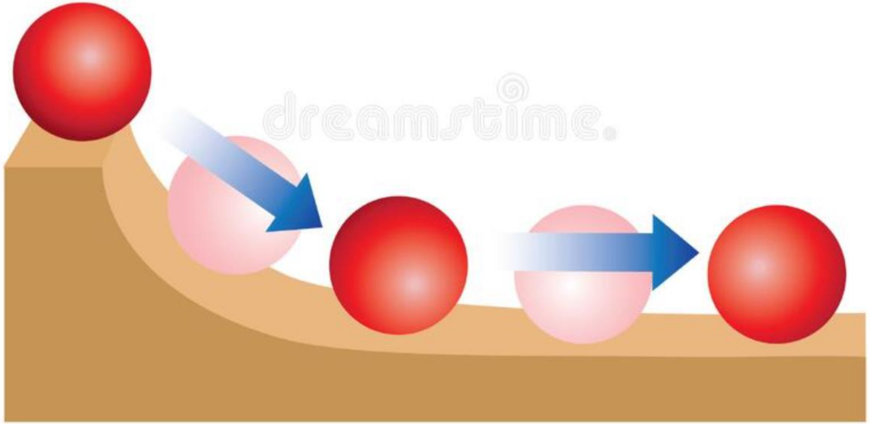
NEWTON'S LAWS OF MOTION



Abhilash Sharma

B.Tech - NIT Calicut

- ☐ Experience - 8+ years
- ☐ 700+ selections in JEE Advanced
- ☐ 6000+ selections in JEE Mains

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for IIT JEE Main and Advanced 2024

Code: ABHILASH

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- Coverage of Class 11 JEE syllabus
- Enhance conceptual understanding of JEE Main & JEE Advanced subjects
- Systematically designed courses
- Strengthen JEE problem-solving ability

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Mathematics Maestro

Nishant Vora
Mathematics Maestro

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Physics Maestro

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For more details, contact **8585858585**

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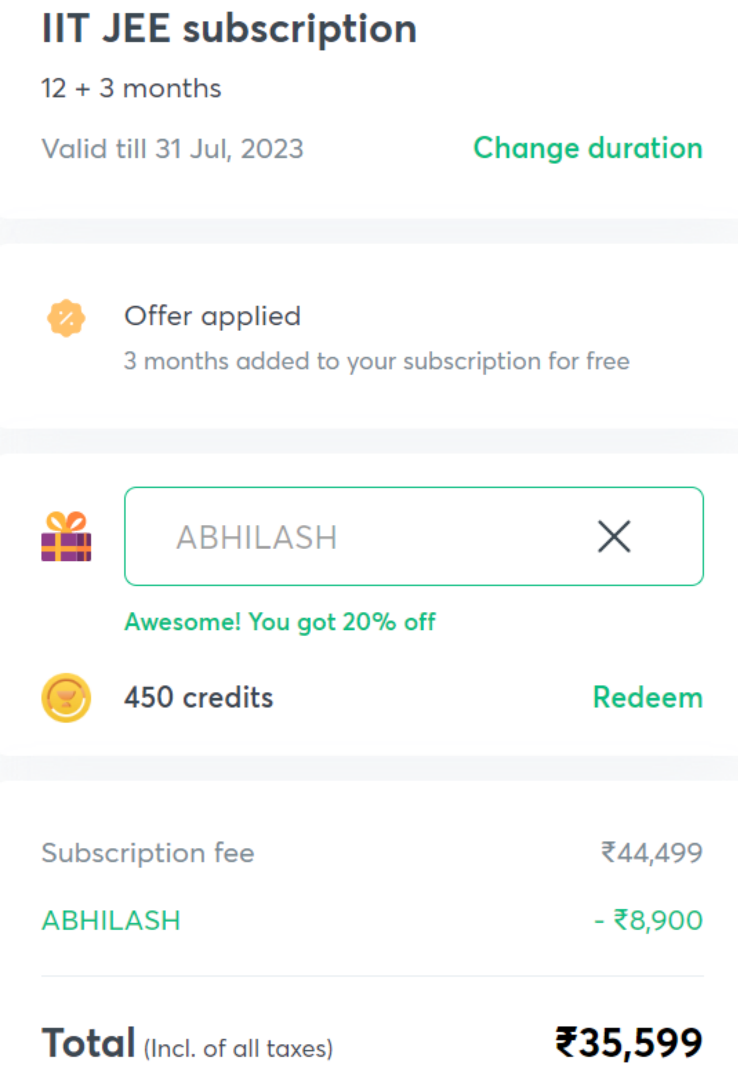

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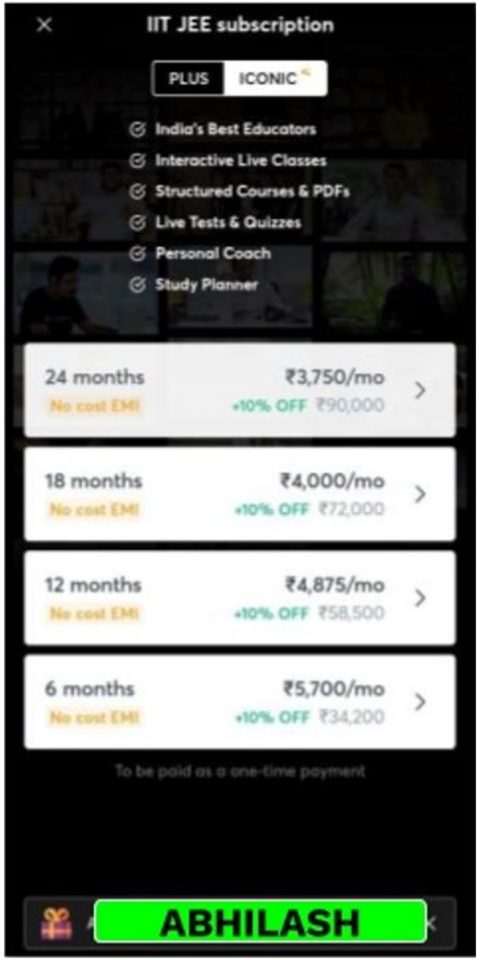

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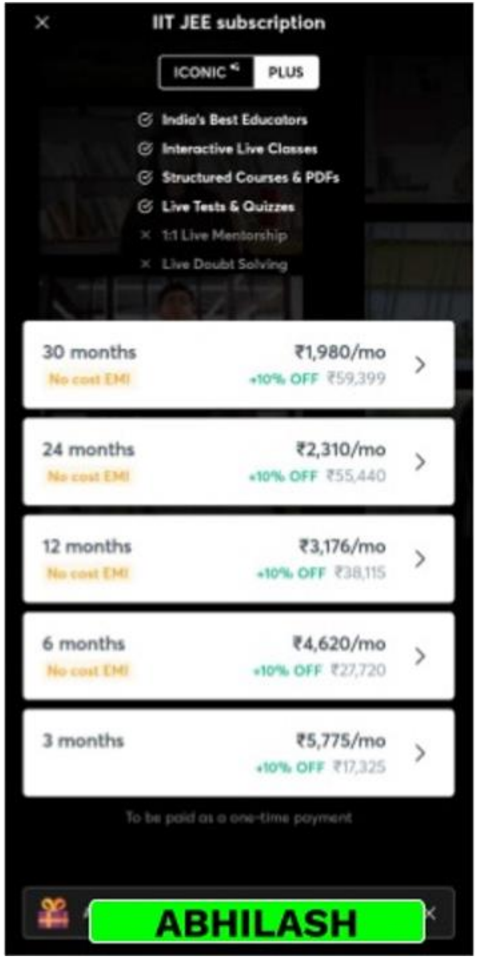

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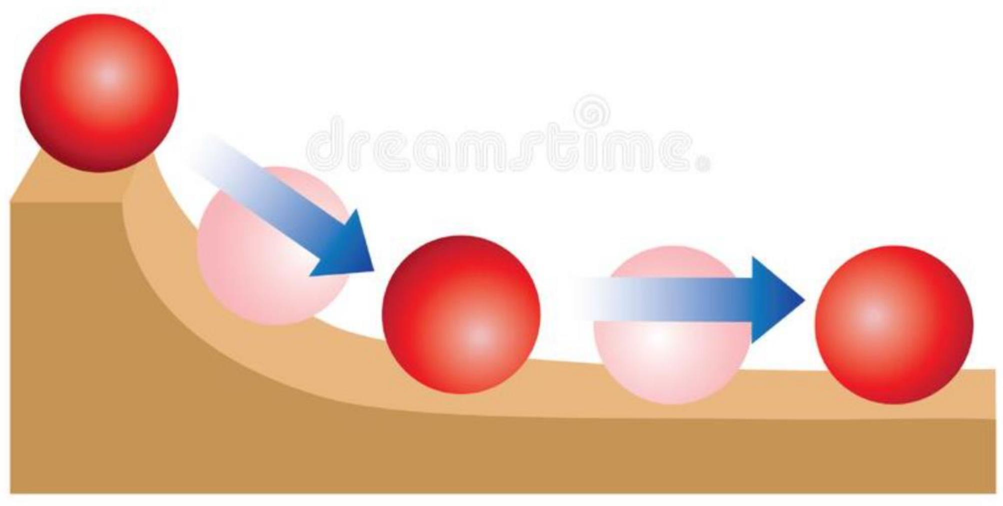
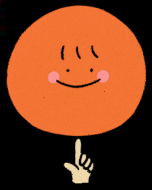
Basic to Advanced Level



Newton's Laws of Motion

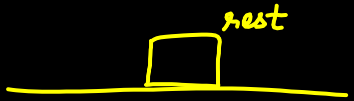


Newton's Laws of Motion

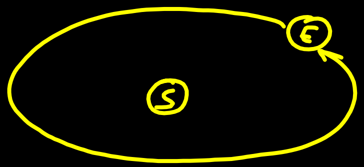
Law 1 : Explains Inertia

⇒ A Net Force can only change the state of the object

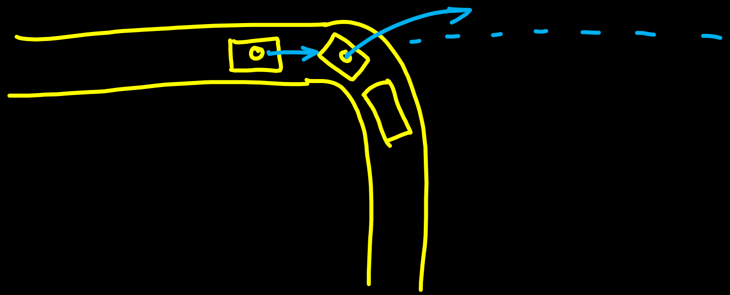
1) Rest



2) Motion



3) Direction



Newton's Laws of Motion

Law 2 : F= dp/dt

$$F_{net} = \frac{dP}{dt} = \frac{d(m\vec{v})}{dt}$$

$$F_{net} = m\frac{dv}{dt} + v\frac{dm}{dt}$$

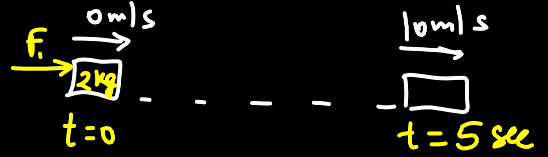
$$\boxed{F_{net} = ma + v\left(\frac{dm}{dt}\right)}$$

In general

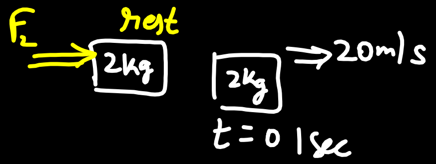
m = const $\quad \frac{dm}{dt} = 0$

$$\boxed{F_{net} = ma}$$

momentum = $\vec{p} = m\vec{v}$



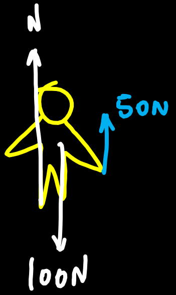
$$(F_1)_{avg} = \frac{\Delta P}{\Delta t} = \frac{2\times10 - 2\times0}{5} = 4N$$

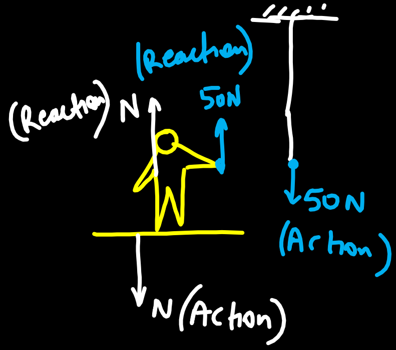


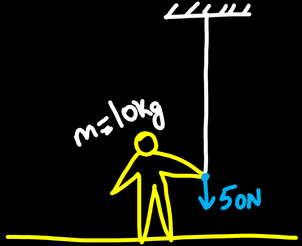
$$F_2 = \frac{\Delta P}{\Delta t} = \frac{2\times20 - 0}{0.1} = 400N$$

Newton's Laws of Motion

Law 3 : Law of Karma

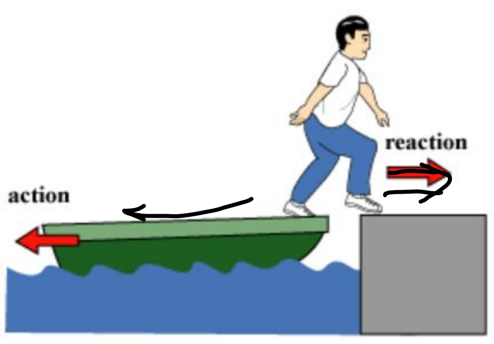






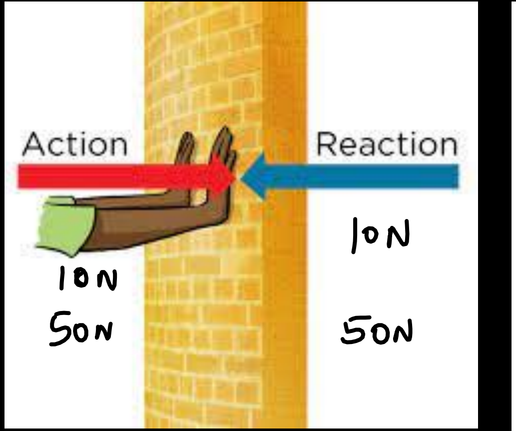
$$N + 50 = 100$$

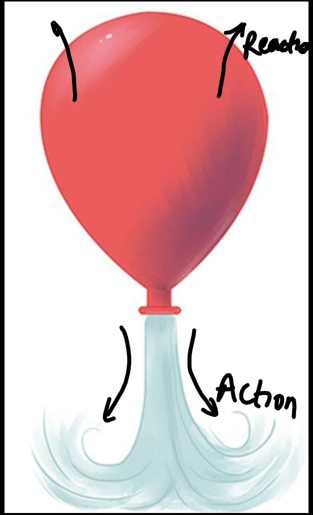
$$\boxed{N = 50N}$$



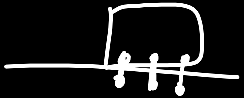
Newton’s Laws of Motion

Law 3 : Law of Karma





Fundamental Forces in Nature

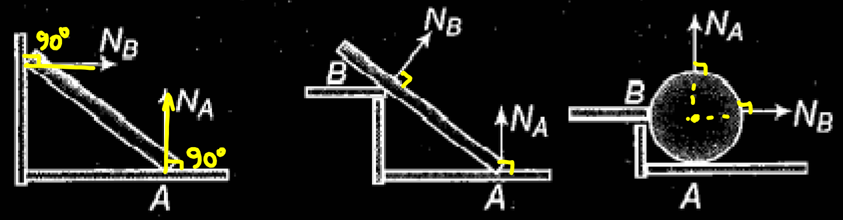


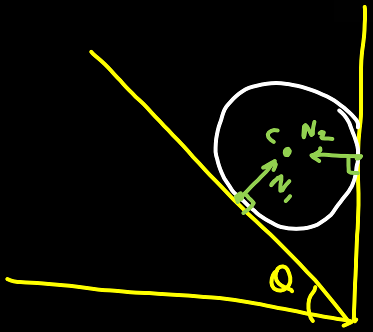
1. Strong Nuclear Force (Strongest)
2. Electromagnetic Force
3. Weak Nuclear Force
4. Gravitational Force (Weakest)

Different Categories of Forces

1) Normal Reaction

Perpendicular to the contact surfaces.

