K. K. Wagh Institute of Engineering Education and Research, Nashik

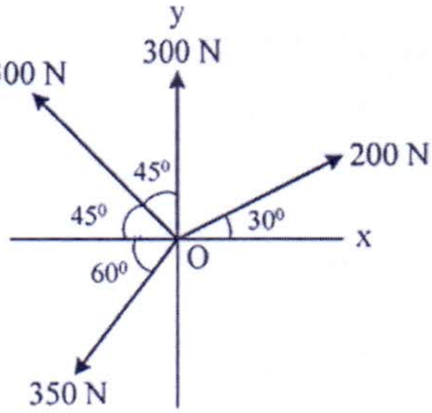
(An Autonomous Institute from A. Y. 2022-23)

End-Sem Examination- Winter 2025

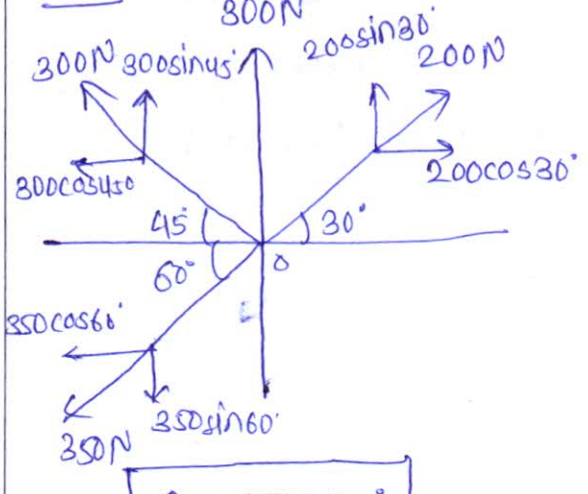
Model Answer Set-1

Academic Year: 2025-26	**Semester: I**
Name of Programme: First year engineering	**Pattern: 2022**
Name of Course: Engineering Mechanics	**Course Code: FYE221009**
Max. Marks: 60	**Duration: 2:30Hr.**

Q. No.	Details	Max. Marks
Q.1	Find the magnitude of the resultant and its direction of the following forces acting at a point O as shown in fig.	[6]



Ans:-



$\boxed{\theta = 55.30^\circ}$

i) $\Sigma fx = 200\cos 30^\circ - 300\cos 45^\circ - 350\cos 60^\circ$

$\Sigma fx = -213.92\,N$

ii) $\Sigma fy = 200\sin 30^\circ + 300 + 300\sin 45^\circ - 350\sin 60^\circ$

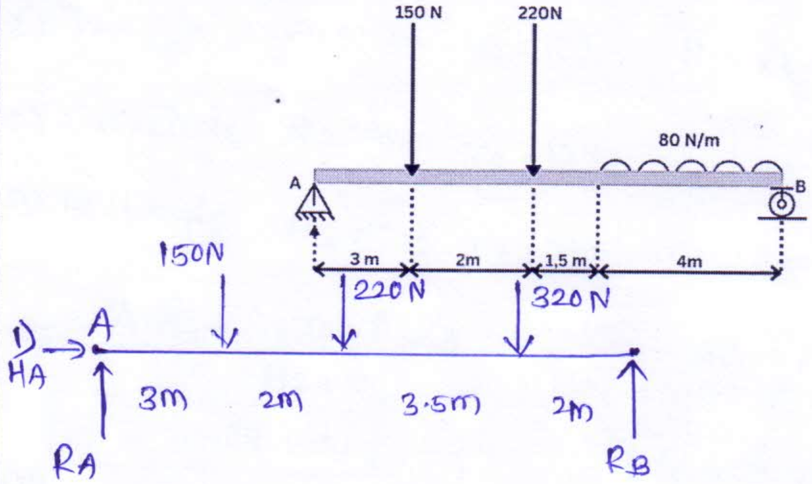
$\Sigma fy = 309.02\,N$

$R = \sqrt{(\Sigma fx)^2 + (\Sigma fy)^2}$

$\boxed{R = 375.83\,N}$

Q.2 [6]

Find support reaction at A and B for the beam AB as shown in fig.



