DPP – 1 (Rotation)

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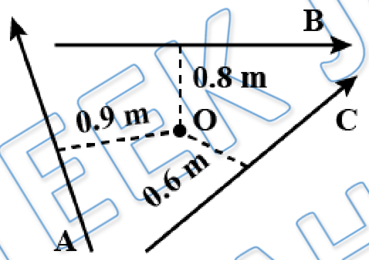
Q 1. A force $10\hat{k}$ acts on the origin of the coordinate system. Find the torque about the point (1m,−1m,0m)

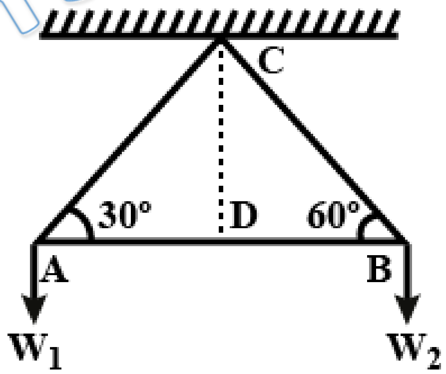
(a) $10\hat{\imath} - 10\hat{\jmath}$ (b) $10\hat{\imath} + 10\hat{\jmath}$
(c) $5\hat{\imath} + 7\hat{\jmath}$ (d) $-10\hat{\imath} + 10\hat{\jmath}$

Q 2. A, B and C are the three forces each of magnitude 4N acting in the plane of paper as shown in Fig. The point O lies in the same plane. What is the resultant torque about the point O?



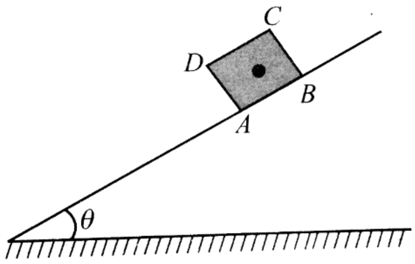
(a) 4 Nm clockwise (b) 4 Nm anti clockwise
(c) 4.4 Nm clockwise (d) 4.4 Nm anti clockwise

Q 3. A triangular set square of angles 30°, 60°, 90° and of negligible mass is suspended freely from the right angled comer and weights are hung at the two comers. If the hypotenuse of the set square sets horizontally, then the ratio of the weights $\frac{W^1}{W^2}$ is



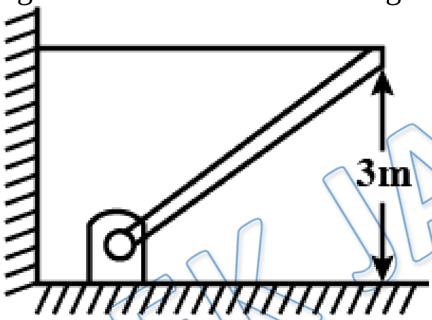
(a) 1 : 1 (b) 1 : 3
(c) $\sqrt{3}$: 1 (d) 1 : $\sqrt{3}$

Q 4. A cube of side a is placed on a rough inclined plane of inclination θ. What is the maximum value of θ for which the cube will not topple?



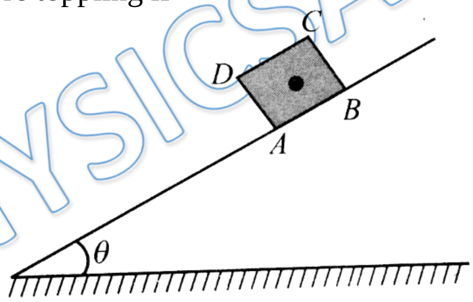
(a) 15° (b) 30°
(c) 45° (d) 69°

Q 5. A uniform rod of mass 15 kg and length 5 m is held stationary with the help of a light string as shown in the figure. The tension in the string is (in N)



(a) 150 N (b) 225 N
(c) 100 N (d) 50 N

Q 6. A cube is placed on an inclined plane of inclination θ as shown in figure. Coefficient of friction between the cube and the plane is μ. As the angle θ is gradually increased, the cube slides before toppling if

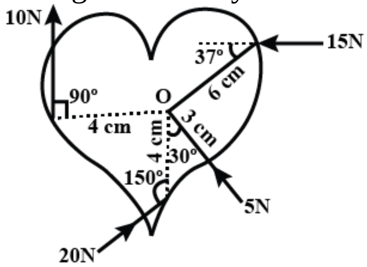


(a) $\mu > 1$ (b) $\mu > \frac{1}{2}$
(c) $\mu < 1$ (d) none of these

Q 7. Find the torque of a force $7\hat{\imath} + 3\hat{\jmath} - 5\hat{k}$ about the origin. The force acts on a particle whose position vector is $\hat{\imath} - \hat{\jmath} + \hat{k}$.
(a) $7\hat{\imath} - 12\hat{\jmath} + 10\hat{k}$ (b) $7\hat{\imath} + 12\hat{\jmath} + 5\hat{k}$
(c) $2\hat{\imath} - 12\hat{\jmath} - 5\hat{k}$ (d) $2\hat{\imath} + 12\hat{\jmath} + 10\hat{k}$

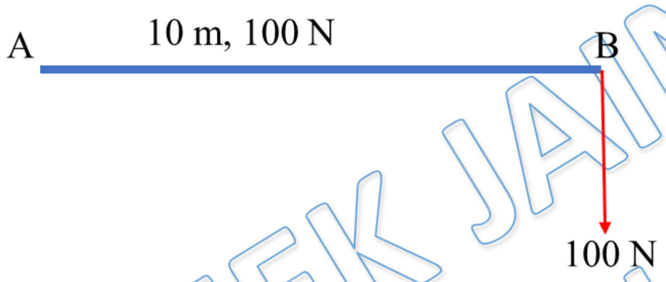
Q 8. Three forces $2\hat{\imath} + 3\hat{\jmath} - 6\hat{k}$, $2\hat{\imath} + 3\hat{\jmath} - 4\hat{k}$ and $\hat{\imath} - \hat{\jmath} + \hat{k}$ are acting on a particle (0,1,2). the magnitude of the moment of forces about the point (1,–2,0) is
(a) $4\sqrt{26}$ (b) $5\sqrt{26}$
(c) $5\sqrt{23}$ (d) none of these