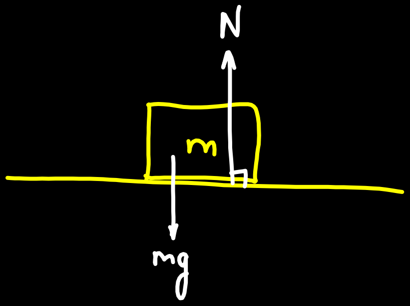


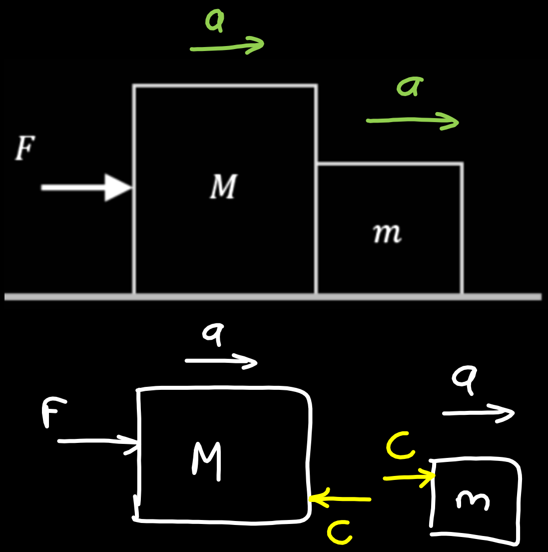


Different Types of Forces

2) Contact Force

(It can act at any angle to the surface)

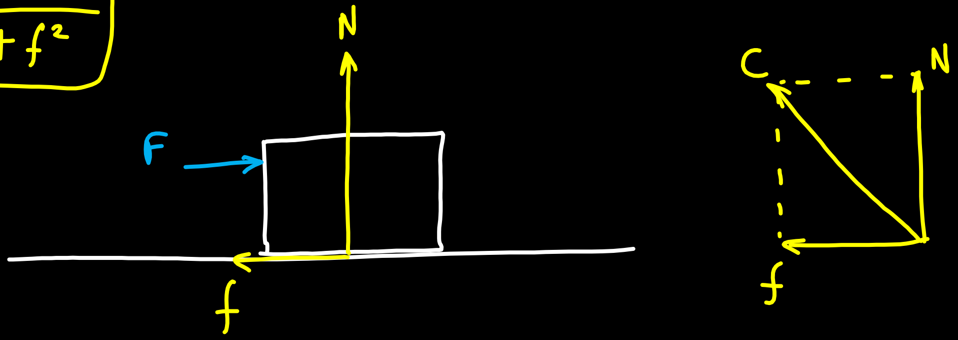




NOTE

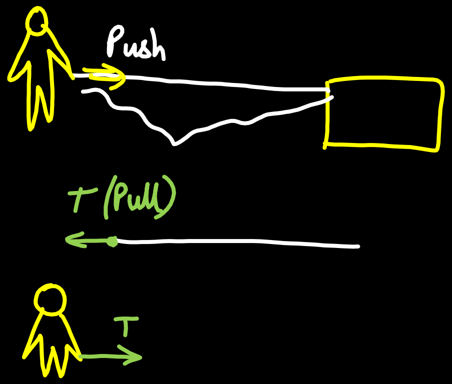
All normal reactions are contact forces but not all contact forces are normal reaction.

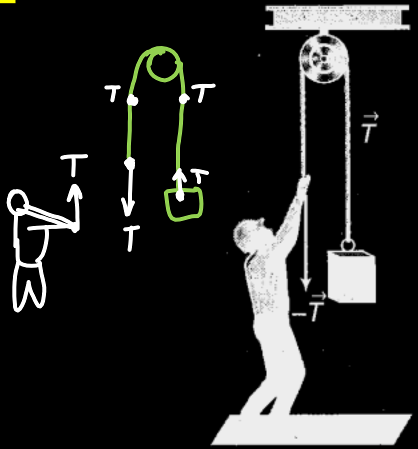
$$\boxed{C = \sqrt{N^2 + f^2}}$$



Different Types of Forces

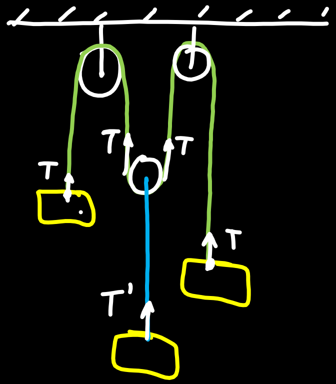
3) Tension Force





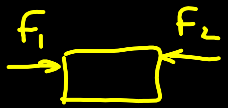
- Tension is always a pulling force
- For a massless rope, tension is same at every point
- In a system with multiple ropes, tension in each string would be different.

Different Types of Forces



Translational Equilibrium

The condition when the net force acting on the object is zero.

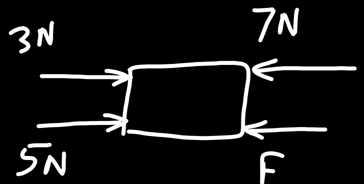


$F_{net} = 0$

$F_1 - F_2 = 0$

$\boxed{F_1 = F_2}$

$\cancel{F_1 = -F_2}$

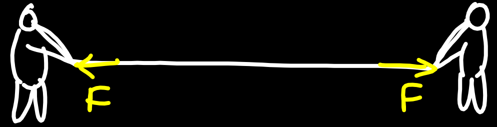


$\Rightarrow$ 8N

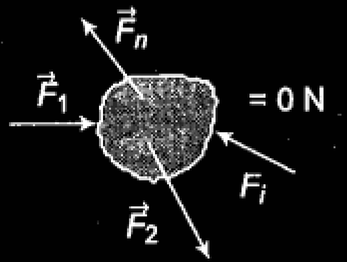
$\Leftarrow$ 7+F

$8 = 7 + F$

$\boxed{F = 1N}$



$$\sum \vec{F}_i = \vec{0}$$

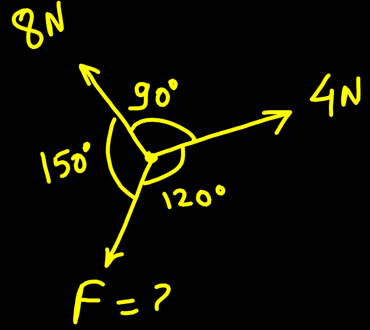


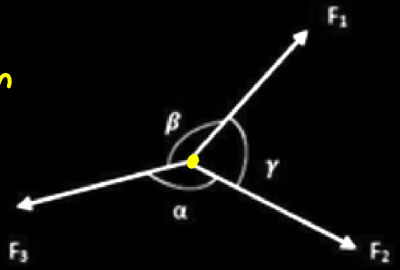
$$\sum F_{ix} = 0 \qquad \sum F_{iy} = 0 \qquad \sum F_{iz} = 0$$

Translational Equilibrium

(optional)

Object is in equilibrium



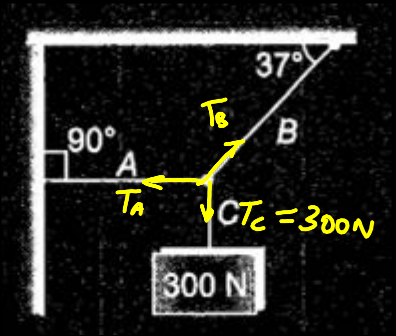


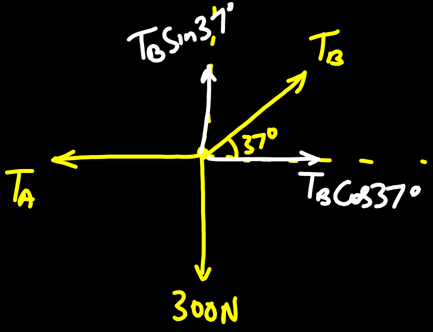
$$\frac{F_1}{\sin\alpha}=\frac{F_2}{\sin\beta}=\frac{F_3}{\sin\gamma}$$

$$\frac{4}{\sin 150^\circ}=\frac{8}{\sin 120^\circ}=\frac{F}{\sin 90^\circ}$$

A block of mass 30 kg is suspended by three strings A,B & C as shown in the figure. The tension in string A is

(a) 300 N
(b) 400 N ✓
(c) 500 N
(d) 150 N





$$T_B \sin 37° = 300$$

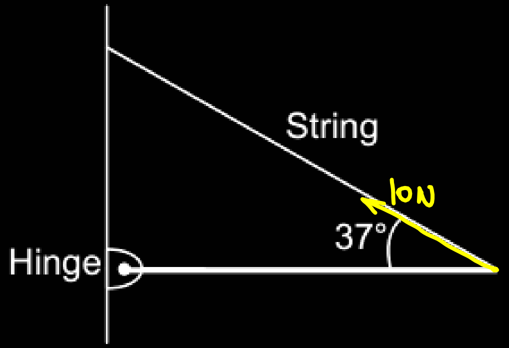
$$T_B \cos 37° = T_A$$

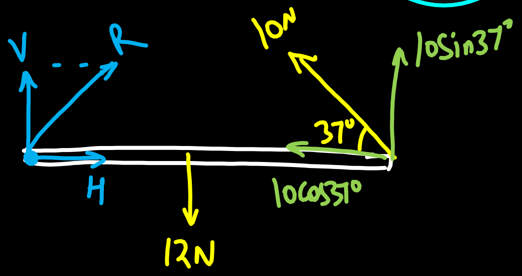
$$\tan 37° = \frac{300}{T_A}$$

$$T_A = \frac{300}{(3/4)} = 400N$$

The rod shown in figure has a mass of 1.2 kg. In equilibrium, find the hinge force acting on the rod if the tension in the string is 10 N

A. 6 N
B. 8 N
C. 10 N ✓
D. 12 N





$H = 10\cos 37° = 10 \times \frac{4}{5} = 8N$

$\boxed{H = 8N}$

$V + 10\sin 37° = 12$

$V + 10 \times \frac{3}{5} = 12$

$\boxed{V = 6N}$

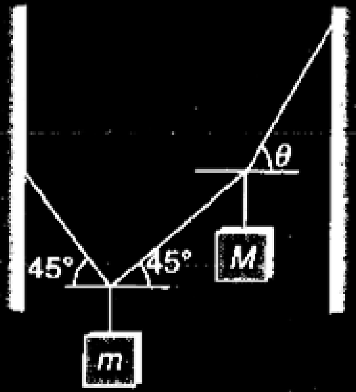
$R = \sqrt{H^2 + V^2}$

$= \sqrt{8^2 + 6^2}$

$\boxed{R = 10N}$

HW

Two masses m and M are attached to the strings as shown in the figure. If the system is in equilibrium, then

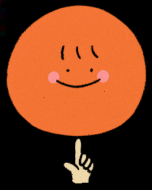


(a) $\tan\theta = 1 + \frac{2M}{m}$

(b) $\tan\theta = 1 + \frac{2m}{M}$

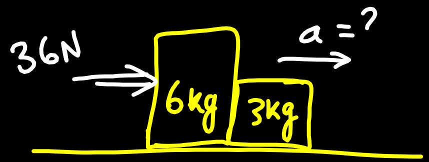
(c) $\cot\theta = 1 + \frac{2M}{m}$

(d) $\cot\theta = 1 + \frac{2m}{M}$



Accelerated System

$\boxed{F_{net} \neq 0}$

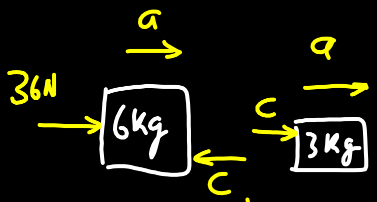


Three Step Method for Problem Solving

1. Choose the right system
2. Draw the FBD
3. Fnet = ma

system → Collection of objects having same acceleration.

Method 1



$36 - c = 6a$

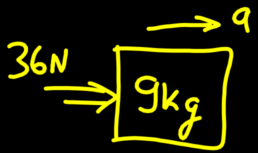
$F = ma$

$c = 3a$

$36 = 9a$

$\boxed{a = 4 m/s^2}$

Method 2



$9a = 36$

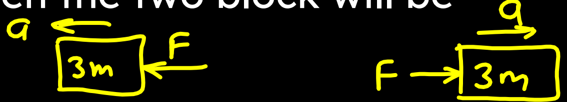
$\boxed{a = 4 m/s^2}$

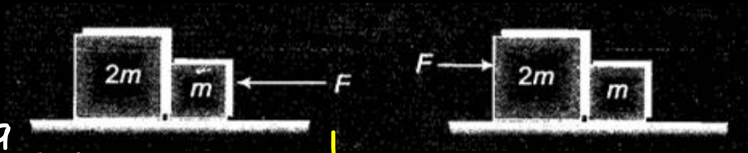
Q

Two blocks are in contact on a frictionless table. One has mass m and the other 2m. A force F is applied on m as shown in the figure. Now the same force F is applied from the right on 2m, In the two cases respectively, the ratio force of contact between the two block will be

$\frac{C_1}{C_2} = ?$

A. Same
B. 1 : 2
[✓ C. 2 : 1]
D. 1 : 3

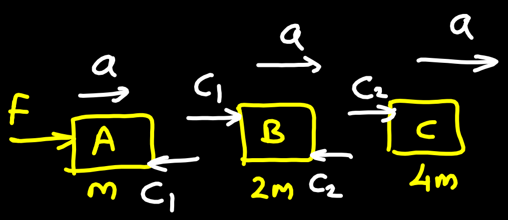




$C_1 = (2m)a$

$C_2 = (m)a$

$$\frac{C_1}{C_2} = \frac{(2m)a}{(m)a}$$



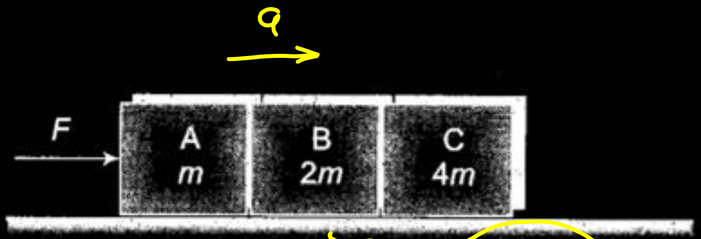
A force F is applied on block A as shown in the figure. The contact force between the blocks A and B and between the blocks B and C respectively are (Assume frictionless surface)

(a) $\frac{F}{7}, \frac{2F}{7}$

[✓ (b)] $\frac{6F}{7}, \frac{4F}{7}$

(c) $F, \frac{F}{2}$

(d) $\frac{4F}{7}, \frac{6F}{7}$



$a = \frac{F}{7m}$

$C_1 - C_2 = (2m)a$

$C_1 = C_2 + 2ma$

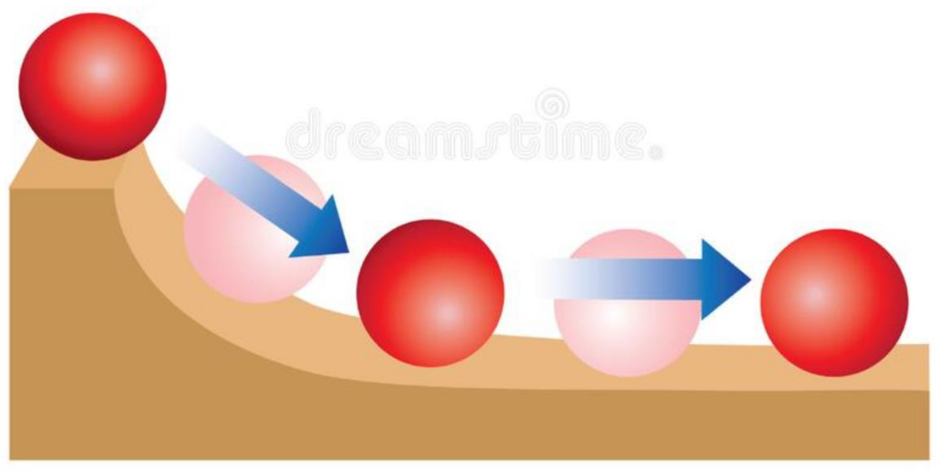
$C_1 = \frac{4F}{7} + 2\cancel{m}\left(\frac{F}{7\cancel{m}}\right)$