2) $\Sigma fx = 0$

$\therefore \boxed{HA = 0}$

3) $\Sigma fy = 0$

$\therefore RA - 150 - 220 - 320 + RB = 0$

$\therefore \boxed{RA + RB = 690}$

4) $\Sigma MA = 0$

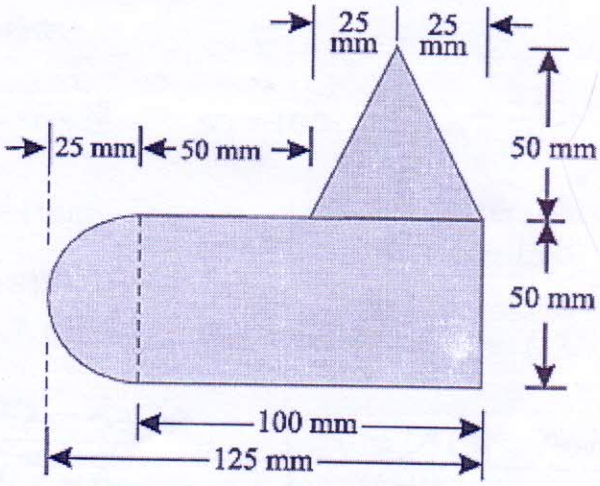
$\therefore (150 \times 3) + (220 \times 5) + (320 \times 8.5) - (RB \times 10.5) = 0$

$\therefore \boxed{RB = 406.67 N}$

$\therefore \boxed{RA = 283.33 N}$

Q.3 [16]

a) Locate the centroid of the shaded region shown in fig.



→ Shape Area $\bar{X}$ $\bar{Y}$

1) Triangle $A_1 = 1250$ $x_1 = 100$ $y_1 = 66.67$

2) semicircle $A_2 = 981$ $x_2 = 14.38$ $y_2 = 25$

3) Rectangle $A_3 = 5000$ $x_3 = 75$ $y_3 = 25$

$$\bar{X} = \frac{A_1x_1 + A_2x_2 + A_2x_3}{A_1 + A_2 + A_3}$$

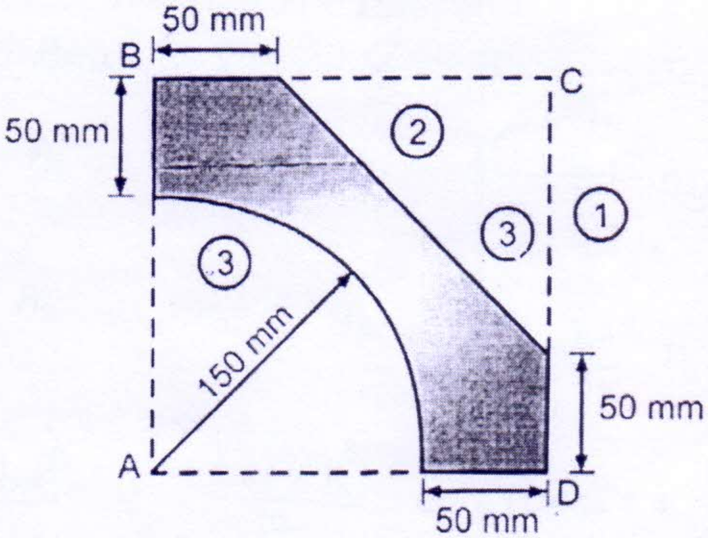
$$\boxed{\bar{X} = 71.09 \text{ mm}}$$

$$\bar{Y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$\boxed{\bar{Y} = 32.20 \text{ mm}}$$

OR

b) Locate the centroid of the shaded region shown in fig.



→ Shape Area $\bar{X}$ $\bar{Y}$

1) Square $A_1 = 40000$ $x_1 = 100$ $y_1 = 100$

2) Triangle $A_2 = 11250$ $x_2 = 150$ $y_2 = 150$

3) Quarter circle $A_3 = \cancel{63.66}$ 17671.45 $x_3 = 63.66$, $y_3 = 63.66$.