Q 9. Calculate the total torque acting on the body shown in the figure about the point O:



(a) 0.54 Nm (b) 0.22 Nm
(c) 0.75 Nm (d) 0.45 Nm

Q 10. Where should be the fulcrum of a uniform rod of length 10 m and weight 100 N be if it is balanced with a weight of 100 N at an extreme point?

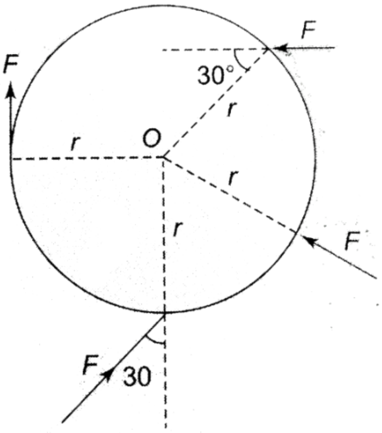


(a) 2.5 m from B
(b) 2.5 m from A
(c) 7.5 m from B
(d) 5 m from B

Q 11. At time t the vector $\vec{r} = 4.0\, t^2\hat{\imath} - (2.0\, t + 6.0\, t^2)\hat{\jmath}$ gives the position of a 3.0 kg particle relative to the origin of an xy coordinates system ($\vec{r}$ is in meters and t is in seconds) Find an expression for the torque acting on the particle relative to the origin
(a) $48t\,\hat{k}$ (b) $24t\,\hat{k}$
(c) $48t\,\hat{\imath} + 24t\,\hat{\imath}$ (d) $-48t\,\hat{\imath}$

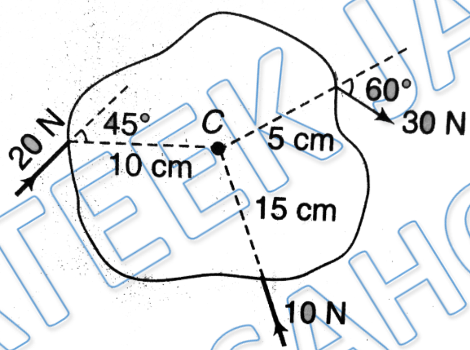
Q 12. Two loads of 40 kg-wt and 60 kg-wt sit either end of see-saw of length 3 m which is supported at its center. The third load of 30 kg-wt should be placed at ____ m from 40 kg-wt so as to balance the see-saw?
(a) 5 (b) 0.5
(c) 1 (d) 3

Q 13. Find the total torque acting on the body shown in the figure about the point O



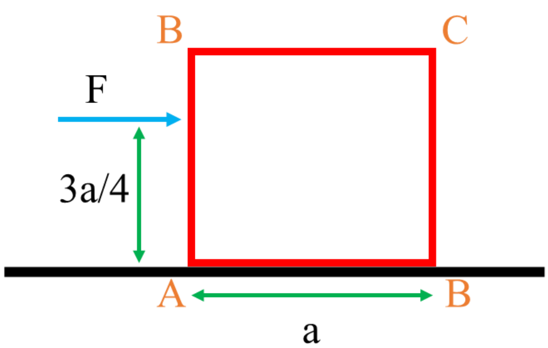
(a) Fr (b) 2Fr
(c) Fr/2 (d) zero

Q 14. Point C is the center of mass of the rigid body shown in figure. Find the total torque acting on the body about point C.