$\boxed{C_1 = \frac{6F}{7}}$

$C_2 = (4m)a$

$= (4m)\left(\frac{F}{7m}\right)$

$\boxed{C_2 = \frac{4F}{7}}$



Problems based on Inclined Plane

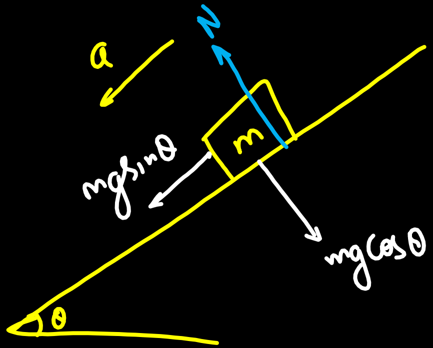
Problems based on Inclined Plane

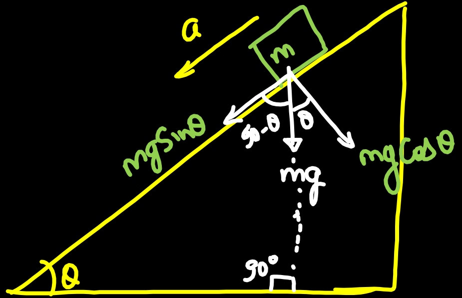
$$F = ma$$

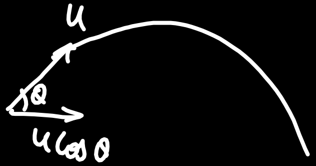
$$\cancel{m}g\sin\theta = \cancel{m}a$$

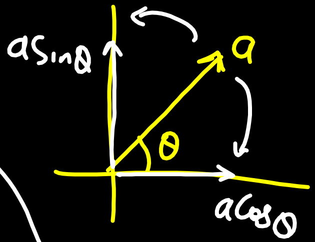
$$\boxed{a = g\sin\theta}$$

$$N = mg\cos\theta$$

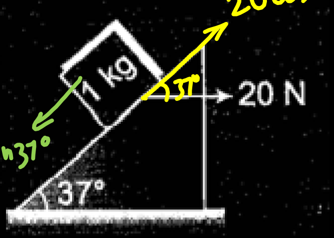








A horizontal force F of 20N is applied on the smooth block of mass 1 kg. The acceleration of block is…



$20\cos37° = 20 \times \frac{4}{5} = 16N$

$10 \times \frac{3}{5} = mg\sin37°$

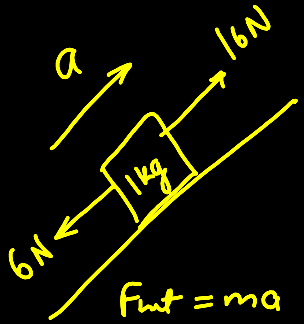
$6N$

(a) 10 m/s2 ✓

(b) 20 m/s2

(c) 14 m/s2

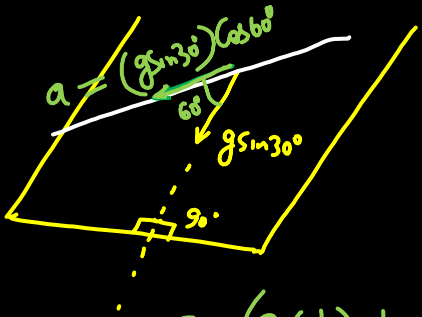
(d) 6 m/s²



$F_{net} = ma$

$16 - 6 = (1)a$

$\boxed{a = 10 m/s^2}$

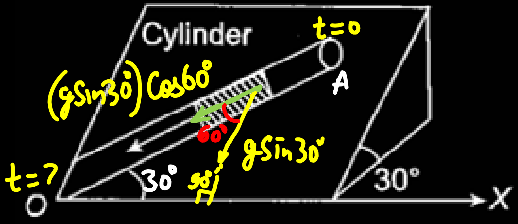


$$a = \left(g \times \frac{1}{2}\right)\frac{1}{2}$$

$$\boxed{a = g/4}$$

An inclined plane makes an angle 30° with the horizontal. A groove (OA) of length = 5 m cut in the plane makes an angle 30° with OX. A short smooth cylinder is free to the slide down the influence of gravity. The time taken by the cylinder to reach from A to O is ($g = 10\ m/s^2$)

A. 4 s
B. 3 s
[✓ C. 2 s]
D. 1 s



$u = 0$, $a = \frac{10}{4}\frac{m}{s^2}$, $S = 5m$, $t = ?$

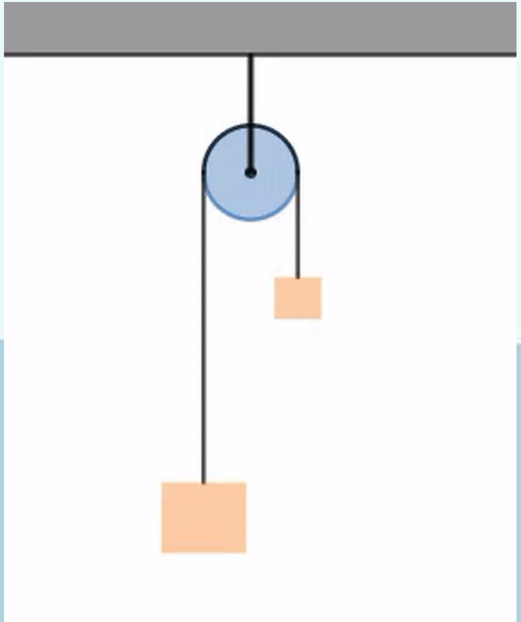
$$S = ut + \frac{1}{2}at^2$$

$$5 = 0 + \frac{1}{2} \times \left(\frac{10}{4}\right) t^2$$

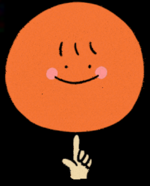
$$5 = \frac{5}{4} t^2$$

$$t = \sqrt{4}$$

$$\boxed{t = 2 \text{ sec}}$$



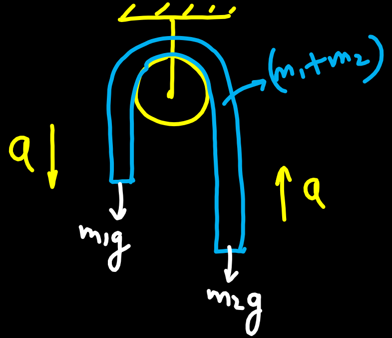
Pulley Based Problems



Pulley Based Questions

Method 2

(रस्सी method)



$F_{net} = m_1g - m_2g$

$a = \frac{F_{net}}{M} = \frac{m_1g - m_2g}{m_1 + m_2}$

Method 1 :

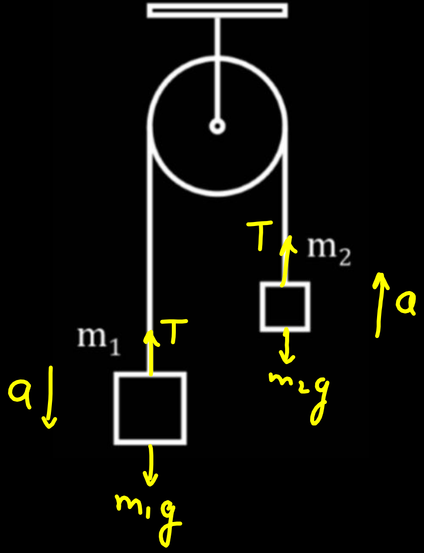
$m_1g - T = m_1a$

$T - m_2g = m_2a$

$m_1g - m_2g = (m_1 + m_2)a$

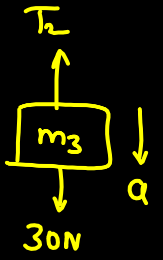
$$\boxed{a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)g}$$

(Atwood machine)



If m1, m2 & m3 are 1kg, 2kg & 3kg respectively, find the tension T2

[✓ (a) 10 N] (b) 20 N (c) 30 N (d) 50 N



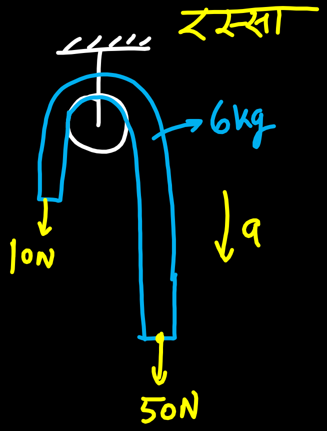
$$30 - T_2 = m_3 a$$

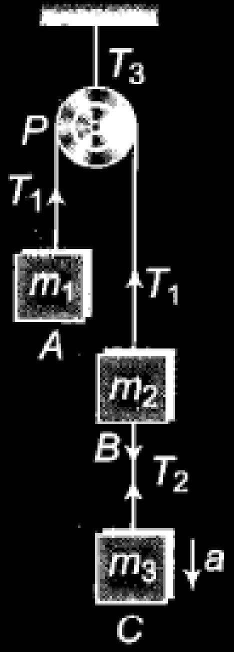
$$30 - T_2 = 3 \times \frac{20}{3}$$

$$\boxed{T_2 = 10N}$$

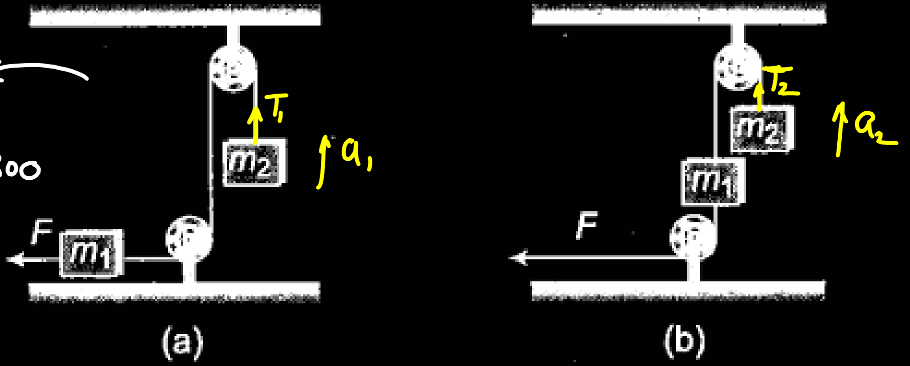
$$a = \frac{50-10}{6}$$

$$\boxed{a = \frac{20}{3}\ m/s^2}$$





The ratio of tensions in the string connected to the block of mass m_2 in figure-(a) and figure-(b) respectively is (friction is absent everywhere): [$m_1 = 50$ kg, $m_2 = 80$ kg and $F = 1000$ N].

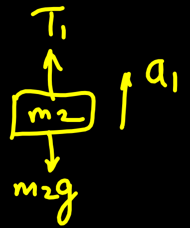


(a) 7 : 2

(b) 2 : 7

[✓ (c) 3 : 4]

(d) 4 : 3

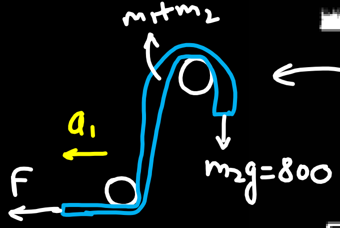


$$T_1 - m_2 g = m_2 a_1$$

$$T_1 - 800 = 80\left(\frac{20\cancel{0}}{13\cancel{0}}\right)$$

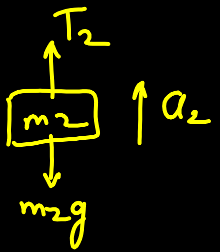
$$T_1 = 800\left[1 + \frac{2}{13}\right]$$

$$\boxed{T_1 = \frac{800 \times 15}{13} N}$$



$$a_1 = \frac{1000-800}{130}$$

$$\boxed{a_1 = \frac{200}{130} \frac{m}{s^2}}$$

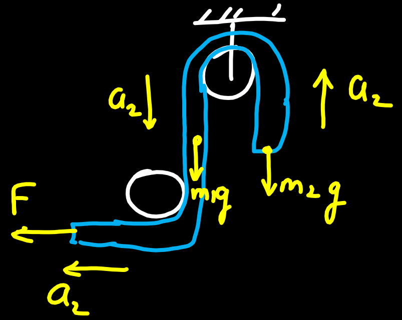


$$T_2 - m_2 g = m_2 a_2$$

$$T_2 - 800 = 80\left(\frac{70}{13}\right)$$

$$T_2 = 800\left(1+\frac{7}{13}\right)$$

$$\boxed{T_2 = \frac{800\times 20}{13}\ N}$$



$$a_2 = \frac{F + m_1 g - m_2 g}{m_1 + m_2}$$

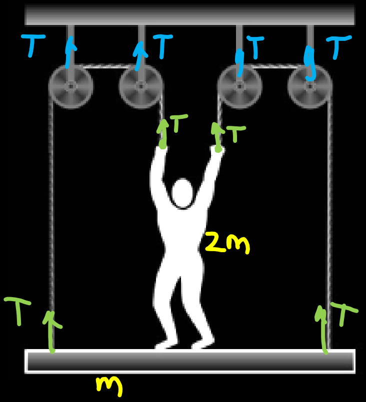
$$a_2 = \frac{1000 + 500 - 800}{130}$$

$$\boxed{a_2 = \frac{700}{130}\ m/s^2}$$

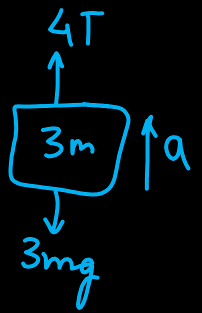
$$\frac{T_1}{T_2} = \frac{15}{20} = \frac{3}{4}$$

A man of mass 2m stands on a platform of mass m and pulls himself by two ropes passing over pulleys as shown in figure. If he pulls each rope with a force equal to his weight, his upward acceleration would be

A. g
B. g/3
[✓ C.] 5g/3
D. zero ✗

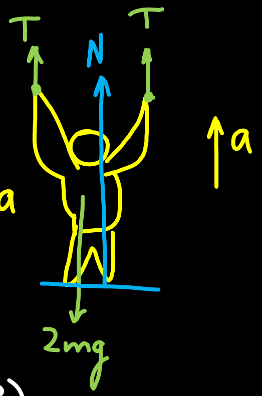


$4T - 3mg = (3m)a$



$$2T + N - 2mg = (2m)a \rightarrow (1)$$

$$\text{(Given)} \quad T = 2mg \rightarrow (2)$$



$$2(2mg) + N - 2mg = 2ma$$

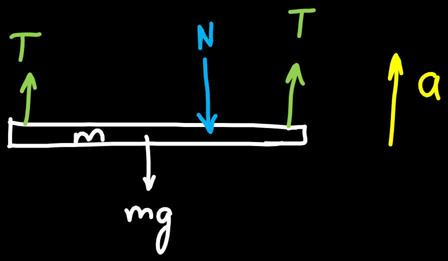
$$2mg + N = 2ma \rightarrow (3)$$

$$N = 2m\left(\frac{5g}{3}\right) - 2mg = \frac{4mg}{3}$$

$$2T - N - mg = ma$$

$$2(2mg) - N - mg = ma$$

$$\boxed{3mg - N = ma} \longrightarrow (4)$$



(3) + (4)

$$(2mg + N) + (3mg - N) = 2ma + ma$$

$$5mg = 3ma$$

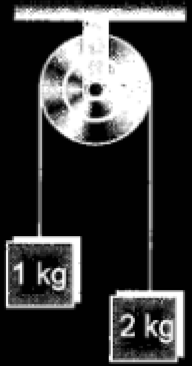
$$\boxed{a = \frac{5g}{3}}$$

$\boxed{\text{HW}}$ (Good Question)

t me/abhilashsharaiitjee

Two unequal masses are connected on two sides of a light string passing over a light and smooth pulley as shown in the figure. The system is released from rest. The larger mass in stopped 1 second after the system is set into motion, and then released immediately. The time elapsed before the string is tight again is (Take g = 10 m/s^2)

