CLASS TEST

S.No. : 01SP_ME_S_130522

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ENGINEERING MECHANICS

MECHANICAL ENGINEERING

Date of Test : 13/05/2022

ANSWER KEY

1.	(b)	7.	(b)	13.	(b)	19.	(c)	25.	(b)
2.	(c)	8.	(d)	14.	(a)	20.	(b)	26.	(c)
3.	(d)	9.	(b)	15.	(a)	21.	(c)	27.	(c)
4.	(b)	10.	(c)	16.	(b)	22.	(b)	28.	(b)
5.	(b)	11.	(b)	17.	(c)	23.	(d)	29.	(a)
6.	(b)	12.	(d)	18.	(c)	24.	(c)	30.	(b)

DETAILED EXPLANATIONS

1. (b)

As per given information,

$$h = 40 \text{ m}, u = 50 \text{ m/s}$$

Let the speed be 'v' when it strike to the ground

Apply law of conservation of energy

$$mgh + \frac{1}{2}mu^2 = \frac{1}{2}mv^2$$

$$m \times 10 \times 40 + \frac{1}{2} \times m \times (50)^2 = \frac{1}{2} \times m \times v^2$$

$$400 + 1250 = \frac{v^2}{2}$$

$$v = 57.44 \text{ m/s}$$

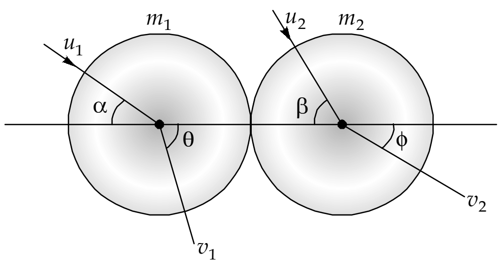
2. (c)

Force in member AH should be zero, as the AH is corner member with only two member connected to each other at 90°. Hence in both member AH and GH force is zero.

3. (d)

4. (b)

Sphere of mass m_1 moving with velocity u_1 impinges obliquely on another sphere of mass m_2 moving with velocity u_2 and if the directions of motions before impact make angle α and β with the common normal.



Let AB be the common normal, v_1 and v_2 be the velocities of the two sphere after impact making angles θ and ϕ with the common normal AB are $u_1 \cos\alpha$ and $u_2 \cos\beta$ and after impact $v_1 \cos\theta$ and $v_2 \cos\phi$.

By the principal of conservation of momentum, the total momentum of two spheres along the common normal is unaltered by the impact.

$$\therefore \quad m_1 v_1 \cos\theta + m_2 v_2 \cos\phi = m_1 u_1 \cos\alpha + m_2 u_2 \cos\phi$$

5. (b)

Given : Velocity ∝ Distance i.e. $\frac{dV}{dt} = -kx$ [where, x : distance]

$$V = \frac{dx}{dt}$$

So, $$\frac{d^2x}{dt^2} = -kx$$

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$$\frac{dx}{dt} = -kxt + c_1$$

$$x = -kx\frac{t^2}{2} + c_1 t + c_2$$

From above equation, we can see that the distance covered will be quadratic in time.

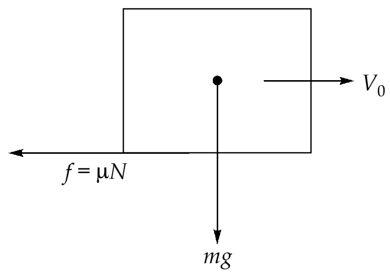
6. (b)

By work-energy principle,

Work done by friction = Change in kinetic energy

Case-1:

From Newton first law,



$$N = mg$$

$$f = -\mu mg$$

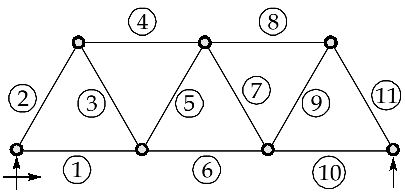
$$-\mu mgd = 0 - \frac{1}{2}mV_0^2 \quad \text{... (i)}$$

Case-2:

$$-\mu mgD = 0 - \frac{1}{2}m\left(2V_0^2\right) \quad \text{... (ii)}$$

Divide II/I, $\frac{D}{d} = \frac{(2V_0)^2}{V_0^2} = 4$

7. (b)



Total number of member, $i = 11$

Number of reaction, $r = 3$

Total number of points $= 2 \times j = 2 \times 7 = 14$

$$i + r = 2j$$

$$11 + 3 = 2 \times 7$$

$$14 = 14$$

Therefore, the truss is stable and internally determinate.