$$\bar{X} = \frac{A_1x_1 - A_2x_2 - A_3x_3}{A_1 - A_2 - A_3}$$

$$\bar{Y} = \frac{A_1y_1 - A_2y_2 - A_3y_3}{A_1 - A_2 - A_3}$$

$$\boxed{\bar{X} = 107.19 \text{ mm}}$$

$$\boxed{\bar{Y} = 107.19 \text{ mm}}$$

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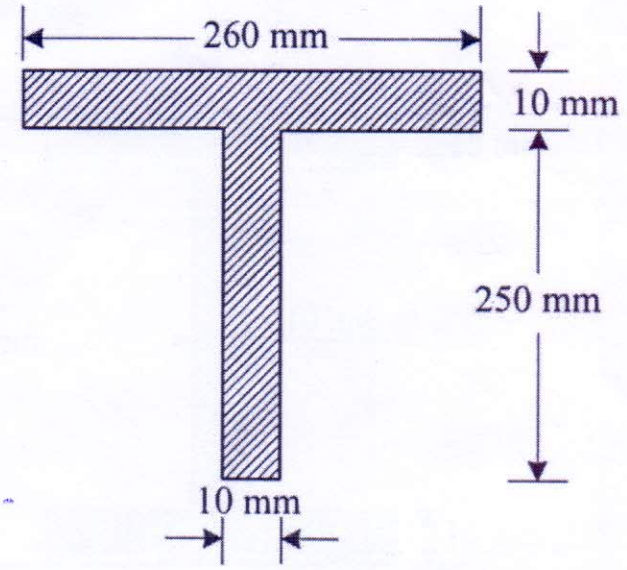
c) Calculate Moment of Inertia for the fig. shown below with respect to X and Y axis (8)



→

Shape	Area	$\bar{X}$	$\bar{Y}$	I_{xx}	I_{yy}	h_x	h_y
1) Rectangle (A)	A_1	x_1	y_1	$I_{xx_1} = \frac{bd^3}{12}$	$I_{yy_1} = \frac{db^3}{12}$	$(\bar{Y} - y_1)$	
2) Rectangle (B)	A_2	x_2	y_2	$I_{xx_2} = \frac{bd^3}{12}$	$I_{yy} = \frac{db^3}{12}$	$(\bar{Y} - y_2)$	

$$\therefore I_{xx_1} = \frac{bd^3}{12} = \frac{(260 \times 10^3)}{12} = 21666.67 \text{ mm}^4$$

$$I_{xx_2} = \frac{bd^3}{12} = \frac{(10 \times 250^3)}{12} = 13.02 \times 10^6 \text{ mm}^4$$

$$I_{yy_1} = \frac{db^3}{12} = \frac{(10 \times 260^3)}{12} = 14.64 \times 10^6 \text{ mm}^4$$

$$I_{yy_2} = \frac{db^3}{12} = \frac{(250 \times 10^3)}{12} = 20.83 \times 10^3 \text{ mm}^4$$

$$\therefore I_{xx} = I_{xx_1} + I_{xx_2} + I_{xx_3}$$

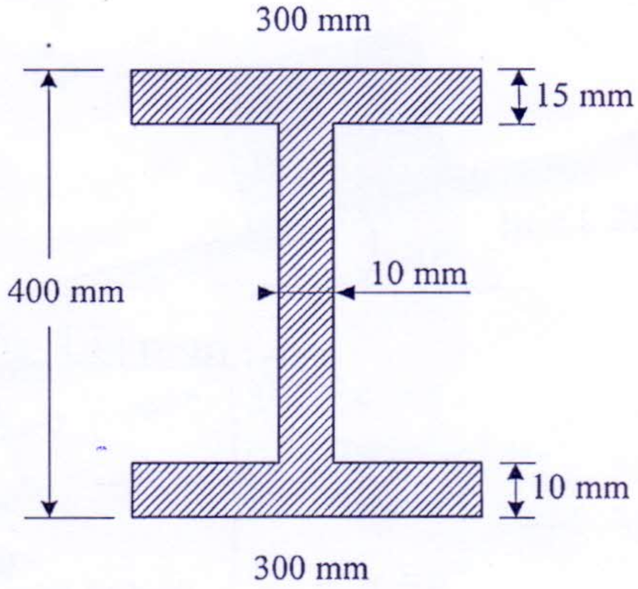
$$\boxed{I_{xx} = 34.58 \times 10^6 \text{ mm}^4}$$

$$I_{yy} = I_{yy_1} + I_{yy_2} + I_{yy_3}$$

$$\boxed{I_{yy} = 14.66 \times 10^6 \text{ mm}^4}$$

OR

d) Calculate Moment of Inertia for the fig. shown below with respect to X axis shown in fig. All dimensions are in mm.