(a) 2.71 Nm CW
(b) 2.71 Nm ACW
(c) 1.17 Nm CW
(d) 1.17 Nm ACW

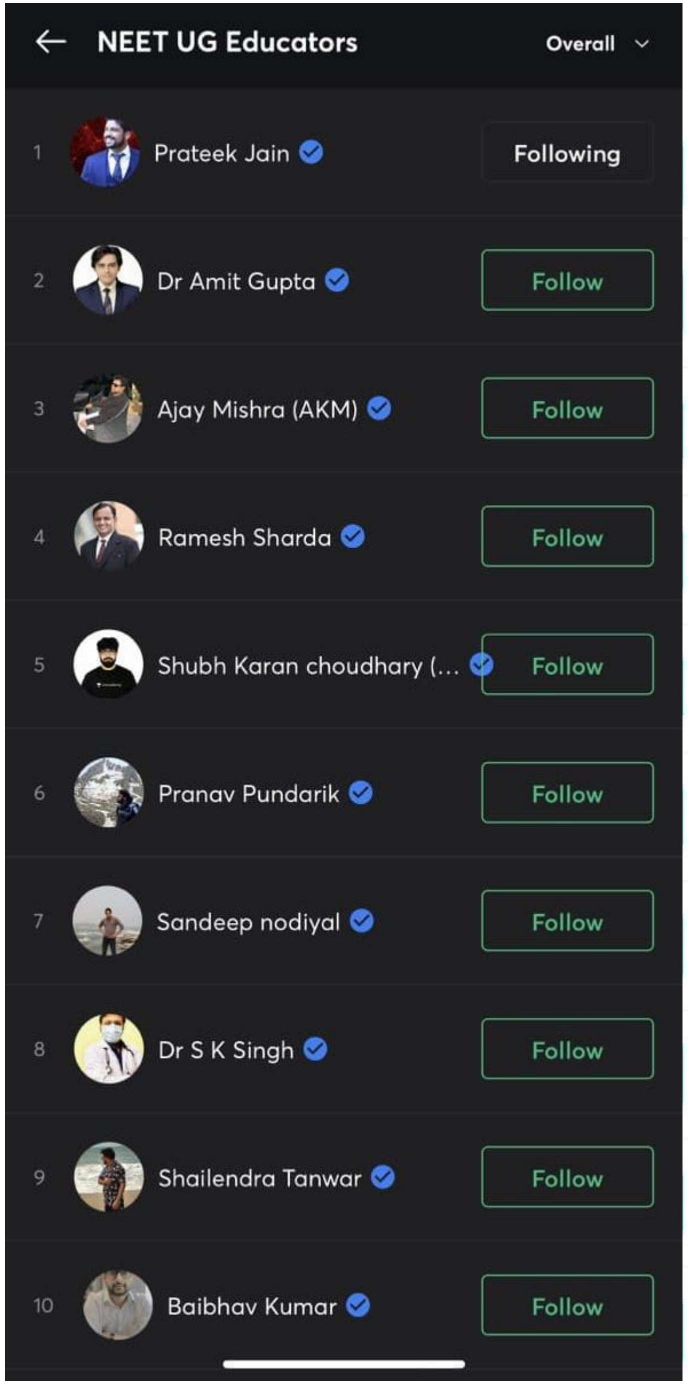
Q 15. A force is applied on the block of mass m as shown. Assume the coefficient of friction between the box and the surface is 0.7. Find minimum value of force F to topple the block



(a) mg (b) $\frac{mg}{3}$
(c) $\frac{2mg}{3}$ (d) $\frac{4mg}{3}$

Answer Key

Q.1 b	**Q.2 c**	**Q.3 b**	**Q.4 c**	**Q.5 c**
Q.6 c	**Q.7 d**	**Q.8 d**	**Q.9 a**	**Q.10 a**
Q.11 a	**Q.12 b**	**Q.13 d**	**Q.14 a**	**Q.15 c**



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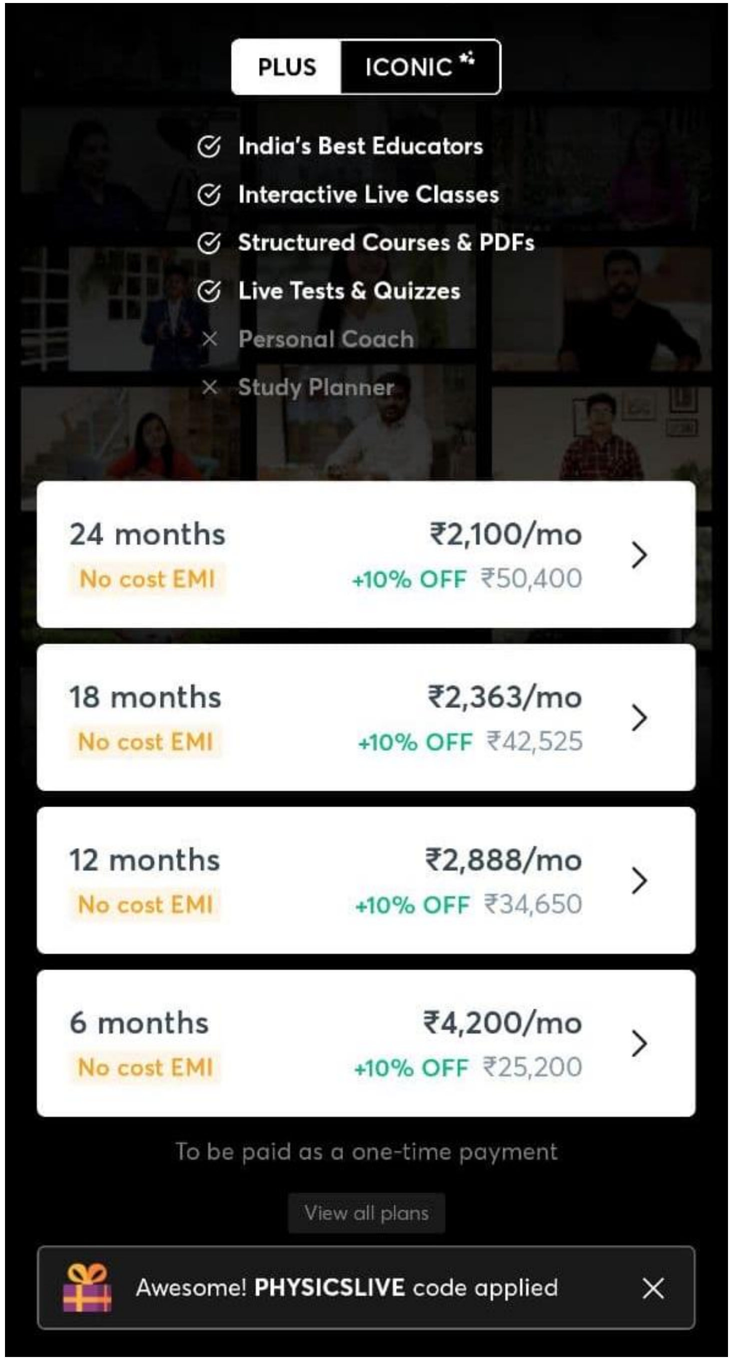

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Written Solution

DPP- 1 Rotation: Torque, Equilibrium & Toppling

By Physicsaholics Team

Solution: 1

$\vec{F} = 10\hat{k}$

$O(0,0,0) \quad A(1,-1,0)$

$\vec{r}_{O/A} = \vec{r}_O - \vec{r}_A = (0\hat{i} + 0\hat{j} + 0\hat{k}) - (\hat{i} - \hat{j})$