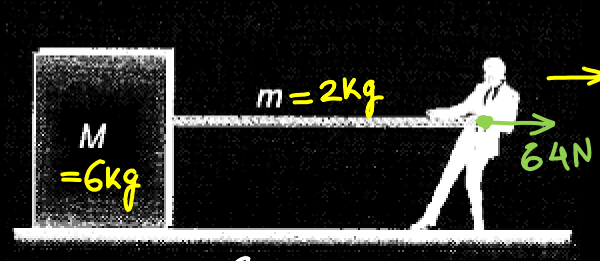
A. 1/4 s
B. 1/2 s
C. 2/3 s
D. 1/3 s

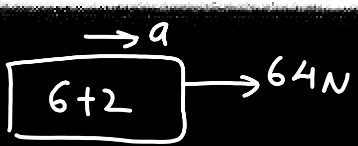


Rope with Mass

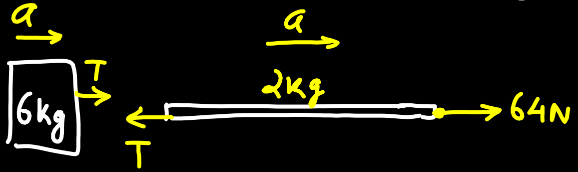
→ Treat the rope like a block

→ Tension will not be same everywhere





$$a = \frac{64}{8} = 8\,m/s^2$$

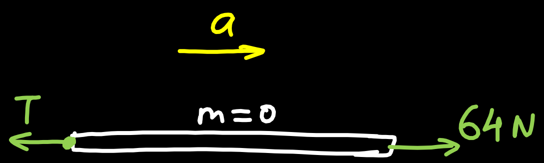


$$T = 6a$$

$$\boxed{T = 48N}$$

Rope with Mass

Massless



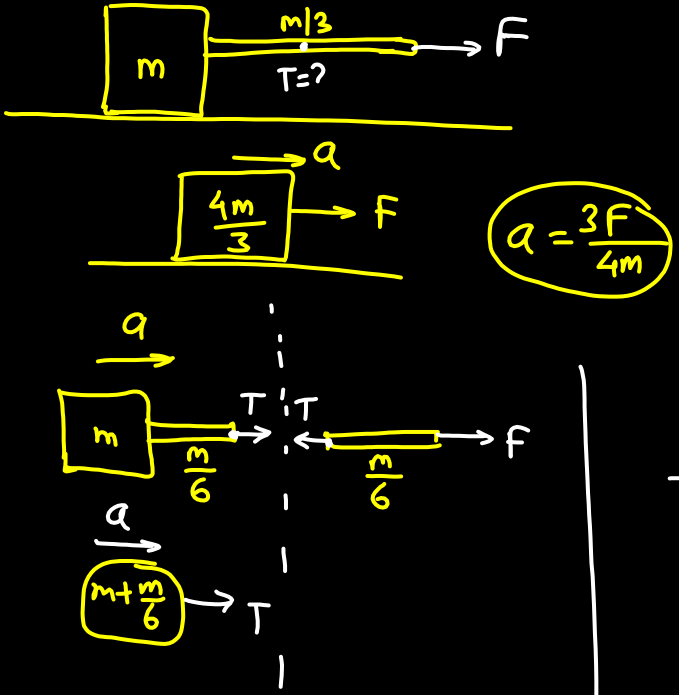
$$F_{net} = ma$$

$$64 - T = (0)a$$

$$T = 64$$

A block of mass m is resting on a smooth horizontal surface. One end of a uniform rope of mass m/3 is fixed to the block, which is pulled in the horizontal direction by applying force F at the other end. The tension in the middle of the rope is

- A. 8/6 F
- B. 1/8 F
- C. 1/5 F
- [✓ D.] 7/8 F



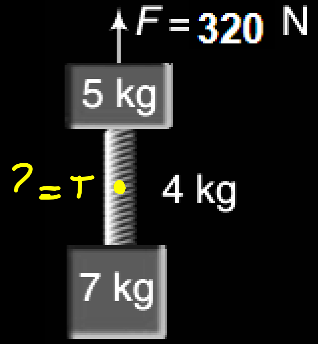
$$\boxed{a=\frac{3F}{4m}}$$

$$T=\left(m+\frac{m}{6}\right)a$$

$$=\frac{7m}{6}\times\frac{3F}{4m}$$

$$\boxed{T=\frac{7}{8}F}$$

Two blocks shown in figure are connected by a heavy uniform rope of mass 4 kg. An upward force of 320 N is applied as shown. What is the tension at the midpoint of the rope ?



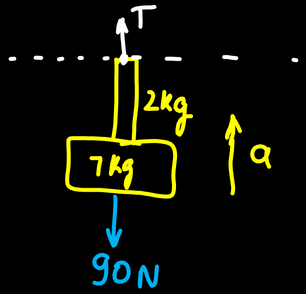
(a) 99 N

(b) 180 N ✓

(c) 240 N

(d) 300 N

$$a = \frac{320-160}{16} = 10 m/s^2$$

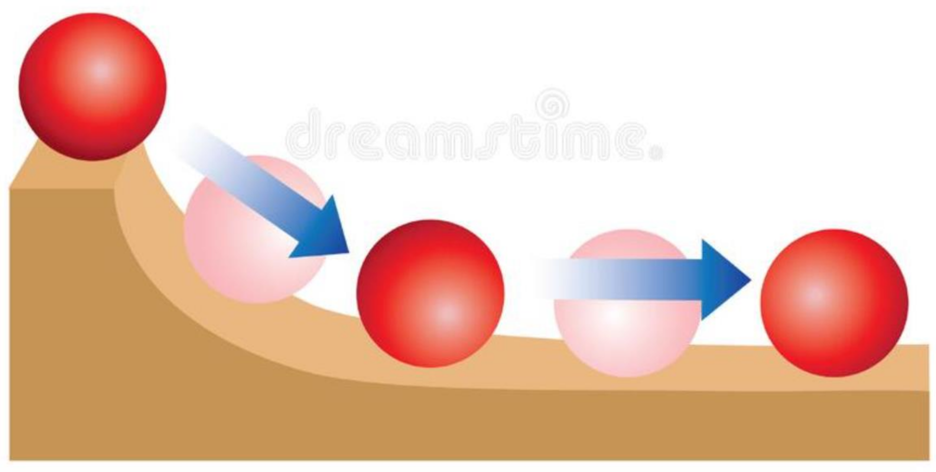


$$T - 90 = 9a$$

$$T = 90 + 9a$$

$$T = 90 + 90$$

$$\boxed{T = 180N}$$



Pseudo Force

Pseudo Force

Frames of Reference

Inertial $(a=0)$

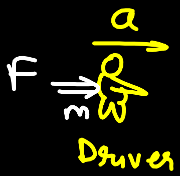
$v=0$, $v=\text{Const}$

(Real Force)

Non Inertial $(a\neq0)$

(Pseudo Force (F_s))

Your Frame (Ground)



$F=ma$

Driver's Frame (car)

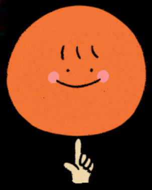
$F_s = Ma$

Pseudo Force

→ Direction ⇒ Always opposite to the observer's acceleration

Magnitude ⇒ $\boxed{F_s = \left(\text{Mass of the object}\right) \times \left(\text{Acceleration of the observer}\right)}$

$F_s = (4)(2) = 8\,N$

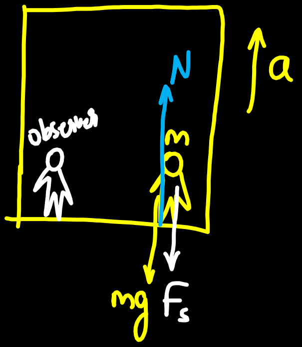


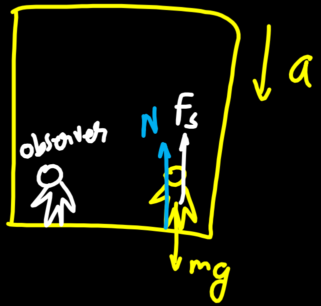
Elevator Case

Equilibrium

$N = F_s + mg$

$$\boxed{N = ma + mg}$$





$N + F_s = mg$

$N = mg - F_s$

$$\boxed{N = mg - ma}$$

Elevator Case

The elevator shown in figure is descending with an acceleration of 2 ms^{-s}. The mass of the block A = 0.5 kg. The force exerted by the block A on the block B is (Take g = 10 m/s^2)

A. 2N

[✓ B. 4N]

C. 6N

D. 8N

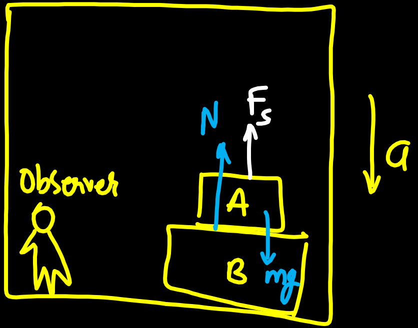
$N + F_s = mg$

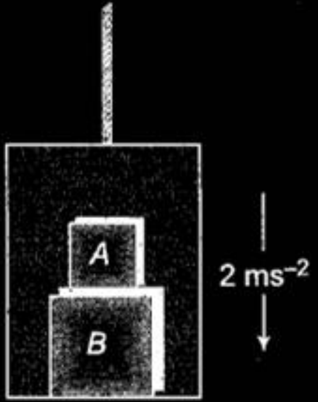
$N + ma = mg$

$N + (0.5)(2) = 0.5 \times 10$

$N = 5 - 1$

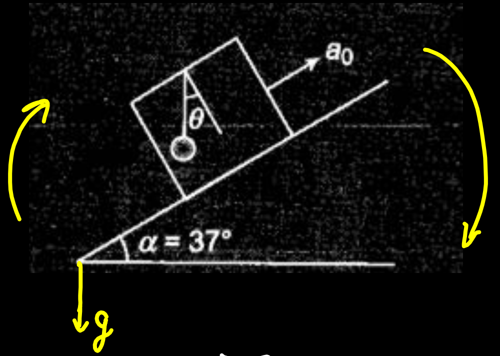
$\boxed{N = 4N}$

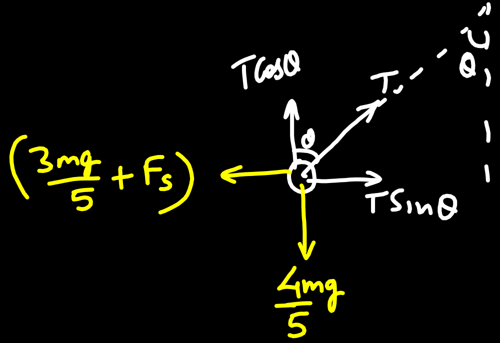




A pendulum hangs from the roof of a cart moving with an acceleration $a_0 = 6\ m/s^2$. The bob is stationary with respect to the cart. Find the value of θ

(a) tan-1(3/4)
(b)tan-1(4/3)
[✓ (c) tan-1(3/2)]
(d) tan-1(2/3)

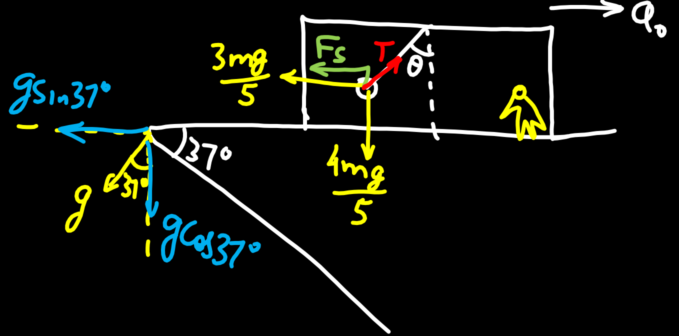




$F_s = ma_0$

$$T\sin\theta = \frac{3mg}{5} + F_s$$

$$T\cos\theta = \frac{4mg}{5}$$



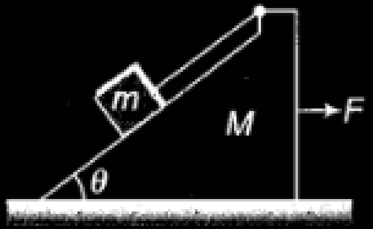
$$\tan\theta = \frac{\frac{3}{5}mg + ma_0}{\frac{4}{5}mg} = \frac{\frac{3}{5}\times 10 + 6}{\frac{4}{5}\times 10} = \frac{12}{8}$$

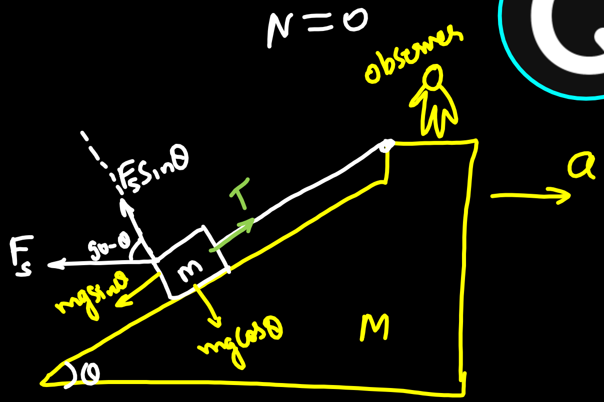
$$\boxed{\tan\theta = \frac{3}{2}}$$

Passage Based Question

(Advanced)

A light inextensible string connects a block of mass m and top of wedge of mass M. The string is parallel to inclined surface and the inclined surface maken an angle θ with horizontal as shown. All surfaces are smooth, Now a constant horizontal force of minimum magnitude F is applied to wedge towards right such that the normal reaction on block exerted by wedge just becomes zero.