8. (d)

Let u, v, w be the components of velocity in x, y and z direction respectively.

$$u = \frac{dx}{dt} = 2\cos t$$

Similarly, $v = -3\sin t$

$$w = \sqrt{5}\cos t$$

$$V = \sqrt{u^2 + v^2 + w^2} = \sqrt{(2\cos t)^2 + (-3\sin t)^2 + \left(\sqrt{5}\cos t\right)^2}$$

$$V = \sqrt{4\cos^2 t + 9\sin^2 t + 5\cos^2 t}$$

$$V = \sqrt{9(\sin^2 t + \cos^2 t)} = 3 \text{ units}$$

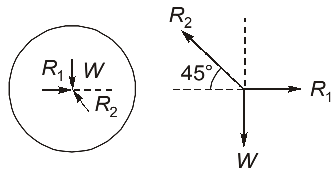
9. (b)

10. (c)

Normal reaction, $N = 200 - P \sin 30° = 200 - 100 \times 0.5 = 150$ N

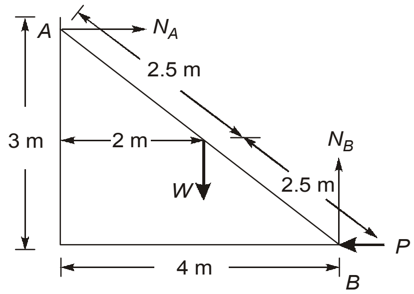
Frictional force, $F = \mu N = 0.3 \times 150 = 45$ N

11. (b)



$$R_2 \cos 45° = R_1$$
$$R_2 \sin 45° = W$$
$$\Rightarrow \quad R_2 = W\sqrt{2}$$
$$\therefore \quad R_1 = W\sqrt{2} \times \frac{1}{\sqrt{2}} = W$$
$$W = 50 \text{ N}$$
$$\therefore \quad R_1 = 50 \text{ N}$$

12. (d)



Considering equilibrium of ladder

$$N_A = P \quad [\because \vec{F}_H = 0]$$
$$W = N_B \quad [\because \vec{F}_V = 0]$$
$$\Sigma M_B = 0$$
$$N_A \times 3 - W \times 2 = 0$$
$$W = \frac{N_A \times 3}{2} = \frac{P \times 3}{2} = \frac{400 \times 3}{2} = 600 \text{ N}$$

13. (b)

$$I_B = \frac{mL^2}{3} + \frac{mL^2}{3} = \frac{2mL^2}{3}$$
$$T = \frac{mgL}{2} = I_B \alpha$$
$$\Rightarrow \quad mg\frac{L}{2} = \frac{2}{3}mL^2\alpha$$
$$\alpha = \frac{3g}{4L}$$

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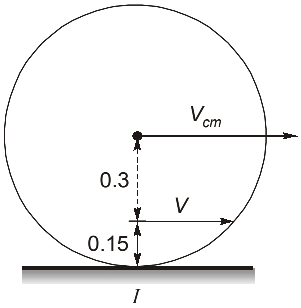
14. (a)



$$V_{cm} = 0.45\,\omega$$

$$\omega = \frac{3}{0.45}\text{ rad/s}$$

$$V = 0.15\ \omega = \frac{0.15\times 3}{0.45}$$

$$V = 1\text{ m/s}$$

15. (a)