$\boxed{\vec{r}_{O/A} = -\hat{i} + \hat{j}}$

torque on O about A

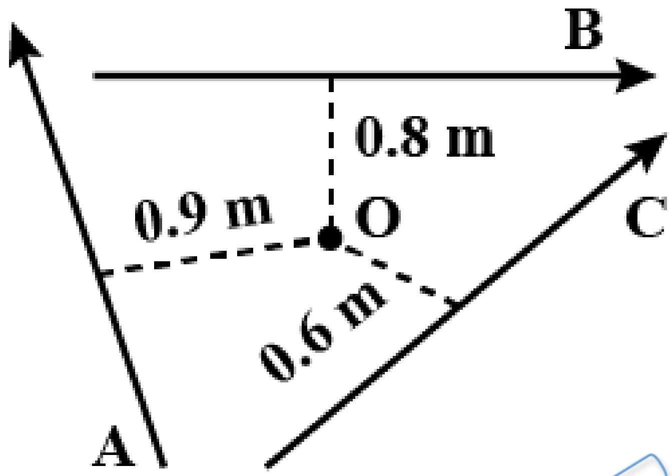
$\vec{\tau}_{O/A} = (-\hat{i} + \hat{j}) \times (10\hat{k})$

$= -10(-\hat{j}) + 10(\hat{i})$

$\boxed{\vec{\tau}_{O/A} = 10\hat{i} + 10\hat{j}}$ Ans

Ans (b)

Solution: 2



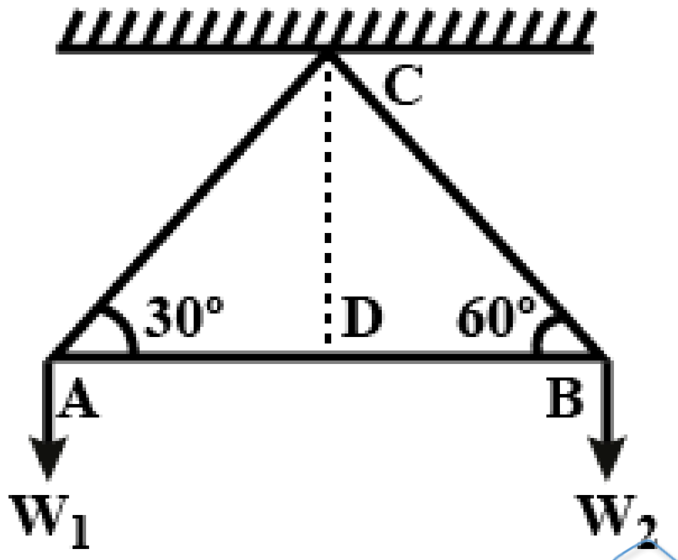
$\tau_0 = 4 \times 0.9 + 4 \times 0.8 - 4 \times 0.6$

$= 4 \times 1.1$

$\tau_0 = 4.4$ N m (clockwise)

Ans (C)

Solution: 3



If system is in equilibrium then; about point 'C'

$\tau_{w_1} + \tau_{w_2} = 0$

from Δ ABC

$AC = AB \cos 30°$

& $BC = AB \cos 60°$

4 from Δ ADC

$AD = AC \cos 30° = (AB \cos 30°) \cos 30°$

$AD = AB \cos^2 30°$

similarly, from Δ BDC

$BD = AB \cos^2 60$

so; $\tau_{w_1} + \tau_{w_2} = 0$

$-w_1 AD + w_2 BD = 0$

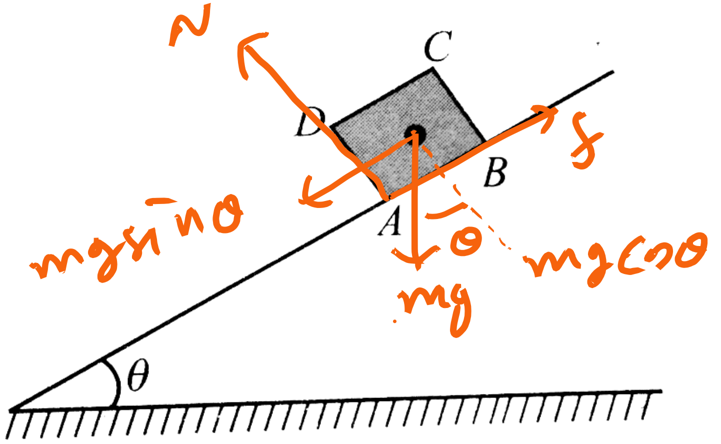
$\frac{w_1}{w_2} = \frac{BD}{AD} = \frac{AB \cos^2 60}{AB \cos^2 30}$

$\frac{w_1}{w_2} = \frac{(1/2)^2}{(\sqrt{3}/2)^2} = \frac{1}{3}$

$\rightarrow \boxed{\frac{w_1}{w_2} = \frac{1}{3}}$ Ans

Ans (b)

Solution: 4



for max inclination; point of action of Normal will shift to point (A)

and to just stop the toppling;