The magnitude of acceleration of wedge is

A. g tan θ
[✓ B.] g cot θ
C. g sin θ
D. g cos θ

$$F_s \sin\theta = mg\cos\theta$$

$$\cancel{m} a = \cancel{m} g\cot\theta$$

$$\boxed{a = g\cot\theta}$$

HW

The magnitude of tension in string is

A. mg sec θ
[✓ B. mg cosec θ]
C. mg tan θ
D. mg cot θ

$$T = mg\sin\theta + F_s\cos\theta$$

$$= mg\sin\theta + (ma)\cos\theta$$

$$= mg\sin\theta + mg\left(\frac{\cos\theta}{\sin\theta}\right)\cos\theta$$

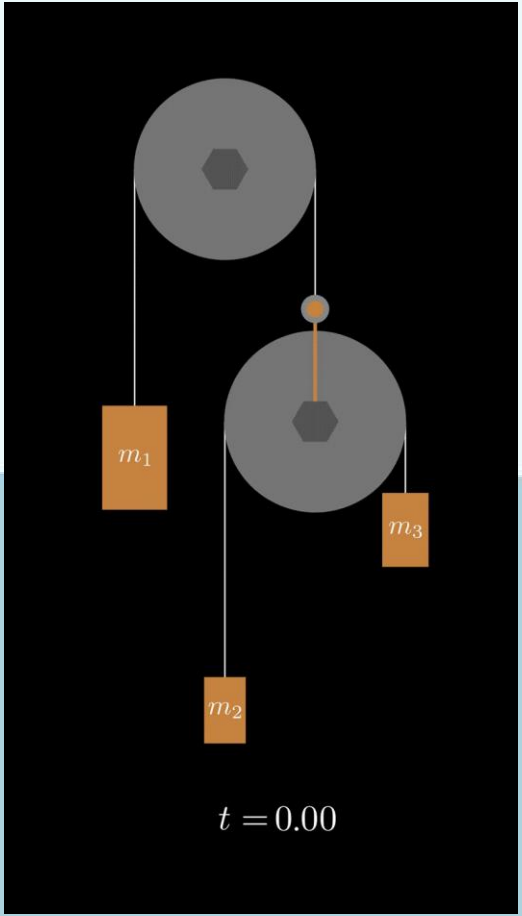
$$T = \frac{mg(\sin^2\theta + \cos^2\theta)}{\sin\theta}$$

$$\boxed{T = mg\,\mathrm{cosec}\,\theta}$$

HW

The magnitude of net horizontal force on wedge is:

A. $Mg \cot \theta$
B. $(M + m)g \sec \theta$
C. $(M + m)g \cot \theta$
D. $Mg \operatorname{cosec} \theta$



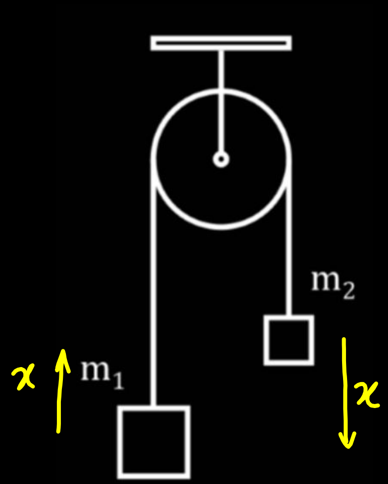
Visualization is the key

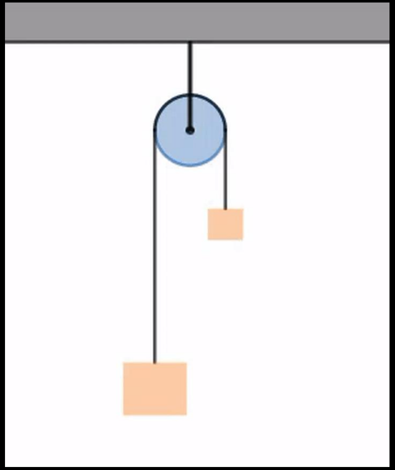
Constrained Motion

Constraint Relations

1) Rope Length Constraint

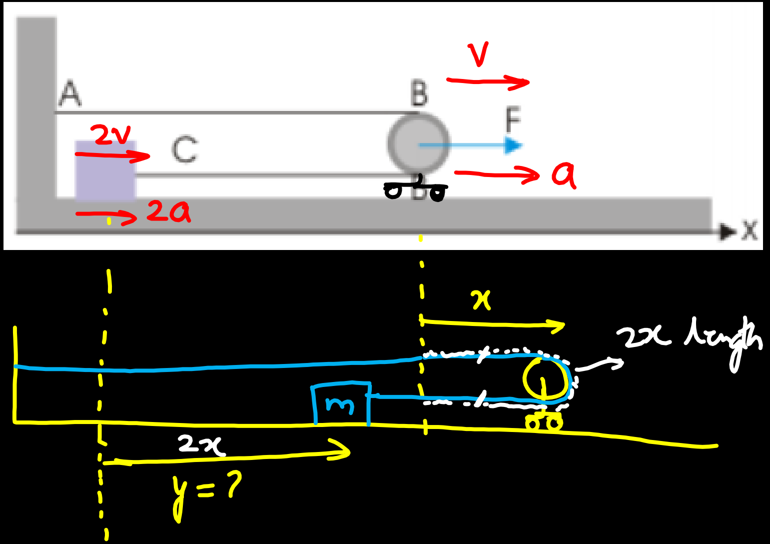
$$\boxed{l = \text{const}}$$

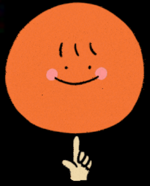




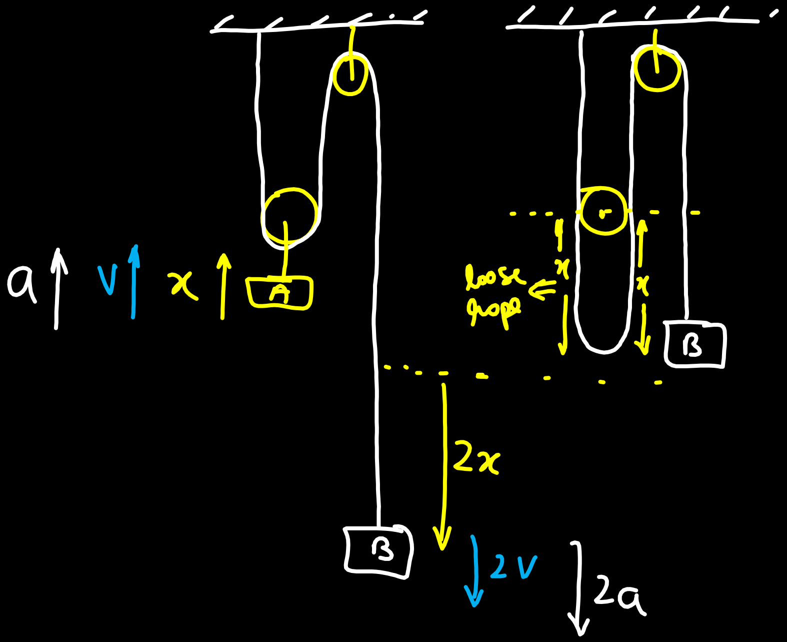
Movable Pulley

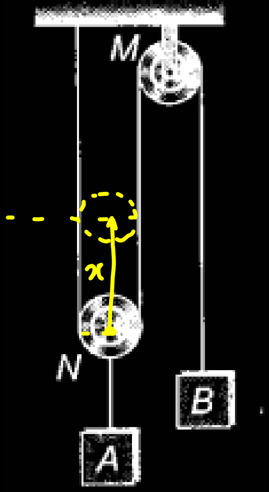
Shortcut

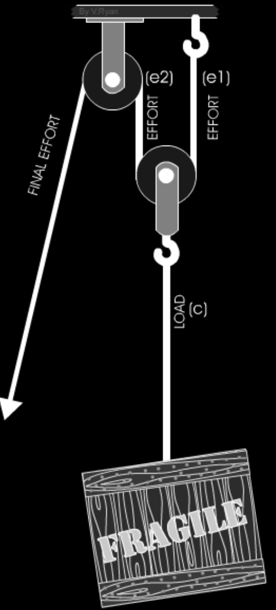




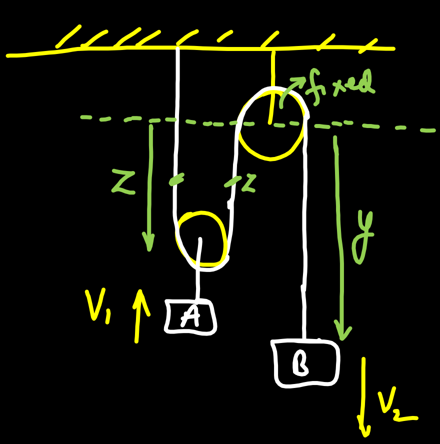
Example


a
v
x
A
B
2x
2v
2a
loose rope
x
x
B


M
x
N
A
B


By V.Ryan
(e2)
(e1)
EFFORT
EFFORT
FINAL EFFORT
LOAD (c)
FRAGILE

Example

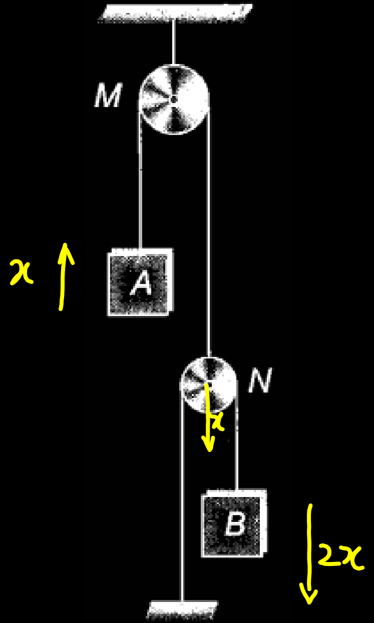


$$2z + y = l$$

$$2\frac{dz}{dt} + \frac{dy}{dt} = \frac{dl}{dt}$$

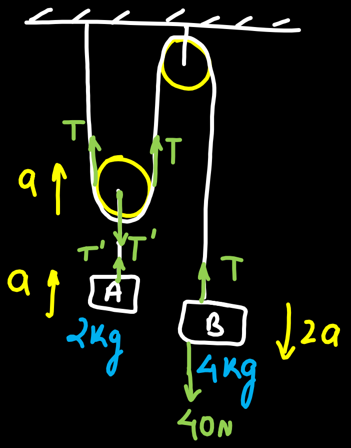
$$2(-v_1) + (v_2) = 0$$

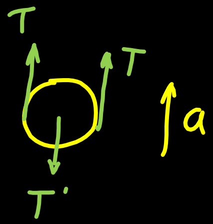
$$\boxed{v_2 = 2v_1}$$



Acceleration of Massless Pulley

Massless Pulleys $(m=0)$





$$2T - T' = ma$$

$$2T - T' = (0)a$$

$$\boxed{T' = 2T}$$

$$40 - T = 4(2a) \rightarrow (1)$$

$$T' - 20 = 2(a) \rightarrow (2)$$

Ratio of a1/a2 is

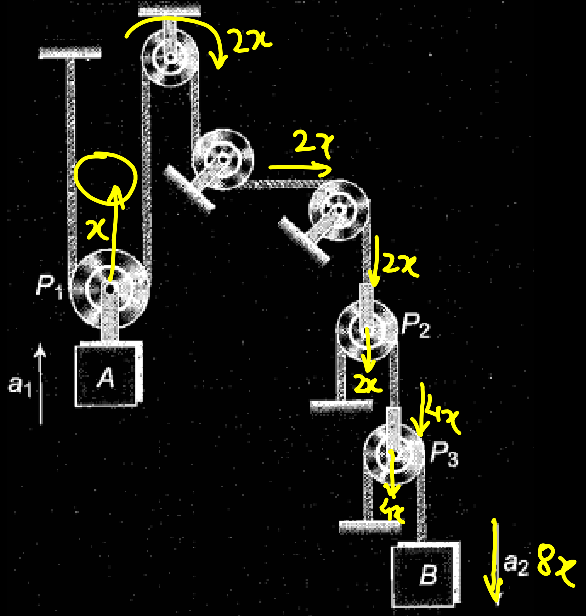
(a) 4

(b) 1/4

(c) 8

(d) 1/8

$a_2 = 8a_1$



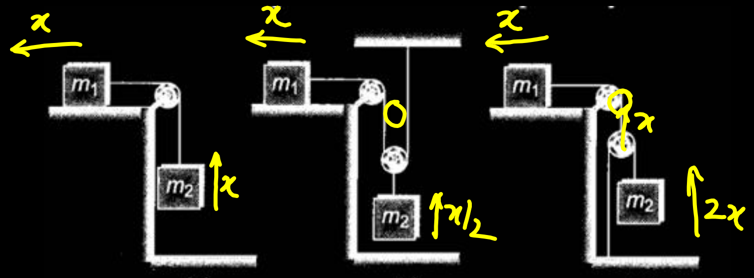
In each of the three arrangements, the block of mass m1 is being pulled left with constant velocity. There is no friction anywhere. The strings are light and inextensible and pulleys are massless. The ratio of the speed of the block of mass m_2 in the three cases respectively is

- A. 2 : 1 : 4 ✓
- B. 2 : 4 : 1
- C. 4 : 2 : 1
- D. Cannot be calculated

$x \quad \frac{x}{2} : 2x$

$1 : \frac{1}{2} : 2$

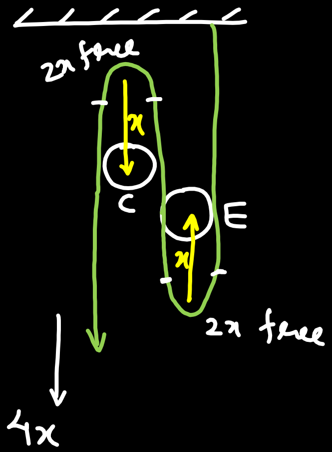
$\boxed{2 : 1 : 4}$



(a) (b) (c)

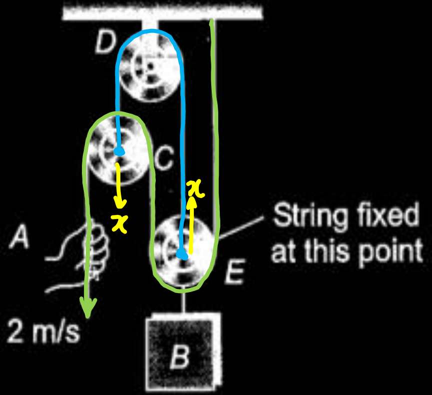
Determine the speed with which block B rises in figure if the end of the cord at A is pulled down with a speed of 2 m/s.

- A. 8 m/s
- B. 0.4 m/s
- C. 4 m/s
- [✓ D. 0.5 m/s]



$$4x = 2$$

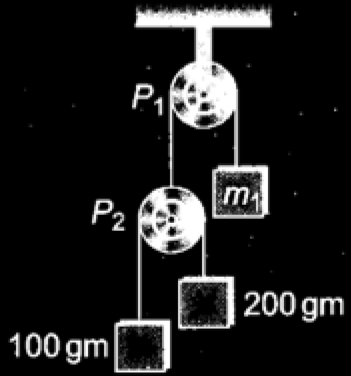
$$\boxed{x = 0.5 \text{ m/s}}$$

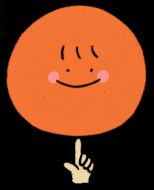


HW

In the system of pulleys shown what should be the value of m_1 (in gram) such that 100 g remains at rest. (Take g = 10 m/s^2)