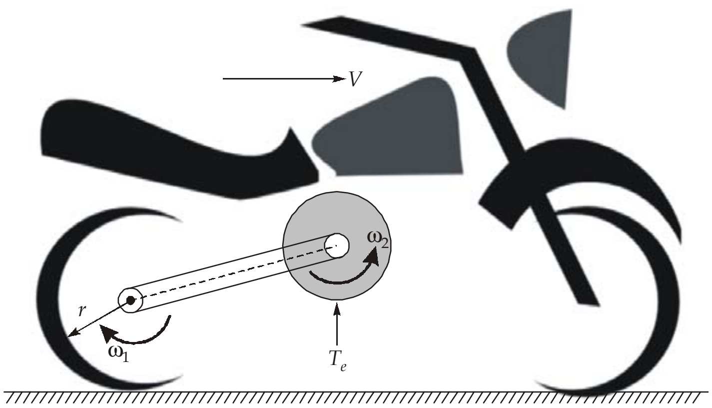


Fig. Actual System

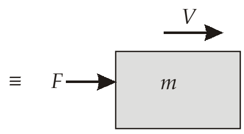


Fig. Equipment System

Here, $$KE_{equivalent} = KE_{actual}$$

$$\frac{1}{2}m'V^2 = \frac{1}{2}mV^2 + 2\left[\frac{1}{2}I_w\omega_1^2\right] + \frac{1}{2}I_e\omega_2^2$$

Where, ω = Angular of wheels speed and $\omega_2 = G\omega_1$ = Angular of engine speed

and $$\omega_1 = \frac{V}{r}$$

So, $$\frac{1}{2}m'V^2 = \frac{1}{2}mV^2 + 2\left[\frac{1}{2}I_w\left(\frac{V}{r}\right)^2\right] + \frac{1}{2}I_e(G\omega_1)^2$$

$$\frac{1}{2}m'V^2 = \left[\frac{1}{2}m + \frac{I_w}{r^2} + \frac{1}{2}I_e\frac{G^2}{r^2}\right]V^2$$

So, $$m' = m + \frac{2I_w}{r^2} + \frac{I_e}{r^2}G^2$$

16. (b)

As per given information,

$$m = 30 \text{ kg}; \quad r = 0.2 \text{ m}$$
$$\omega = 20 \text{ rad/s}; \quad T = 5 \text{ Nm}$$
$$F = 10 \text{ N}$$

$$I = \frac{1}{2}mr^2 = \frac{1}{2}\times 30\times 0.2^2 = 0.6 \text{ kg.m}^2$$

Let the disk rotate an angle of θ rad.

From work energy principle

$$T\cdot\theta + F\times r\cdot\theta = \frac{1}{2}\times I\times\omega^2 \quad [\because \text{ Workdone = change in energy}]$$

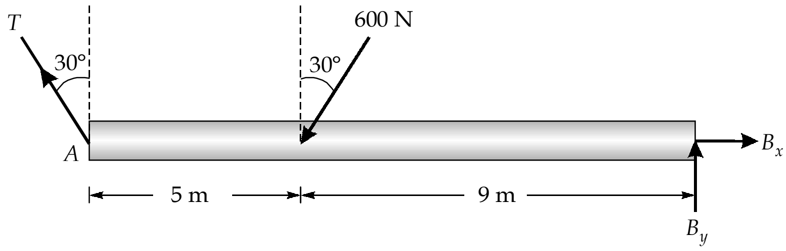
$$5\cdot\theta + 10\times 0.2\times\theta = \frac{1}{2}\times 0.6\times(20)^2$$

$$7\cdot\theta = 120$$

$$\theta = 17.14 \text{ rad}$$

$$\text{Number of revolution} = \frac{\theta}{2\pi} = \frac{17.14}{2\pi} = 2.73 \text{ rev}$$

17. (c)



Let T be the tension in the rope,

The equilibrium equations are:

$\Sigma F_x = 0;$ $\quad -T\sin 30° - 600\sin 30° + B_x = 0$

$\Sigma F_y = 0;$ $\quad T\cos 30° - 600\cos 30° + B_y = 0$

$\Sigma M_B = 0;$ $\quad (600\cos 30°)9 - (T\cos 30°)14 = 0$

By solving above three equation,

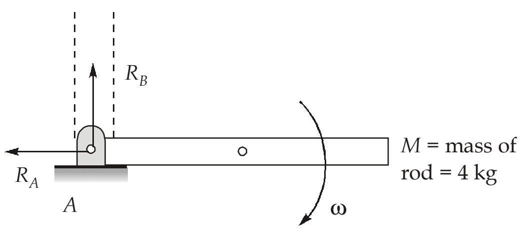
we get $\quad T = 386 \text{ N}, B_x = 493 \text{ N}, B_y = 186 \text{ N}$

Note : Calculation steps are left for students.