→

Shape	Area	$\bar{X}$	$\bar{Y}$
1) Rectangle (A)	$A_1 = 4500$	$x_1 = 150$	$y_1 = 392.5$
2) Rectangle (B)	$A_2 = 3750$	$x_2 = 150$	$y_2 = 197.5$
3) Rectangle (C)	$A_3 = 3000$	$x_3 = 150$	$y_3 = 5$

$$\bar{X} = \frac{A_1x_1 + A_2x_2 + A_3x_3}{A_1 + A_2 + A_3} \qquad \bar{Y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$\boxed{\bar{X} = 150 \text{ mm}} \qquad \boxed{\bar{Y} = 224.16 \text{ mm}}$$

$$I_{xx_1} = \frac{bd^3}{12} = \frac{300 \times 15^3}{12} = 25000 \text{ mm}^4 \qquad h_{x_1} = \bar{Y} - y_1$$

$$I_{xx_2} = \frac{bd^3}{12} = \frac{10 \times 375^3}{12} = 43945312.5 \text{ mm}^4 \qquad h_{x_2} = \bar{Y} - y_2$$

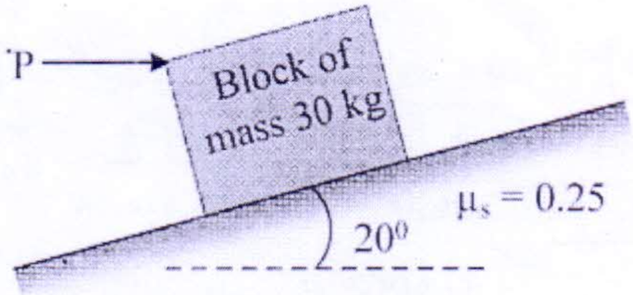
$$I_{xx_3} = \frac{bd^3}{12} = \frac{300 \times 10^3}{12} = 84375 \text{ mm}^4 \qquad h_{x_3} = \bar{Y} - y_3$$

$$I_{XX} = I_{xx_1} + I_{xx_2} + I_{xx_3}$$

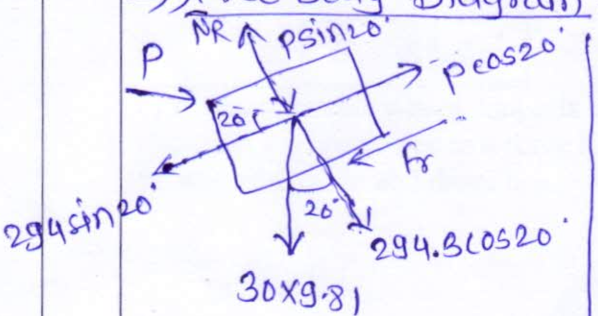
$$\boxed{I_{XX} = 318.09 \times 10^6 \text{ mm}^4}$$

Q.4 **[16]**

a) Determine the horizontal force P needed to just start moving the 30 kg block up the plane as shown in fig. Take $\mu_s = 0.25$