(a) 300 (b) 150 (c) 160 (d) 320

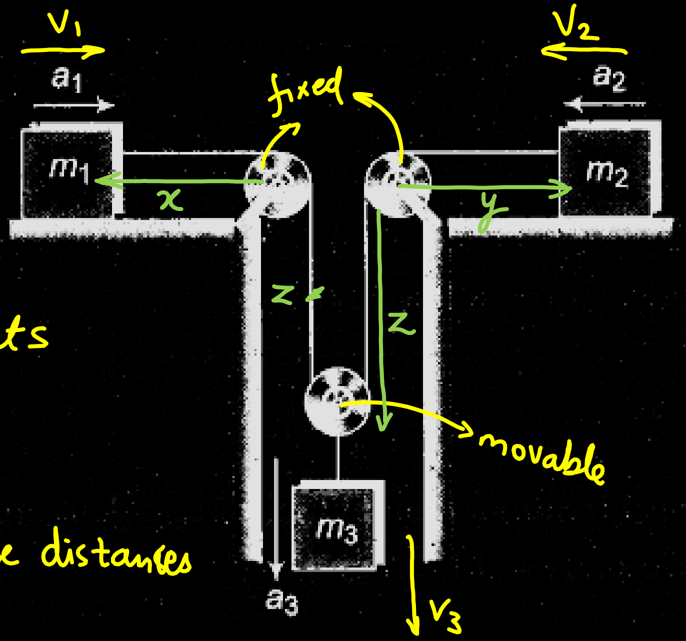




Constraint Relations

Alternate Method $(l = \text{const.})$

1) Identify all the moving objects
2) Identify all the fixed objects
3) Write the distances of all moving objects from fixed ones
4) Write rope length in terms of these distances
5) Differentiate



$$l = x + y + 2z$$

$$\frac{dl}{dt} = \frac{dx}{dt} + \frac{dy}{dt} + 2\frac{dz}{dt}$$

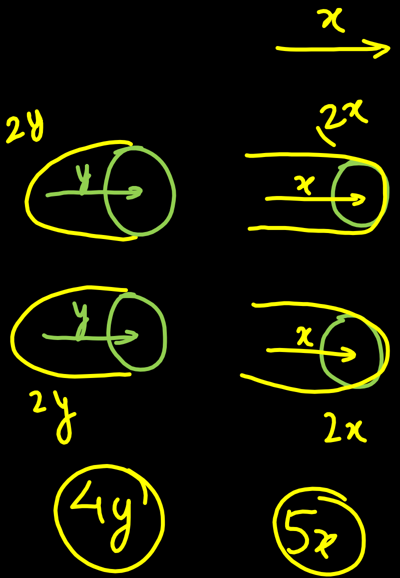
$$0 = (-V_1) + (-V_2) + 2(+V_3)$$

$$V_1 + V_2 = 2V_3$$

Diff $\Rightarrow \boxed{a_1 + a_2 = 2a_3}$

Ratio of a1/a2 is

[✓ (a) 4/5] (b) 5/4 (c) 3/5 (d) 5/3



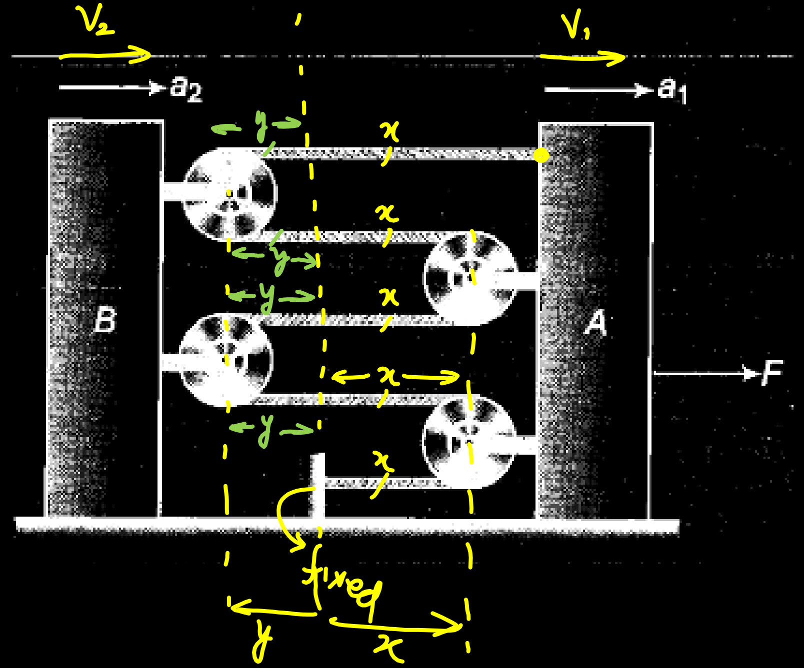
$$5x + 4y = l$$

$$5\frac{dx}{dt} + 4\frac{dy}{dt} = \frac{dl}{dt}$$

$$5(+v_1) + 4(-v_2) = 0$$

$$5v_1 = 4v_2$$

$$\boxed{5a_1 = 4a_2}$$



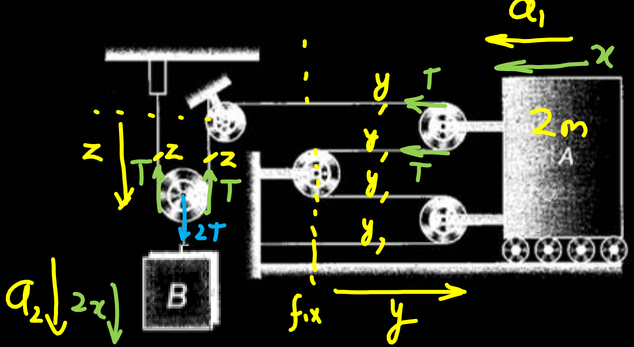
Blocks A and B of mass 2m & m respectively , are connected with light inextensible strings as shown in figure. If the system is released, the acceleration of block b will be

A. g/3

[✓ B.] 2g/3

C. g/6

D. None of these



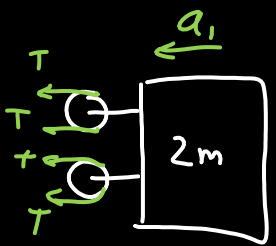
$4y + 2z + \text{Const} = l$

$4\frac{dy}{dt} + 2\frac{dz}{dt} = 0$

$4(-v_1) + 2(v_2) = 0$

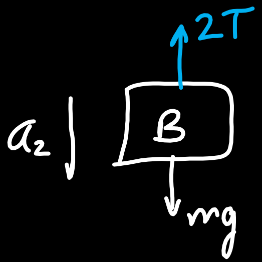
$v_2 = 2v_1$

$\boxed{a_2 = 2a_1} \rightarrow (1)$



$4T = (2m)a_1$

$\boxed{2T = ma_1} \rightarrow (2)$



$$mg - 2T = m a_2$$

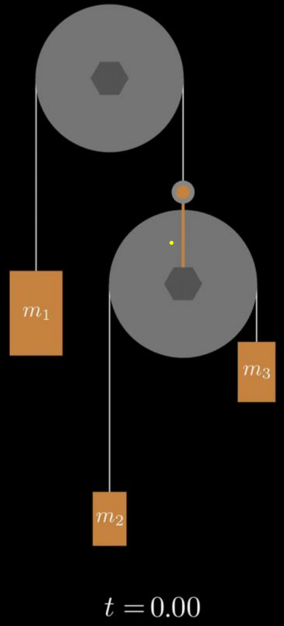
$$mg - m a_1 = m a_2$$

$$g - \frac{a_2}{2} = a_2$$

$$g = \frac{3}{2} a_2$$

$$\boxed{a_2 = \frac{2g}{3}}$$

Special Case

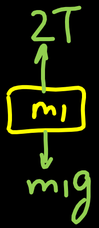


Special Case

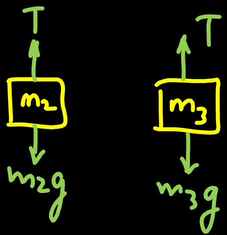
$$\boxed{2a_1 = a_3 - a_2}$$

$$a_1 + a_2 = a_3 - a_1$$

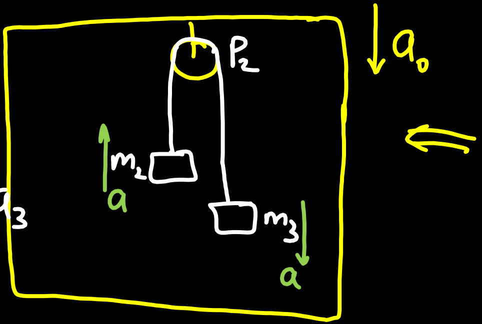
$a_1 = a_0 \uparrow$

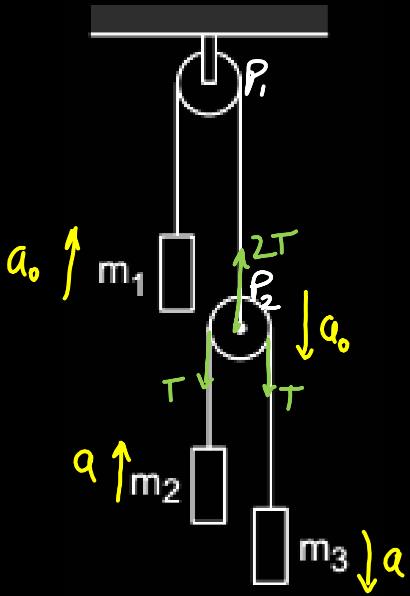


$a_2 = a - a_0 \uparrow$



$\downarrow a + a_0 = a_3$



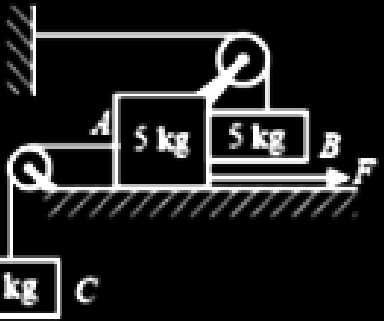


HW

(Advanced Level)

Figure shows a system of 3 blocks of 5 kg mass each. Find the value of external force F required to move the block A at acceleration 5 m/s^2. Take all surfaces smooth and g = 10 m/s^2.

A. 50 N
B. 100 N
C. 150 N
D. 200 N



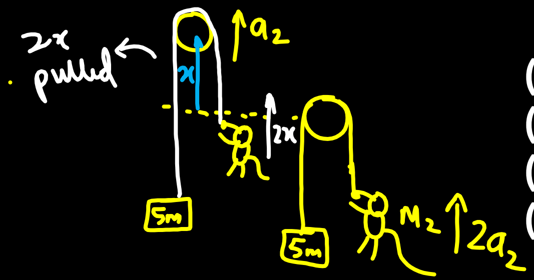
Q

$\boxed{T = 5mg}$

$T - mg = m(2a_2)$

$5mg - mg = 2ma_2$

$\boxed{a_2 = 2g}$



Two monkeys M_1 and M_2 of equal mass 'm' can climb strings of a pulley arrangement as shown in figure. Find magnitude of acceleration (in m/s^2) of M_1 with respect to rope so that block remains stationary. It is given that M_2 is just holding the string. Assume pulley is frictionless and string is massless and inextensible.

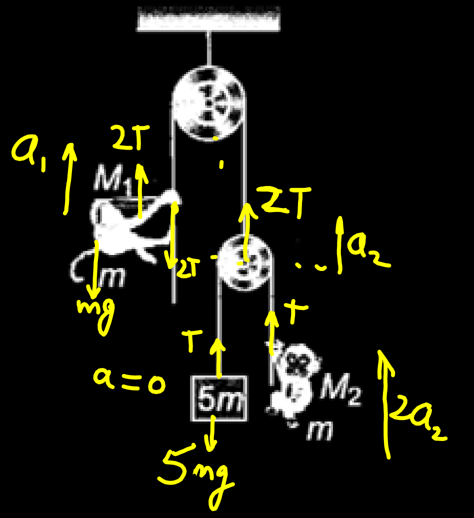
(a) 9g
(b) 2g
(c) 7g
(d) 11g

$2T - mg = ma_1$

$2(5mg) - mg = ma_1$

$9mg = ma_1$

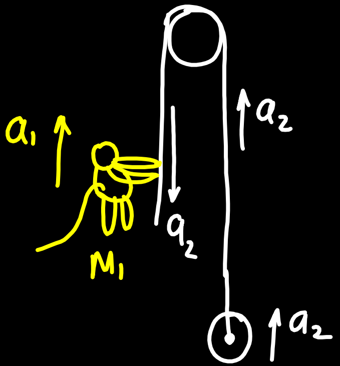
$\boxed{a_1 = 9g}$



$$a_{relative} = a_1 - a_2$$

$$= (+9g) - (-2g)$$

$$\boxed{a_{relative} = 11g}$$



Constraint Relations

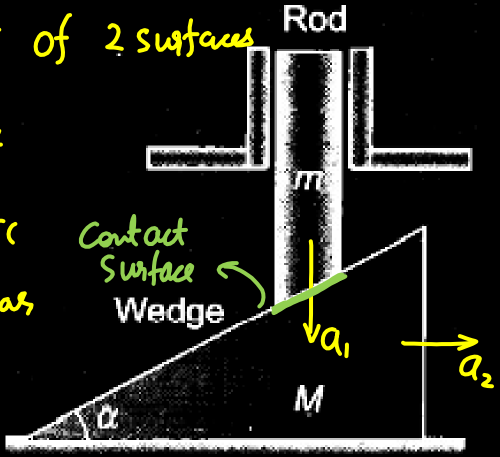
2) Sliding Surface Constraint

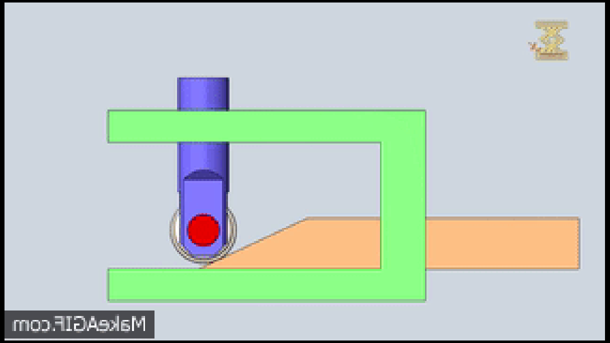
a) Constraint is contact of 2 surfaces

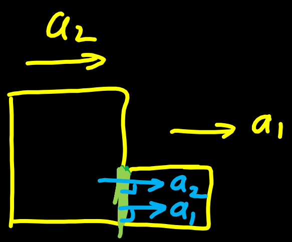
b) Mark the contact surface

c) Take components of acc in direction perpendicular to contact surface.

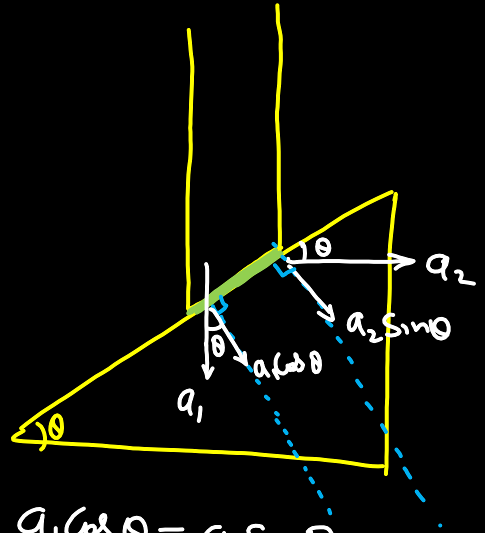
d) Equate them







$a_1 = a_2$

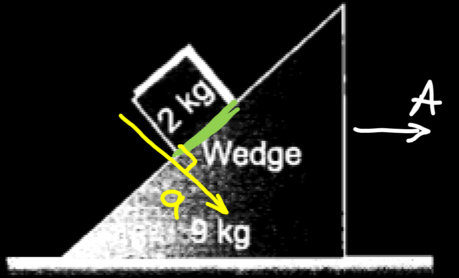


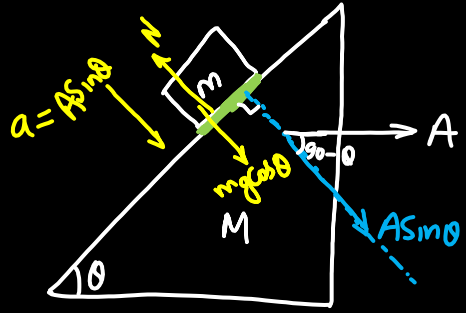
$$\Rightarrow a_1 \cos\theta = a_2 \sin\theta$$

$$\boxed{a_2 = a_1 \cot\theta}$$

A block of mass 2 kg slides down the face of smooth 45º wedge of mass 9 kg as shown in the figure. The wedge is placed on a frictionless horizontal surface. Determine the acceleration of the wedge.