$\tau_A = 0$ [Torque about A]

for linear equilibrium

$N = mg\cos\theta$

& $f = mg\sin\theta$

Now

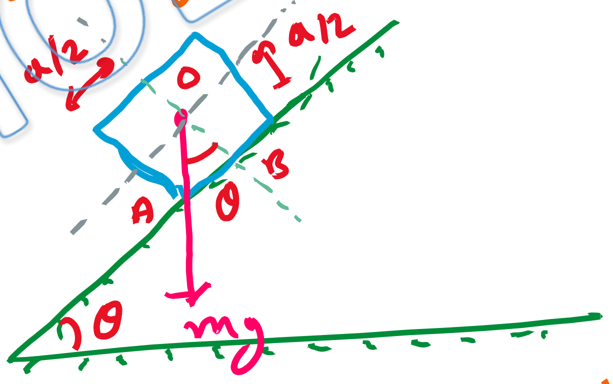
$\tau_A = \tau_f + \tau_N + \tau_{mg} = 0$

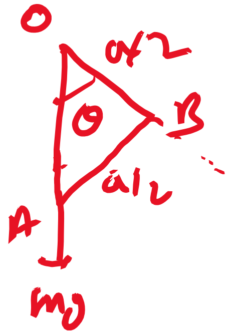
$= 0 + 0 + \tau_{mg} = 0$

$\boxed{\tau_{mg} = 0}$

↳ torque due to mg should be zero about point 'A'

⇒ mg should pass through 'A'



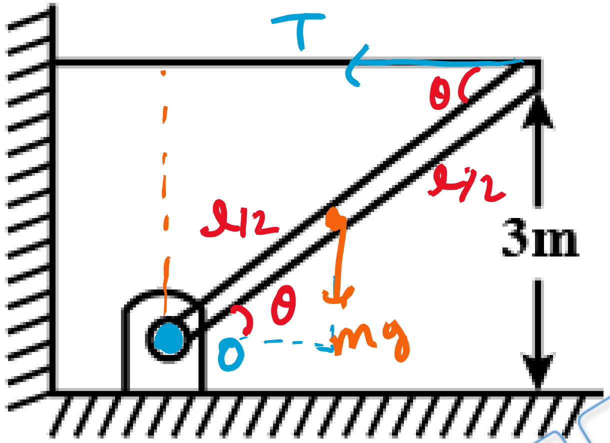


$\tan\theta = \frac{AB}{OB} = \frac{a/2}{a/2} = 1$

$\boxed{\theta = 45^\circ}$

Ans (c)

Solution: 5



$\tau_O = 0$

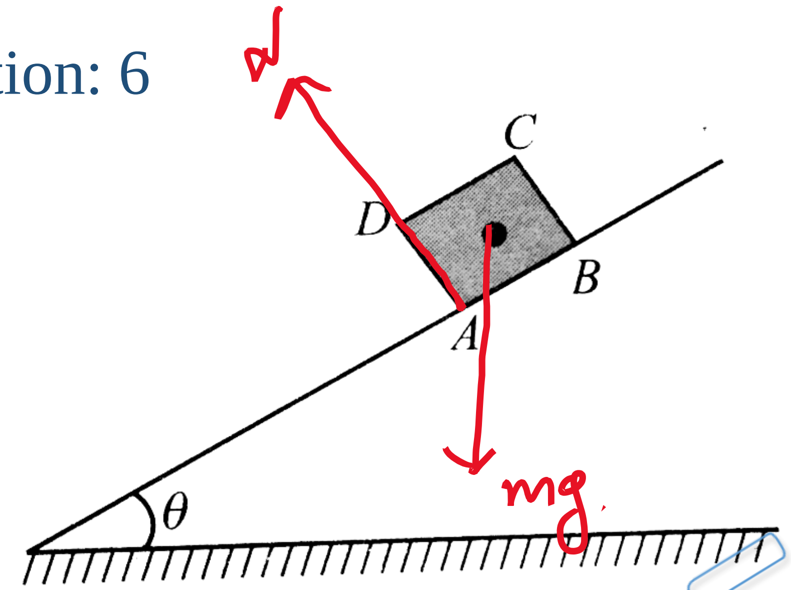
$mg\frac{\ell}{2}\cos\theta - T \times 3 = 0$

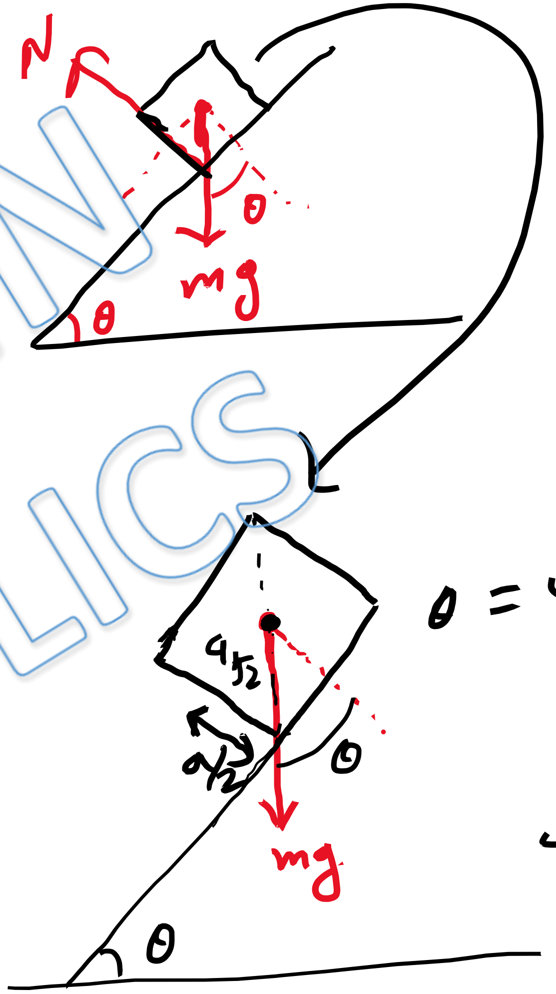
$15 \times 10 \times \frac{5}{2} \times \frac{4}{5} = T \times 3$

$\boxed{T = 100\ N}$ Ans.

