Rightarrow \boxed{\frac{N_1}{N_3} = \frac{T_3}{T_1} = VR}$$ in case of odd idle gear

$$\frac{N_1}{\cancel{N_2}} \times \frac{\cancel{N_2}}{\cancel{N_3}} \times \frac{\cancel{N_3}}{N_4} = \frac{\cancel{T_2}}{T_1} \times \frac{\cancel{T_3}}{\cancel{T_2}} \times \frac{T_4}{\cancel{T_3}} \Rightarrow \boxed{\frac{N_1}{N_4} = \frac{T_4}{T_1} = VR}$$ in case of even idle gears.

Q.2(d) **Polygon Law of Forces** ⇒ If a no. of concurrent forces acting simultaneously on a particle, be represented in magnitude & direction, by the sides of a polygon, taken in order; then the resultant of all these forces may be represented, in magnitude & direction, by the closing side of the polygon taken in opposite order.

(It is an extension of Triangle Law of Forces)





$\vec{AC} = \vec{AB} + \vec{BC}$

$\vec{AD} = \vec{AC} + \vec{CD} = \vec{AB} + \vec{BC} + \vec{CD}$

$\vec{AE} = \vec{AD} + \vec{DE} = \vec{AB} + \vec{BC} + \vec{CD} + \vec{DE}$

$\boxed{R = P_1 + P_2 + P_3 + P_4}$ (proved)

(c) (i) When the Resultant is equal to P.

$P = \sqrt{P^2 + P^2 + 2 \cdot P \cdot P \cdot \cos\theta}$

$\Rightarrow P^2 = 2P^2 + 2P^2 \cos\theta$

$\Rightarrow P^2 = 2P^2 (1 + \cos\theta)$

$\Rightarrow 1 + \cos\theta = \frac{1}{2} = 0.5$

$\Rightarrow \cos\theta = 0.5 - 1 = (-0.5)$

$\Rightarrow \theta = \cos^{-1}(-0.5) = 120^\circ$

$\Rightarrow \boxed{\theta = 120^\circ}$

(ii) When the Resultant is equal to $\frac{P}{2}$,

$\Rightarrow \left(\frac{P}{2}\right)^2 = 2P^2 + 2P^2 \cos\theta$

$\Rightarrow \frac{P^2}{4} = 2P^2 (1 + \cos\theta)$

$\Rightarrow 1 + \cos\theta = \frac{1}{8} = 0.025$

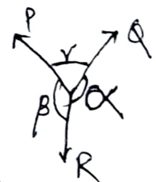
$\Rightarrow \cos\theta = 0.025 - 1 = (-0.875)$

$\Rightarrow \theta = \cos^{-1}(-0.875) = 151^\circ$

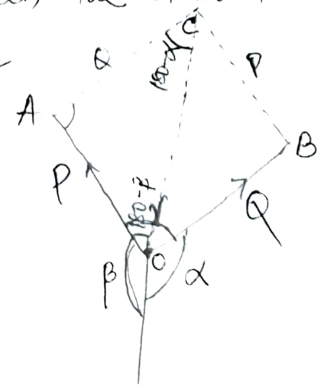
$\Rightarrow \boxed{\theta = 151^\circ}$

Q. 2(f) Lami's Theorem

It states, If three coplanar forces acting at a point be in equillibrium, then each force is proportional to the sine of the angle between the other two. Mathematically $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$



Proof



From the geometry

$BC = P$, $AC = Q$, $\therefore \angle AOC = (180^\circ - \beta)$ &

$\angle ACO = \angle BOC = (180^\circ - \alpha)$

$\therefore \angle CAO = 180^\circ - (\angle AOC + \angle ACO)$

$= 180^\circ - [(180^\circ - \beta) + (180^\circ - \alpha)]$

$= \cancel{180^\circ} - \cancel{180^\circ} + \beta - 180^\circ + \alpha = \alpha + \beta - 180^\circ$

But we know that $\alpha + \beta + \gamma = 360^\circ$

Subtracting 180° from both sides of the above equation

$(\alpha + \beta - 180^\circ) + \gamma = 360^\circ - 180^\circ = 180^\circ$

$\Rightarrow \angle CAO + \gamma = 180^\circ$

$\Rightarrow \angle CAO = 180^\circ - \gamma$

Let P, Q, R are the three coplanar forces acting at a point O. Let the opposite angles to three forces be α, β, γ as shown on figure.

We know that in ΔAOC

$\frac{OA}{\sin\angle ACO} = \frac{AC}{\sin\angle AOC} = \frac{OC}{\sin\angle CAO}$

$\Rightarrow \frac{OA}{\sin(180^\circ - \alpha)} = \frac{AC}{\sin(180^\circ - \beta)} = \frac{OC}{\sin(180^\circ - \gamma)}$

$\Rightarrow \boxed{\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}}$ [$\because \sin(180^\circ - \theta) = \sin\theta$]

Proved