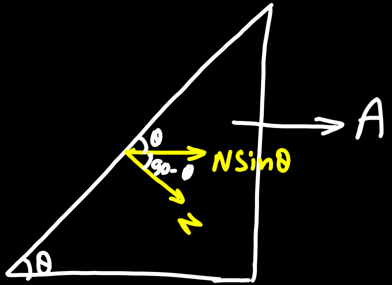
A. $2\ m/s^2$
B. $11/\sqrt{2}\ m/s^2$
[✓ C. $1\ m/s^2$]
D. None of these





$$mg\cos\theta - N = ma$$

$$mg\cos\theta - N = m(A\sin\theta) \ . \ . \ - - \rightarrow (1)$$



$$N\sin\theta = MA \text{ - - - - -}\rightarrow (2)$$

$$\frac{N}{\sqrt{2}} = 9A$$

$$N = 9\sqrt{2}A$$

$$mg\cos\theta - N = m(A\sin\theta)$$

$$\frac{20}{\sqrt{2}} - 9\sqrt{2}A = \frac{2A}{\sqrt{2}}$$

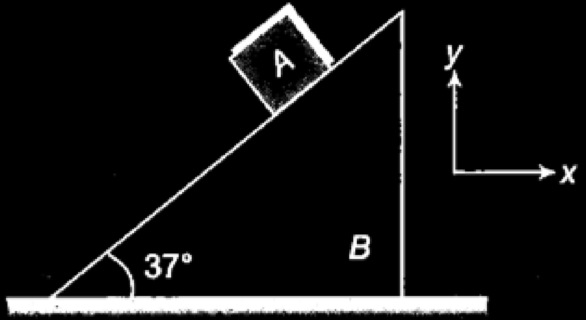
$$20 - 18A = 2A$$

$$\boxed{A = 1\ m/s^2}$$

Q

HW (Good Question)

In the figure shown the acceleration of A is, then the acceleration a_A = 15j + 15j of B is (A remains in contact with B)



(a) $6\hat{i}$

(b) $-15\hat{i}$

(c) $-10\hat{i}$

(d) $-5\hat{i}$

Constraint Relations

3) General Constraints

$l = \text{const}$

Method 1

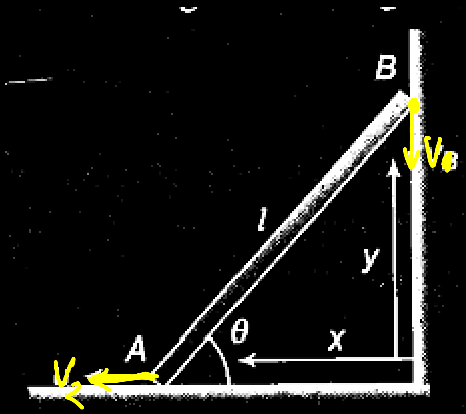
$$l^2 = x^2 + y^2$$

$$0 = 2x\left(\frac{dx}{dt}\right) + 2y\left(\frac{dy}{dt}\right)$$

$$0 = x(+V_2) + y(-V_1)$$

$$V_2 = \frac{y}{x} V_1$$

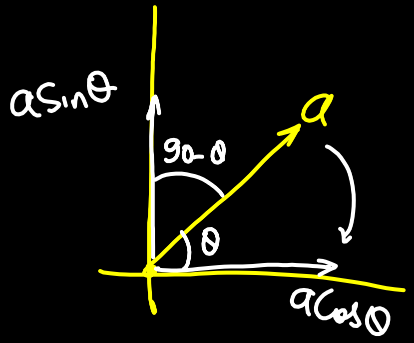
$$\boxed{V_2 = V_1 \tan\theta}$$

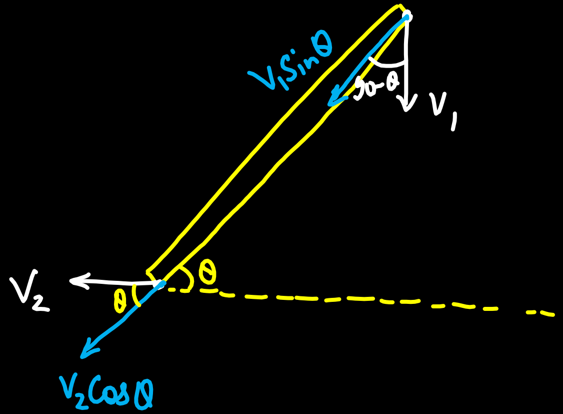


Method 2

$$V_2 \cos\theta = V_1 \sin\theta$$

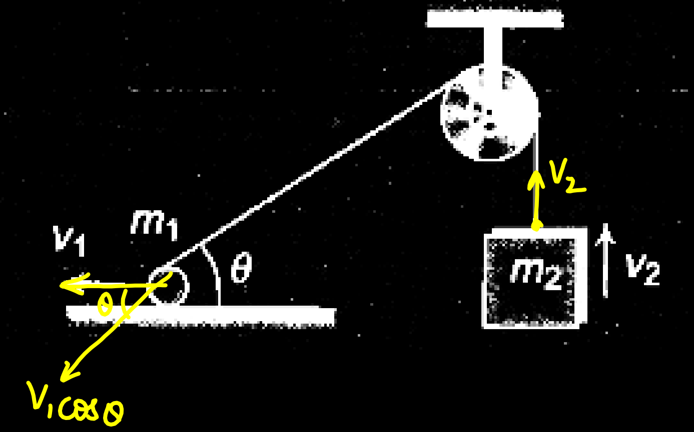
$$\boxed{V_2 = V_1 \tan\theta}$$





Find the relation between v1 & v2

$$\boxed{V_2 = V_1 \cos\theta}$$

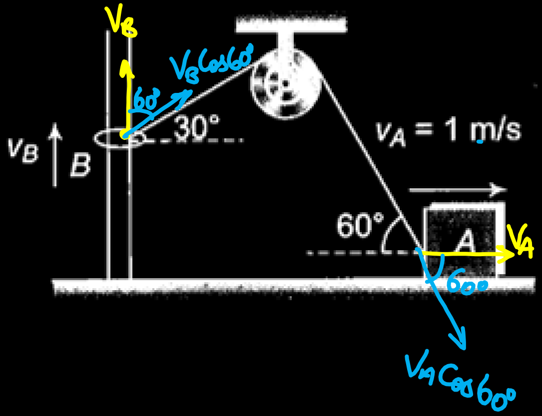


Find the velocity of ring B(V_B) at the instant shown. The string is taut and inextensible

- A. 1/2 m/s
- B. √3/4 m/s
- C. 1/4 m/s
- [✓ D. 1 m/s]

$$V_B \cos 60^\circ = V_A \cos 60^\circ$$

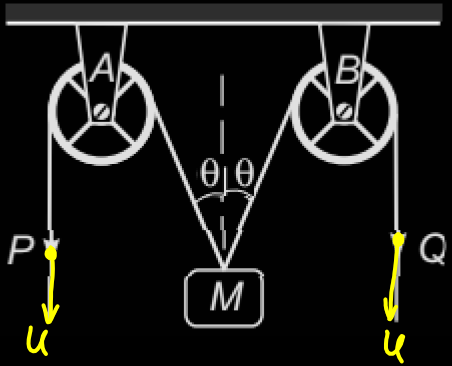
$$\boxed{V_B = V_A}$$



HW

In the arrangement shown in the figure, the ends P and Q of an unstretchable string move downwards with uniform speed u. Pulleys A and B are fixed. Mass M moves upwards with a speed

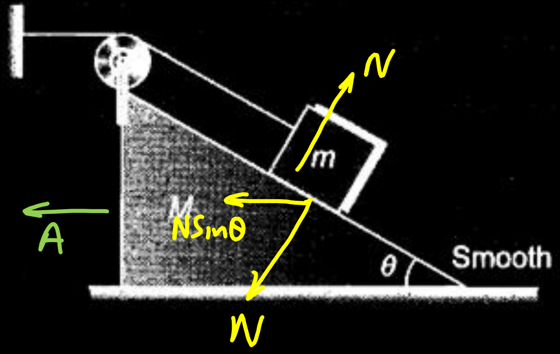
A. 2u cosθ
B. u / cosθ
C. 2u / cosθ
D. u cosθ



Constraint Relations

4) Pulley Wedge Constraint

(I.E Irodov)



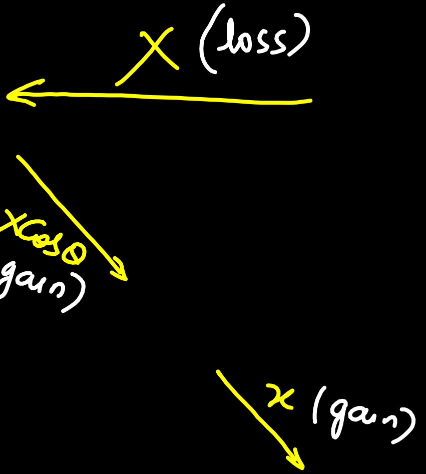
$l = \text{const}$

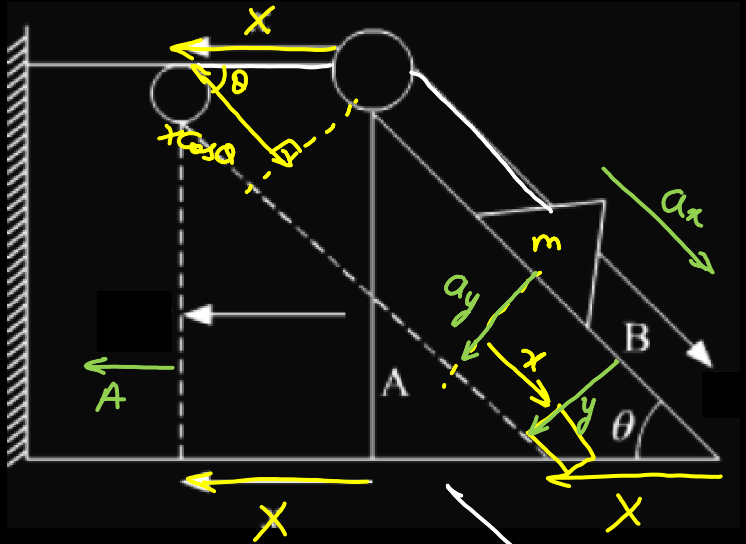
$\text{loss} = \text{gain}$

$X = X\cos\theta + x$

$x = X(1-\cos\theta)$

$$\boxed{a_x = A(1-\cos\theta)}$$

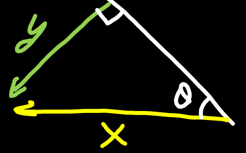




$\sin\theta = y/X$

$y = X\sin\theta$

$$\boxed{a_y = A\sin\theta}$$



Spring Force

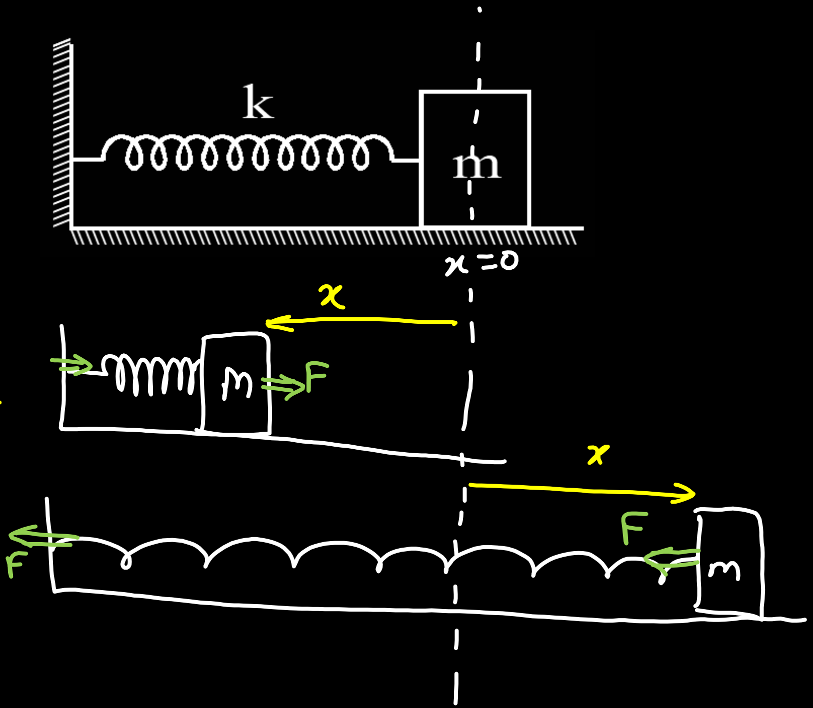
Spring Force

$$\vec{F} \propto -\vec{x}$$

$$\boxed{\vec{F} = -k\vec{x}}$$

k ⇒ Stiffness constant

$$\boxed{F = kx}$$ ⇒ scalar form



Spring Constant

$$K = \frac{F}{x}$$

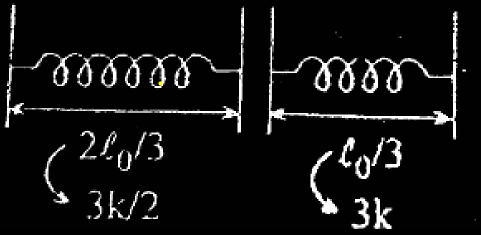
$$K_1 = \frac{1N}{0\ 1m} = 10\,\frac{N}{m}$$

$$K_2 = \frac{100\,N}{0\ 1m} = 1000\,\frac{N}{m}$$

K ⇒ Strength of the spring

K → length (l)
→ cross section area (A)
→ Material

$$\boxed{K \propto \frac{A}{l}}$$

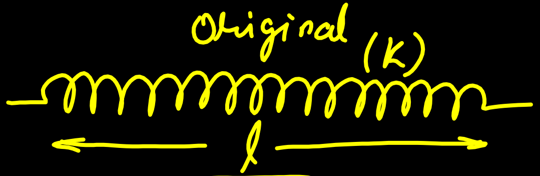


$x = 10cm$

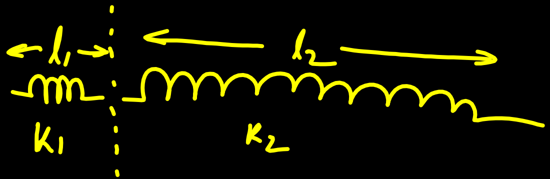
$K_1 = 10\frac{N}{m}$

$x = 10cm$

$K_2 = 1000N/m$



$$\boxed{K \propto \frac{1}{l}}$$



$$\frac{l_1}{l_2} = \frac{1}{10} \Rightarrow l_1 + l_2 = l$$

$$l_1 + 10l_1 = l$$

$$\boxed{l_1 = \frac{l}{11}}$$

A spring of stiffness constant 'k' is cut into two parts in the ratio 1:10 by length.Find the stiffness constant of smaller part

(a) 10k

(b) k/10

(c) 10k/11

[✓ (d) 11k]

$k \propto \frac{1}{l}$ $\qquad$ $k_1 \propto \frac{1}{l_1}$

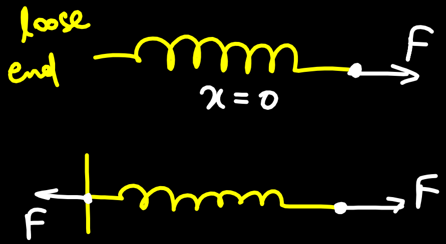
$$\frac{k_1}{k} = \frac{1/l_1}{1/l} = \frac{l}{l_1}$$

$$\boxed{k_1 = \left(\frac{l}{l_1}\right) k}$$

$$k_1 = \frac{l}{(l/11)} k$$

$$\boxed{k_1 = 11 k}$$

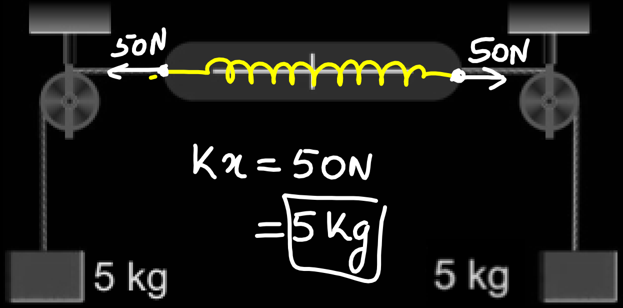
$$\boxed{\text{Reading} = \text{Spring Force}}$$



$F = kx$

For the arrangement shown in the figure, the reading of spring balance is

✗ (a) 0
✓ (b) 5 kg
✗ (c) 10 kg
(d) 20 Kg



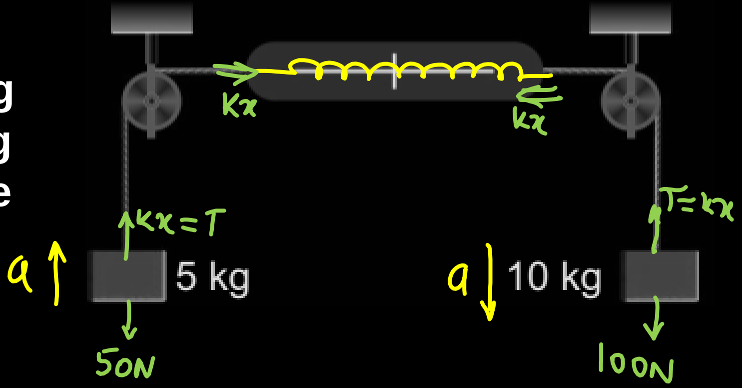
$Kx = 50N$

$= \boxed{5\,kg}$

Q

For the arrangement shown in the figure, the reading of spring balance is

(a) 5
(b) 10 kg
(c) 15 kg
[✓ (d) None]