Ans (C)

Solution: 6





for slipping only mg should pass from right side of A so that its torque about A doesn't allow it to topple.

so; for critical situation, mg can pass through A.

$\theta = 45^\circ$

$\mu = \tan\theta$ for slipping.

so; $\theta < 45^\circ$

$\tan\theta < \tan 45^\circ$

$$\boxed{\mu < 1}$$

Ans (C)

Solution: 7

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$= (\hat{i} - \hat{j} + \hat{k}) \times (7\hat{i} + 3\hat{j} - 5\hat{k})$$

$$= 3\hat{k} - 5(-\hat{j}) - 7(-\hat{k}) + 5(\hat{i}) + 7(\hat{j}) + 3(-\hat{i})$$

$$= 3\hat{k} + 5\hat{j} + 7\hat{k} + 5\hat{i} + 7\hat{j} - 3\hat{i}$$

$$\vec{\tau} = 2\hat{i} + 12\hat{j} + 10\hat{k}$$

$$\boxed{\vec{\tau} = 2\hat{i} + 12\hat{j} + 10\hat{k}}$$ Ans.

Ans (d)

Solution: 8

$$\vec{F} = \vec{F_1} + \vec{F_2} + \vec{F_3} = 5\hat{i} + 5\hat{j} - 9\hat{k}$$

$A(0,1,2)$; $\vec{r_1} = \hat{j} + 2\hat{k}$

$B(1,-2,0)$; $\vec{r_2} = \hat{i} - 2\hat{j}$

$$\vec{r_{12}} = \vec{r_1} - \vec{r_2} = -\hat{i} + 3\hat{j} + 2\hat{k}$$

$$\vec{\tau_B} = \vec{F} \times \vec{r_{12}} = (5\hat{i} + 5\hat{j} - 9\hat{k}) \times (\hat{i} - 3\hat{j} - 2\hat{k})$$

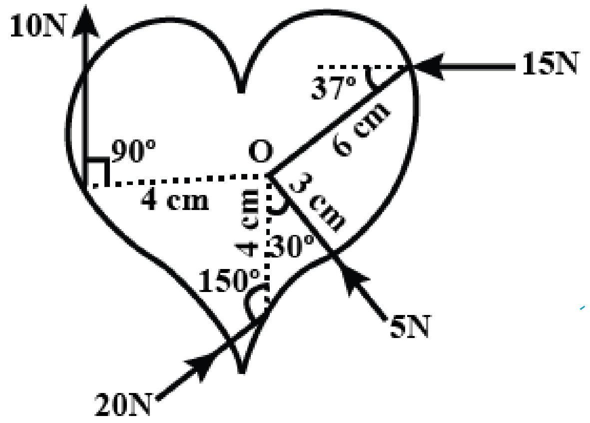
$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & 5 & -9 \\ 1 & -3 & -2 \end{vmatrix} = \hat{i}(-10-27) - \hat{j}(-10+9) + \hat{k}(-15-5)$$

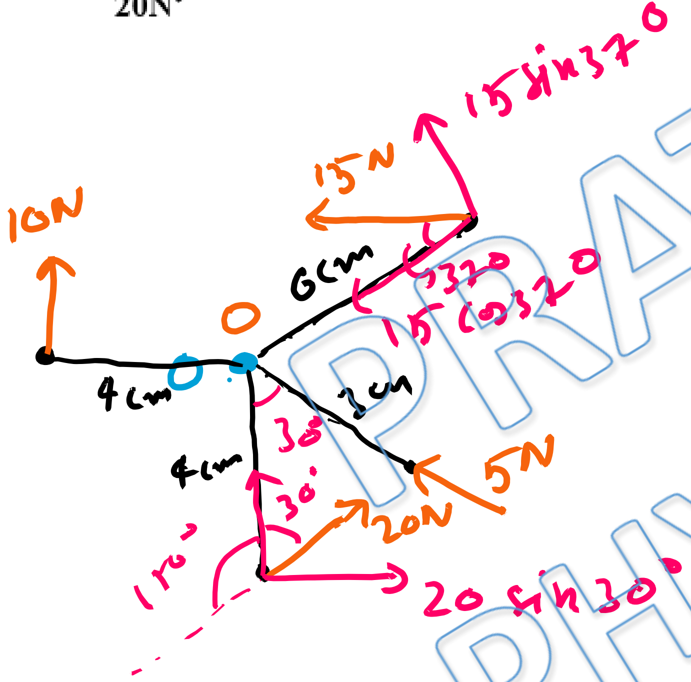
$$\boxed{\vec{\tau_B} = -37\hat{i} + \hat{j} - 20\hat{k}} \text{ Ans}$$

$$\boxed{\tau_B = \sqrt{1770}} \text{ N-m Ans}$$

Ans (d)

Solution: 9





$\tau_0 = 10(0.04) - (20\sin 30^\circ \times 0.04) + (5\times 0)$

$-(15\sin 37^\circ \times 0.06)$

$\tau_0 = 0.4 - 0.4 + 0 - 15\times\frac{3}{5}\times 0.06$

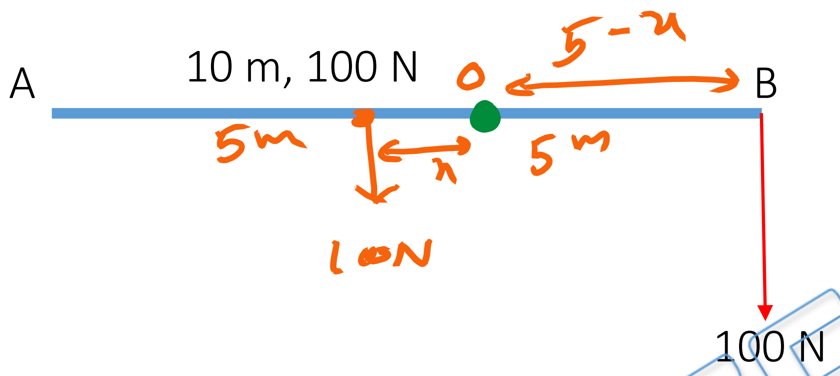
$\tau_0 = -0.54$ N-m

$\boxed{\tau_0 = 0.54 \text{ N-m}}$ (anticlockwise)