18. (c)

$$\frac{1}{2}\times\frac{ML^2}{3}\times\omega^2 = \frac{MgL}{2}$$

$$\Rightarrow \quad \frac{L}{3}\times\omega^2 = g = \omega = \sqrt{\frac{3g}{L}}$$



$$\text{Horizontal force balance} \Rightarrow R_A = M\omega^2\frac{L}{2}$$

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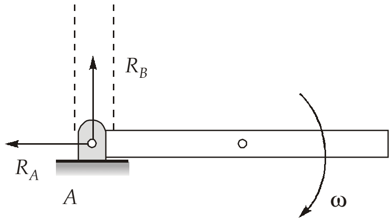
$$\Rightarrow \quad R_A = M\frac{3g}{L}\times\frac{L}{2} = \frac{3Mg}{2} = R_A = 58.86 \text{ N}$$

Vertical force balance



$$Mg - R_B = Ma$$

$$a = \frac{\alpha L}{2}$$

$$\Rightarrow \quad \Sigma\tau_{net\_A} = I\alpha$$

$$Mg\times\frac{L}{2} = \frac{ML^2}{3}\times\alpha$$

$$\alpha = \frac{3g}{2L}$$

So,

$$a = \alpha\frac{L}{2} = \frac{3g}{4}$$

$$Mg - Ma = R_B$$

$$\Rightarrow \quad R_B = \frac{Mg}{4} = 9.81 \text{ N}$$

$$\Rightarrow \quad R_{Net} = \sqrt{R_A{}^2 + R_B{}^2} = 59.67 \text{ N}$$

19. (c)

Initial momentum of bullet and block = Final momentum of bullet and block

$$m_1V_1 + m_2 \times 0 = (m_1 + m_2) \times V$$

$$V = \left(\frac{m_1}{m_1 + m_2}\right)V_1 = \left(\frac{25}{25+520}\right)\times 180 = 8.26 \text{ m/s}$$

By work energy principle:

$$\text{Final KE} - \text{Initial KE} = \text{Work done}$$

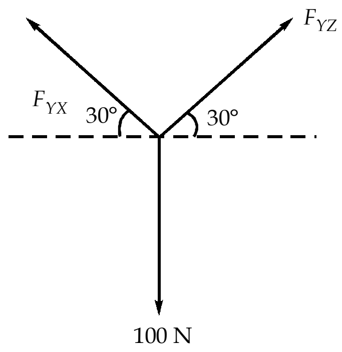
$$\frac{1}{2}mV^2 - 0 = \mu \times Mgx$$

$$\mu = \frac{V^2}{2gx}$$

$$= \frac{(8.26)^2}{2\times 9.8\times 8.2} = 0.4245$$

20. **(b)**

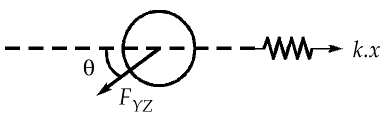
From sine rule,



$$\frac{100}{\sin 120°} = \frac{F_{YZ}}{\sin 120°}$$

$$F_{YZ} = F_{YZ} = 100 \text{ N}$$

FBD



$$F_{YZ} \cos 30° = k.x$$

$$100 \times \frac{\sqrt{3}}{2} = 10 \times 10^3 .x$$

$$x = \frac{100 \times \sqrt{3} \times 1000}{2 \times 10 \times 10^3} \text{ mm}$$

$$x = 5\sqrt{3} \text{ mm}$$

21. **(c)**

$$a = \frac{dv}{dt}$$

Let resisting force,

$\Rightarrow$ $$F = Kv^2$$

Let m is mass of bullet

$\therefore$ $$a = \frac{F}{m} = \frac{Kv^2}{m}$$

$$\frac{dv}{dt} = \frac{Kv^2}{m}$$

$$\frac{1}{v^{-2}} dv = \frac{K}{m} dt$$

$$\left[\frac{v^{-1}}{-1}\right]_u^v = \frac{K}{m}\int_0^t dt$$

$\Rightarrow$ $$\left[\frac{v-u}{uv}\right] = \frac{K}{m} t$$

$\Rightarrow$ $$t = \frac{(u-v)}{uv} \times \frac{-m}{K}$$

$\therefore$ $$t \propto (u-v)\,(uv)^{-1}$$

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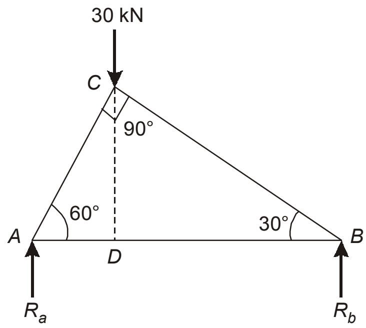
22. (b)