→ i) Free Body Diagram :-



a) $\Sigma F_x = 0$

$\therefore P\cos 20^\circ - 294.3\sin 20^\circ - \mu_s . N = 0$

$\therefore P\cos 20^\circ - 294.3\sin 20^\circ - 0.25 N = 0$

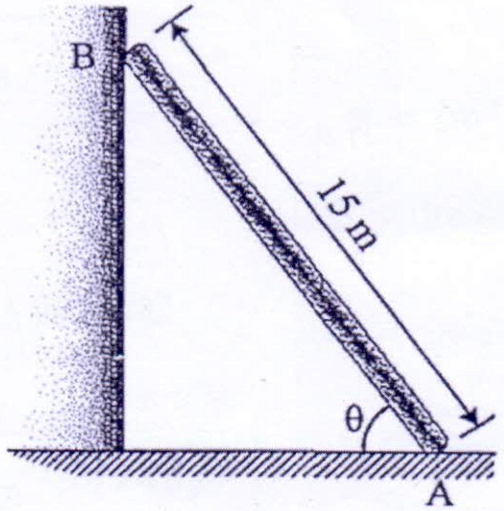
b) $\Sigma F_y = 0$

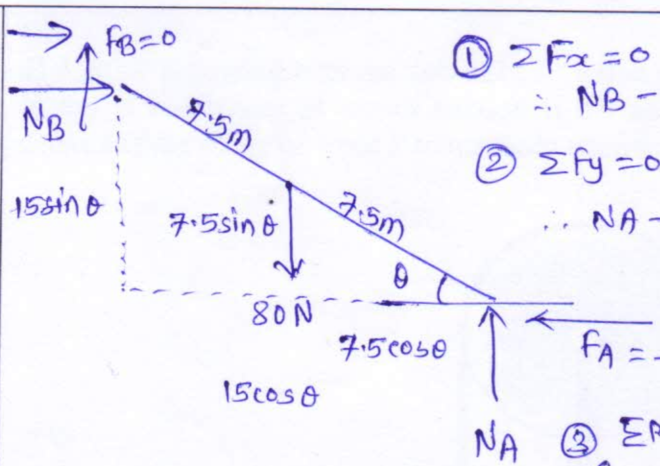
$\therefore N - P\sin 20^\circ - 294.3\cos 20^\circ = 0$

$\boxed{N_R = 287.08 \text{ N}}$ $\boxed{P = 80.818 \text{ N}}$

OR

b) The 15 m ladder has a uniform weight of 80 N and rest against the smooth wall at B shown in Fig. If the coefficient of statics friction at A is $\mu_A = 0.4$. Determine the smallest angle at which the ladder will not slip.





① $\Sigma F_x = 0$

$\therefore N_B - \mu_s . N_A = 0$

② $\Sigma F_y = 0$

$\therefore N_A - 80 = 0 \qquad \therefore \boxed{N_A = 80\ N}$

$\therefore F = \mu_s . N_R = 0.4 \times 80$

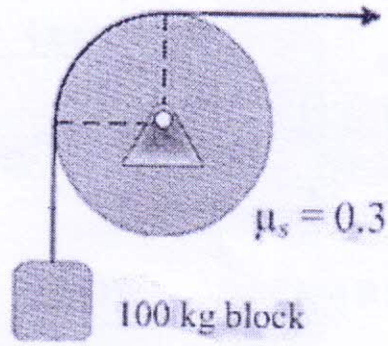
$\boxed{F = 32\ N}$

③ $\Sigma M_A = 0$

$\therefore (-80 \times 7.5\cos\theta) + (N_B \times 15\sin\theta) = 0$

$\therefore \boxed{\theta = 67.20^\circ}$

c) A flexible cable which supports the 100 kg block is passed over a fixed circular drum shown in Fig. subjected to a force P to maintain equilibrium. If the coefficient of friction between the cable and drum is $\mu_s = 0.3$, determine the range of P.



→ Belt friction formula:-

$$\frac{T_1}{T_2} = e^{\mu\beta} \qquad \beta = 90^\circ$$

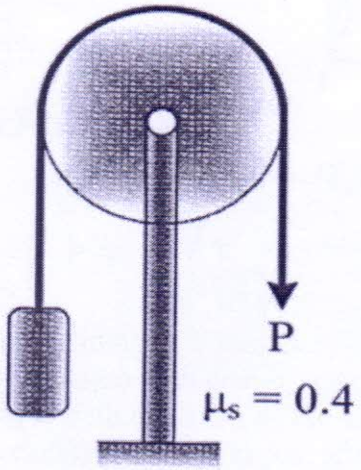
$$\frac{P}{W} = e^{\mu\beta} \qquad \therefore \beta = 90 \times \frac{\pi}{180} = \frac{\pi}{2} \text{ radian}$$

$$P = 981 \times e^{(0.3 \times 1.5708)} \qquad \beta = 1.5708 \text{ Radians.}$$

$$\boxed{P = 1572.15 N}$$

OR

d) A cable is passing over the disc of belt friction apparatus at a lap angle 180^0 as shown in fig. If coefficient of statics friction is 0.4 and the weight of the block is 500 N, determine the range of force P to maintain equilibrium.