Ans

Ans (a)

Solution: 10



$\tau_O = 0$

$100(5-x) = 100x$

$500 = 200x$

$x = \frac{5}{2} = 2.5\ m$

So; 2.5 m. from B

i.e. 7.5 m from A

Ans (a)

Solution: 11

$$\vec{r} = 4.0\,t^2\hat{\imath} - (2.0\,t + 6.0\,t^2)\hat{\jmath}$$

$$\vec{v} = \frac{d\vec{r}}{dt} = 8t\,\hat{i} - (2+12t)\hat{j}$$

$$\vec{a} = \frac{d\vec{v}}{dt} = 8\hat{i} - 12\hat{j}$$

$$\vec{F} = m\vec{a} = 3\vec{a}$$

$$\vec{F} = 24\hat{i} - 36\hat{j}$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$= [(4t^2)\hat{i} - (2t + 6t^2)\hat{j}] \times [24\hat{i} - 36\hat{j}]$$

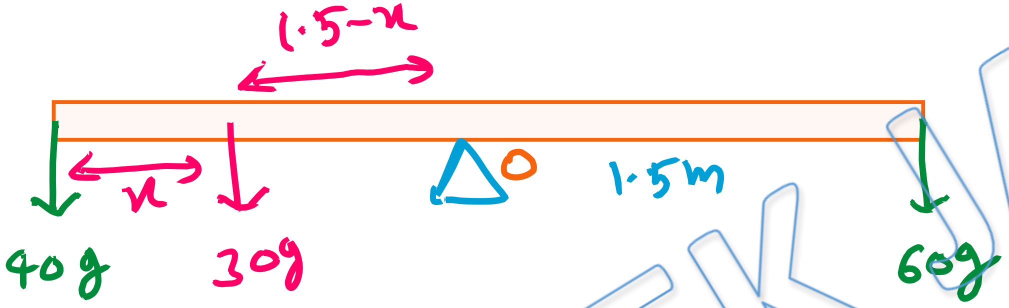
$$= -144t^2\hat{k} - (48t + 144t^2)(-\hat{k})$$

$$= -144t^2\hat{k} + 144t^2\hat{k} + 48t\,\hat{k}$$

$$\vec{\tau} = 48t\,\hat{k}$$ Ans

Ans (a)

Solution: 12



$\tau_0 = 0$

$60g \times 1.5 = 40g \times 1.5 + 30g(1.5 - x)$

$60g \times 1.5 = 60g + 45g - 30gx$

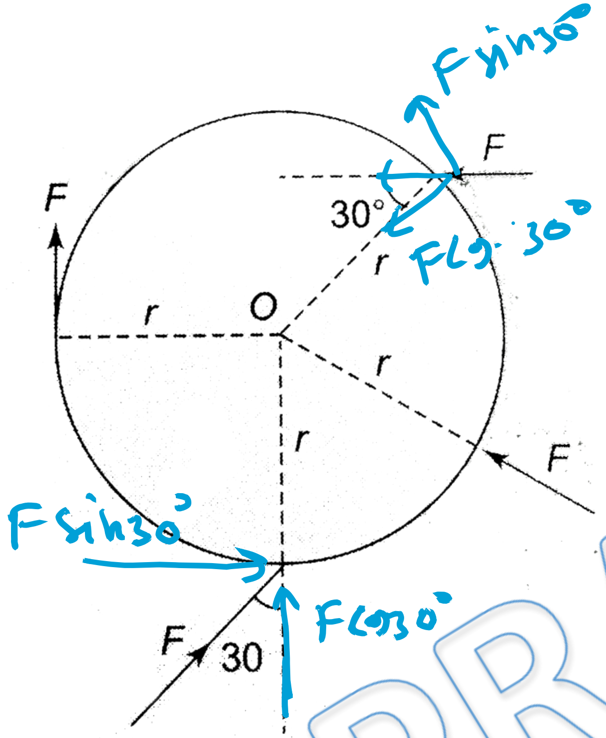
$90 = 60 + 45 - 30x$

$-15 = -30x$

$\boxed{x = 0.5\,m}$ Ans

Ans (b)