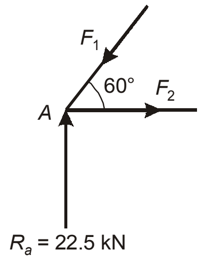


$$AC = AB \cos 60° = 2.5 \text{ m}$$
$$AD = AC \cos 60° = 2.5 \times 0.5 = 1.25$$

∴ Taking moments about A,

$$R_b \times 5 = 30 \times 1.25$$
$$R_b = 7.5 \text{ kN}, \quad R_a = 30 - 7.5 = 22.5 \text{ kN}$$

Considering joint A,



$$\Sigma F_x = 0, \quad F_2 - F_1 \cos 60° = 0$$
$$F_1 \sin 60° - R_a = 0$$
$$F_1 = \frac{R_a}{\sin 60°} = \frac{22.5}{\sin 60°} = 25.97 \text{ kN} \quad \text{(compressive)}$$
$$F_2 = F_1 \cos 60° = 12.99 \text{ kN} \quad \text{(tensile)}$$

∴ AB is in tension.

23. (d)

For no tipping or prevent overturning

$$Ph < \frac{Wb}{2}$$

where $W \rightarrow$ weight of block

and $b \rightarrow$ width of block

$$h < \frac{Wb}{2P} \quad ...(1)$$

and for slipping without tipping

$$P > f(\text{force of friction})$$
$$P > \mu W \quad ...(2)$$

From (1) and (2)

$$h < \frac{b}{2\mu}$$

∴ $$h < \frac{60}{0.6}$$

∴ $$h < 100 \text{ mm}$$

Option (d) is correct.

24. (c)

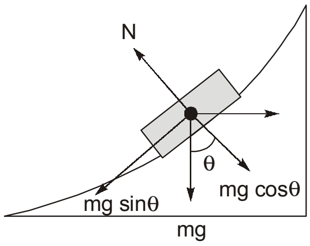
$$\text{Resistance} = mg + W = 200 \times 9.81 + 100 = 2062 \text{ N}$$

$$\therefore \quad a = \frac{2062}{200}$$

$$a = 10.31 \text{ m/s}^2$$

$$\frac{V^2}{2a} = S = \frac{4^2}{2 \times 10.31} = 0.776 \text{ m}$$

25. (b)



$$\tan\theta = \frac{dy}{dx} = \frac{x^2}{2}$$

Now, $mg\sin\theta = \mu mg\cos\theta$

$\Rightarrow \quad \tan\theta = \mu$

$\Rightarrow \quad \dfrac{x^2}{2} = 0.5$

$\Rightarrow \quad x = 1$

$$y = \frac{1}{6}\text{m}$$

26. (c)

$$\Sigma F_x = 0$$

$$T_1 \cos 45° + 100 \cos 30° = T_2 \cos 60° + 100$$

$$\Sigma F_y = 0$$

$\therefore \quad T_1 \sin 45° + T_2 \sin 60° = 100 \sin 30°$

$\Rightarrow \quad 0.707\, T_1 + 86.602 = 0.5\, T_2 + 100$

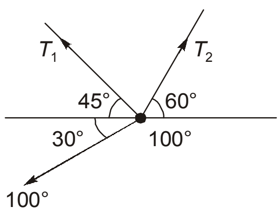
$\Rightarrow \quad 0.707\, T_1 - 0.5\, T_2 = 13.398$