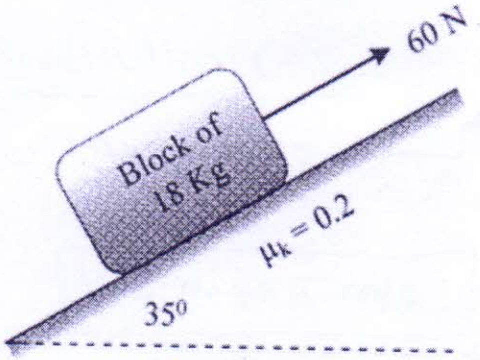
→ Belt friction formula:

$$\frac{T_{tight}}{T_{slack}} = e^{\mu\beta} \qquad \beta = \text{lap angle}$$

$$\beta = 180^\circ = \pi \text{ radians}$$

$$\frac{P}{W} = e^{\mu\beta} \quad \therefore \frac{P}{500} = e^{(0.4\times\pi)} \quad \therefore \boxed{P = 1756.7N}$$

Q.5 a) Determine the work done by all forces acting on the block of 18 kg as shown in Fig. as it moves 12 m upwards along the plane. Take coefficient of kinetic friction $\mu_k = 0.2$. **[16]**



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1) Workdone by applied force (W_{60})

$W = f \cdot d \cos\theta = f \cdot d \cos 0^\circ$

$W_{60} = 60 \times 12 \times 1$

$\boxed{W_{60} = 720\ J}$

2) workdone by gravity (W_g)

$W_g = W\sin\theta \cdot d \cdot \cos 180^\circ$

$\boxed{W_g = -1212.84\ J}$

3) Workdone by reaction (W_N)

$W_N = N \cdot d \cdot \cos 90^\circ$

$\boxed{W_N = 0\ J}$

4) Workdone by friction (W_F)

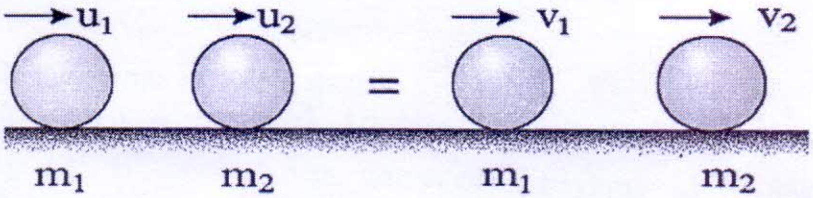
$W_F = f_k \cdot d \cdot \cos 180^\circ$

$\boxed{W_F = -347.16\ J}$

$\boxed{W = -840\ J}$

OR

b) Disk A has a mass of 250 g and is sliding on a smooth horizontal surface with an initial velocity of 2 m/s. It makes direct collision with disk B, which has a mass of 175 g and is originally at rest as shown in Fig If both disks are of the same size and the collision is perfectly elastic, determine the velocity of each disk just after collision.



→ Conservation of linear momentum :-

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$\therefore (0.250 \times 2) + (0.175 \times 0) = (0.250 \times v_1) + (0.175 \times v_2)$

$\therefore 0.500 = 0.250\,v_1 + 0.175\,v_2$ —— (1)

Coefficient of Restitution (e):-

$e = \dfrac{v_2 - v_1}{u_1 - u_2} = 1$ $\quad v_2 = v_1 + 2$ —— (2)

$\therefore 1 = \dfrac{v_2 - v_1}{2 - 0}$

$\boxed{v_1 = 0.353\ m/s}$ $\quad \boxed{v_2 = 2.353\ m/s}$

c) A ball has a mass of 30 kg and is thrown upward with a speed of 15 m/s. Determine the time to attain maximum height using impulse momentum principle. Also find the maximum height (8)

→ Impulse - momentum Principle :-

Impulse = change in momentum

Σ force = $(mv)_{final} - (mv)_{initial}$

$\boxed{t = 1.529 \text{ sec}}$

maximum Height (h) :-

$v^2 = u^2 + 2as$

$\boxed{h_{max} = 11.468 \text{ m}}$

OR

d) define following terms with neat sketch

1) Central impact - central impact is type of collision in which the line of impact (the common normal at the point of contact) passes through the centers of mass of both colliding bodies.
2) Direct impact -
- initial velocities of the colliding bodies are along the line of impact.
3) Oblique impact
- initial velocities of the colliding bodies are not along the line of impact.
4) Eccentric impact
- line of impact does not pass through the center of mass of one or both colliding bodies.
5) Direct Central impact
- Line of impact passes through the centers of mass of both bodies (central).
- Inital velocities of the bodies are along the line of impact (direct).