Solution: 13



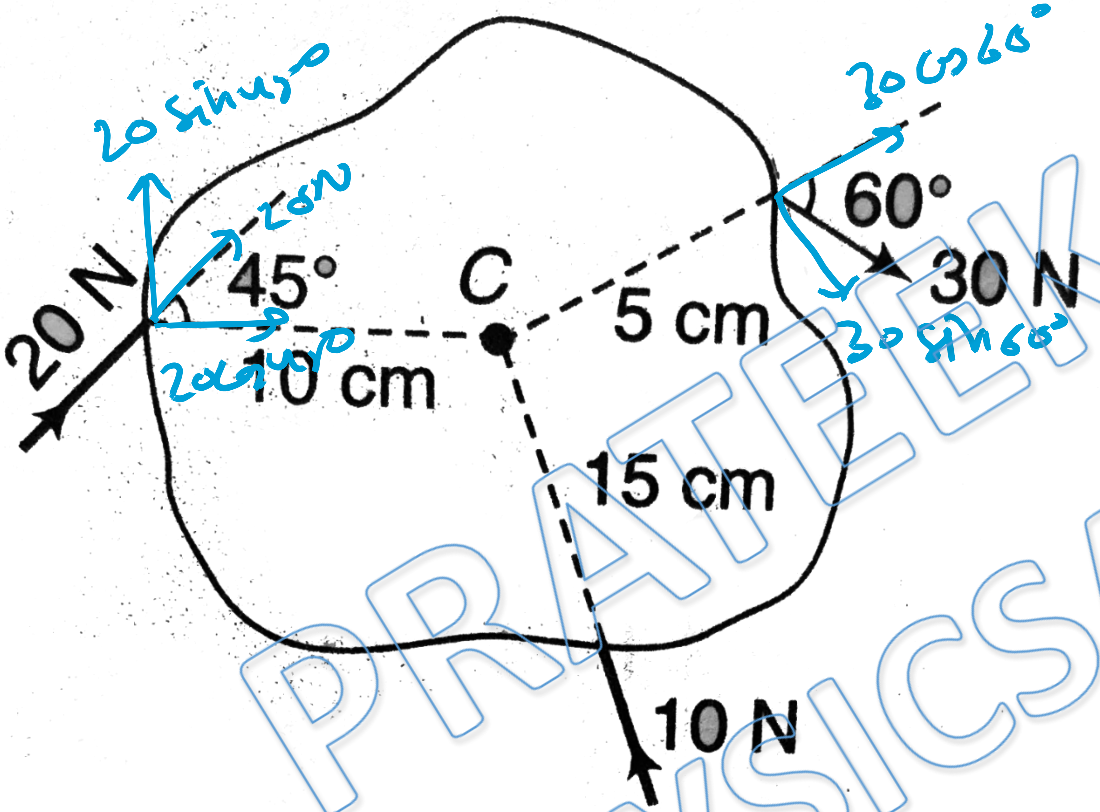
$\tau_o = -(F\sin 30° \times r) + (F \times 0) - (F\sin 30° \times r) + Fr$

$= -\frac{F}{2}r + 0 - \frac{F}{2}r + Fr$

$\boxed{\tau_o = 0}$ Ans.

Ans (d)

Solution: 14



$\tau_c = (20\sin 45^\circ \times 0.1) + (30\sin 60^\circ \times 0.05) + 0$

$= \sqrt{2} + \frac{1.5\sqrt{3}}{2}$

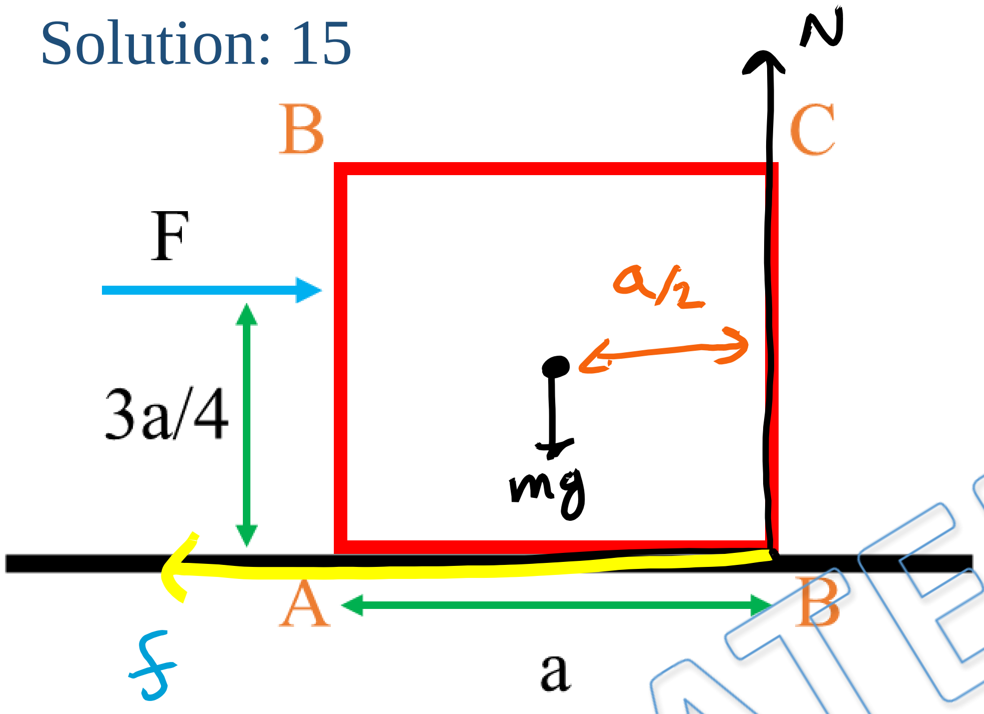
$= 1.414 + 0.75\sqrt{3}$

$\tau_c = 2.71\ N\text{-}m$ (clockwise)

Ans

Ans (a)

Solution: 15



$f = \mu mg$

$\boxed{f = \frac{1}{2}mg}$

$\boxed{N = mg}$

For toppling; Normal reaction will shift to point B

and

$\Rightarrow \tau_B \geq 0$

$\tau_N + \tau_{mg} + \tau_f + \tau_F \geq 0$

$0 - mg\frac{a}{2} + 0 + F\frac{3a}{4} \geq 0$

$F\left(\frac{3}{4}\right) \geq \frac{mg}{2}$

$\boxed{F \geq \frac{2mg}{3}}$

$\boxed{F_{min} = \frac{2mg}{3}}$ Ans

Ans (C)

Since; 2mg/3 is smaller than limiting friction. So, block will not slide on ground.

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