$$0.707\, T_1 + 0.866\, T_2 = 50$$

$$T_1 = 37.9 \text{ N}$$

$$T_2 = 26.795$$

$\therefore \quad T_1/T_2 = 1.414$



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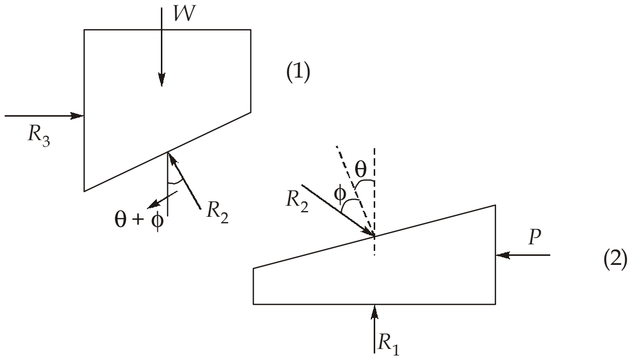
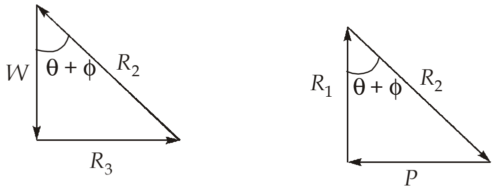
27. (c)





$$\cos(\theta + \phi) = \frac{W}{R_2}, \quad \sin(\theta + \phi) = \frac{P}{R_2}$$

$$\frac{P}{W} = \tan(\theta + \phi)$$

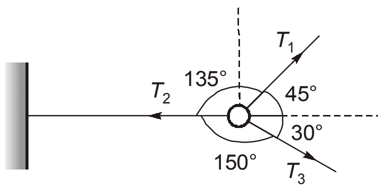
$$P = W \tan(\theta + \phi)$$

$$= 500 \tan(\theta + \phi)$$

$$\phi = \tan^{-1} 0.20 = 11.309$$

$$P = 500 \tan(15 + 11.309) = 247.21 \text{ N}$$

28. (b)



∴ Applying lami's theorem as the disc is in equilibrium,

$$\frac{T_1}{\sin 150°} = \frac{T_2}{\sin 75°} = \frac{T_3}{\sin 135°}$$

$$\therefore \quad \frac{T_1}{T_2} = \frac{\sin 150°}{\sin 75°} = 0.517$$

29. (a)

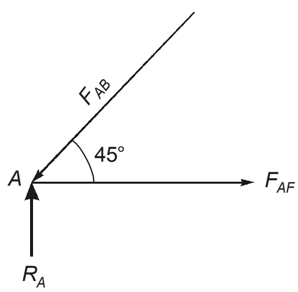
Reaction at A is R_A

Taking moments from point E,

$$W \times \frac{a}{2} + Wa = 2a \cdot R_A$$

$$\therefore \quad R_A = 0.75 \text{ W}$$

Joint A

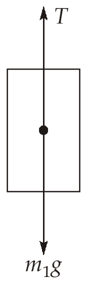


$$F_{AB} \sin 45° = R_A$$

$$F_{AB} = 1.06\,W \text{ (compressive)}$$

30. **(b)**

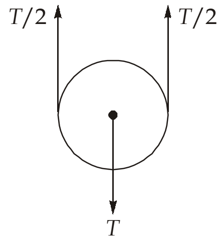
Cylinder



From Newton's first law,

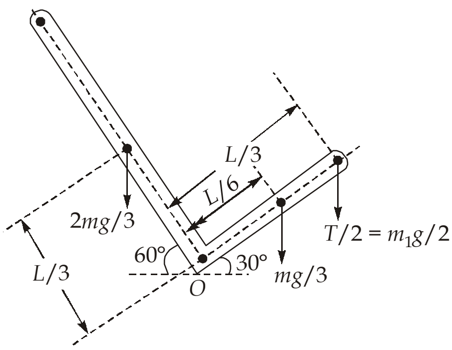
$$m_1g - T = 0$$
$$T = m_1g$$

Pulley



$$\frac{T}{2} = \frac{m_1g}{2}$$

To cause loss of contact at A, reaction at A will be zero.



$\Sigma M_o = 0$

$$\frac{2mg}{3}\times\frac{L}{3}\cos 60° - \frac{mg}{3}\times\frac{L}{6}\cos 30° - \frac{T}{2}\times\frac{L}{3}\cos 30° = 0$$

$$\Rightarrow \quad \frac{2mg}{9}gL\cos 60° = \frac{m}{18}gL\cos 30° + \frac{m_1g}{2}\times\frac{L}{3}\cos 30°$$

$$\Rightarrow \quad \frac{2m}{9}\cos 60° = \frac{m}{18}\cos 30° + \frac{m_1}{6}\cos 30°$$

$$m_1 = 0.436 \text{ m}$$

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