$kx - 50 = 5a$

$100 - kx = 10a$

$100 - 50 = 15a$

$a = \frac{50}{15}\ \frac{m}{s^2}$

$\boxed{a = \frac{10}{3}\ \frac{m}{s^2}}$

$kx = 50 + 5a$

$= 50 + \frac{50}{3}$

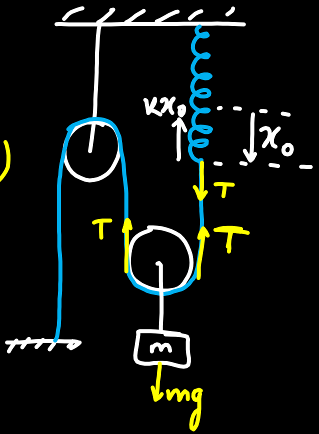
$\boxed{kx = \frac{200}{3}\ N}$

Equilibrium

$2T = mg$

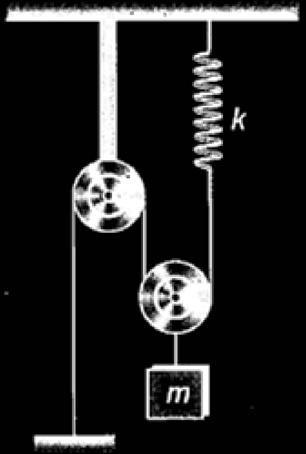
$T = kx_0$

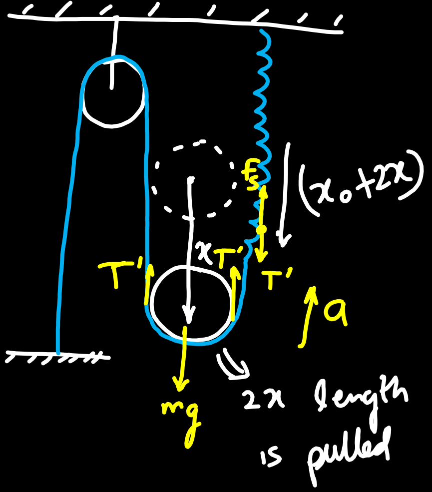
$$\boxed{2(kx_0) = mg} \rightarrow (1)$$



Mass m shown in the figure is in equilibrium. If it is displaced further by x and released find its acceleration just after it is released. Take pulleys to be light and smooth and strings light.

A. 2kx/m
B. 2kx/5m
[✓ C.] 4kx/m
D. None of these





$$2T' - mg = ma$$

$$T' = F_s$$

$$T' = K(x_0 + 2x)$$

$$2[Kx_0 + 2kx] - mg = ma$$

$$\cancel{2kx_0} + 4kx - \cancel{mg} = ma$$

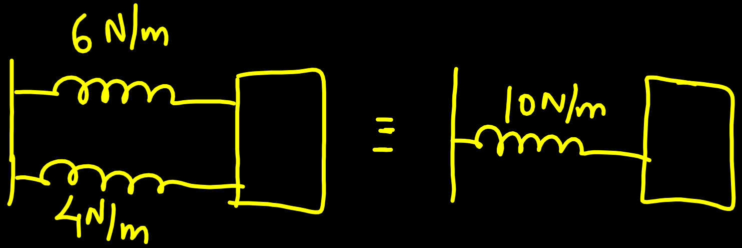
$$4kx = ma$$

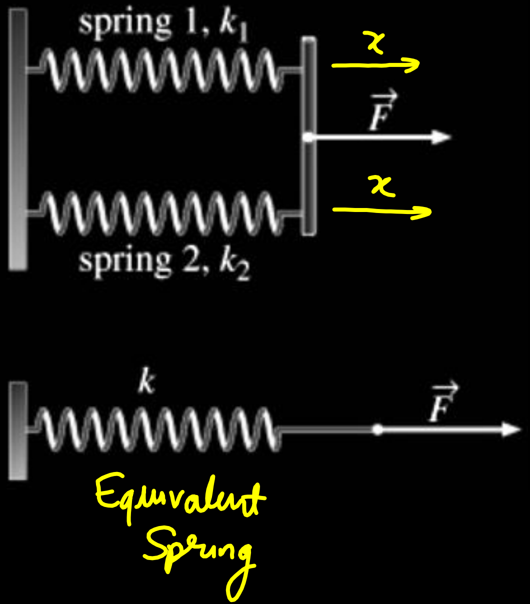
$$\boxed{a = \frac{4kx}{m}}$$

Combination of Spring

Parallel Combination

$$\boxed{K = K_1 + K_2}$$

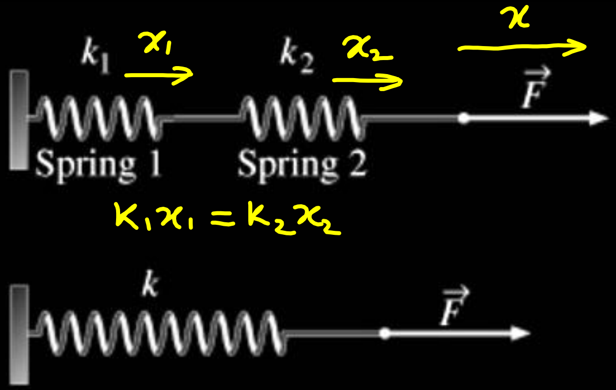




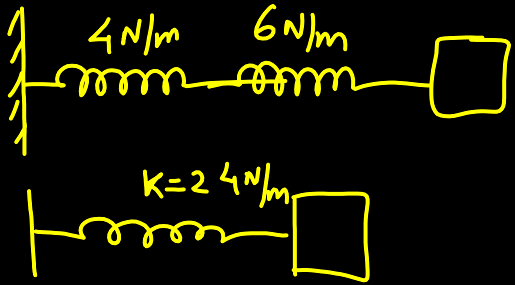
Combination of Spring

Series Combination

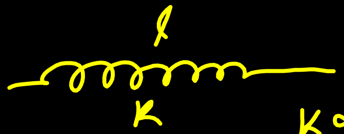
$$\boxed{\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}}$$



$K_1x_1=K_2x_2$



$$K=\frac{K_1K_2}{K_1+K_2}=\frac{4\times6}{4+6}=24\ \text{N/m}$$



$K \propto \frac{1}{l}$

$K' \propto \frac{1}{(l/3)} = \frac{3}{l}$

$\boxed{K' = 3K}$

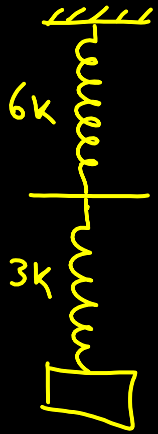
A spring of constant k is cut into three identical parts. The parts are now connected as shown in the figure. If the mass of the block is m, the equilibrium elongation in the equivalent spring will be

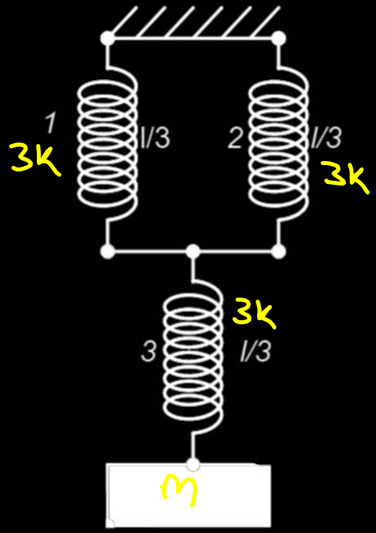
(a) mg/3k

(b) 3mg/k

[✓ (c) mg/2k]

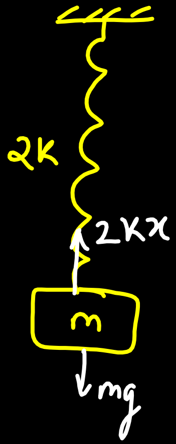
(d) mg/6k





$K_{eq} = \frac{6k \times 3k}{6k + 3k}$

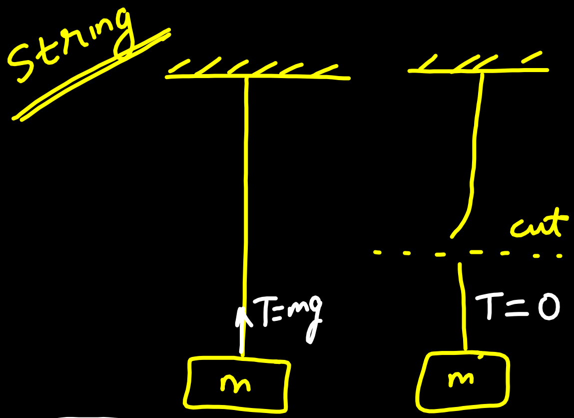
$K_{eq} = 2k$



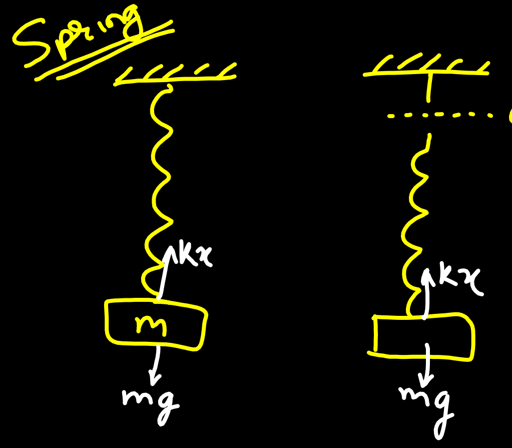
$$2kx = mg$$

$$\boxed{x = \frac{mg}{2k}}$$

Cutting of Spring/String



Tension ⇒ Immediately becomes zero



$Kx = mg$

$\boxed{Kx = mg}$

Spring ⇒ Remains same Instantly after cutting

Equilibrium

$k x \sin 53^\circ = T$

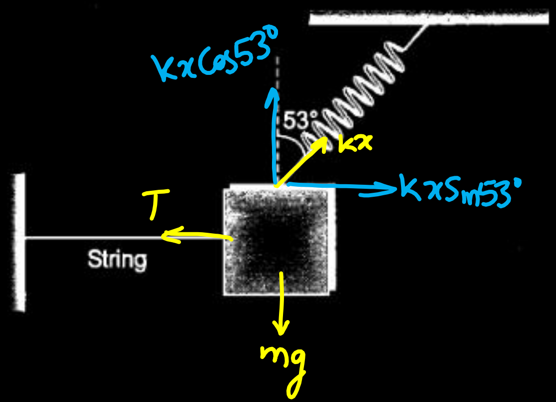
$k x \cos 53^\circ = mg$

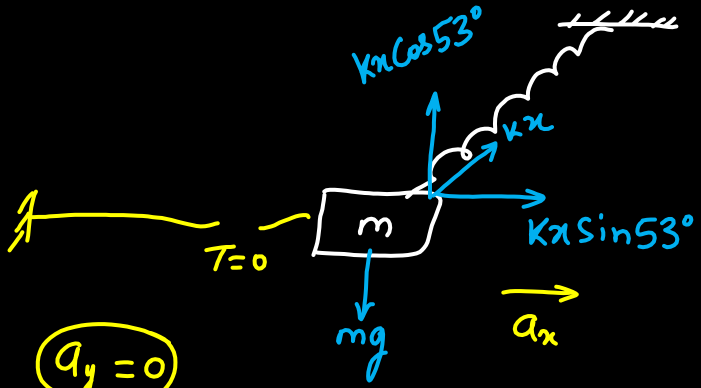
$k x \left(\frac{3}{5}\right) = mg$

$$\boxed{k x = \frac{5}{3} mg}$$

The block shown in the figure is in equilibrium. Find acceleration of the block just after the string is cut.

A. 3g/5
B. 4g/5
[✓ C. 4g/3]
D. none





$$\boxed{a_y = 0}$$

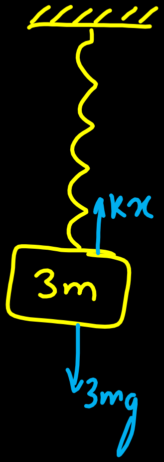
$$F_x = ma_x$$

$$kx\sin 53^\circ = ma_x$$

$$\left(\frac{5}{3}mg\right)\left(\frac{4}{5}\right) = ma_x$$

$$\boxed{a_x = \frac{4}{3}g}$$

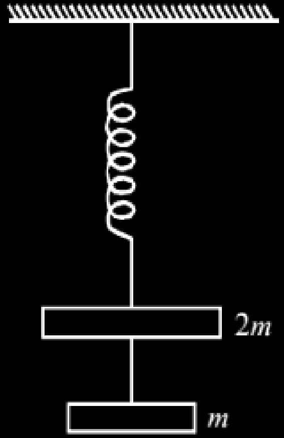
Equilibrium

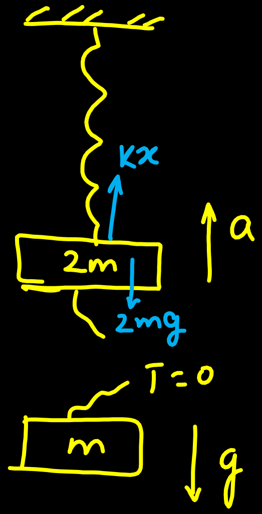


$\boxed{kx = 3mg}$

The string between blocks of mass m and 2m is massless and inextensible. The system is suspended by a massless spring as shown. If the string is cut find the magnitudes of accelerations of mass 2m and m (immediately after cutting)

A. g,g
B. g, g/2
[✓ C. g/2 , g]
D. g/2, g/2





$$kx - 2mg = (2m)a$$

$$3mg - 2mg = (2m)a$$

$$\boxed{a = g/2}$$

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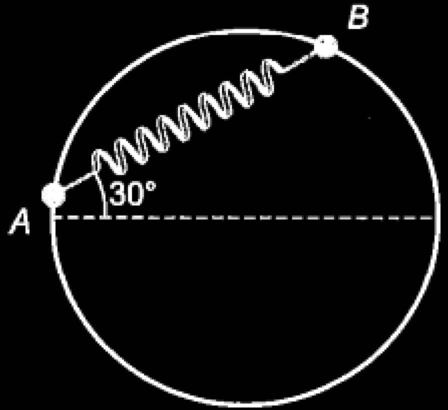
Q

HW (Advanced)



A bead of mass m is attached to one end of a spring of natural length R and spring constant $K = \dfrac{(\sqrt{3}+1)mg}{R}$. The other end of the spring is fixed at a point A on a smooth vertical ring of radius R as shown in the figure. The normal reaction at B just after it is released to move is

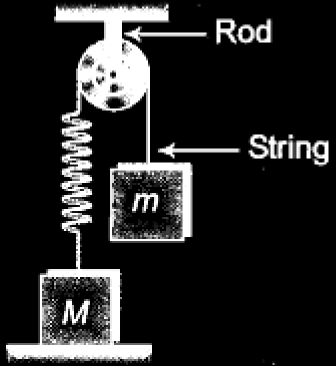
(a) $mg/2$

(b) $\sqrt{3}\, mg$

(c) $3\sqrt{3}\, mg$

(d) $\dfrac{3\sqrt{3}\, mg}{2}$

HW



In figure, a block of mass m is released from rest when spring was in its natural length. The pulley also has mass m but it is frictionless. Suppose the value of m is such that finally it is just able to lift the block M up after releasing it.

(a) The weight of m required to just lift M is $\frac{M}{2}g$

(b) The tension in the rod, when m has zero acceleration is $\frac{M}{2}g$

(c) The normal force acting on M when m has zero acceleration $\frac{M}{2}g$

(d) The tension in the string when displacement of m is maximum possible is Mg

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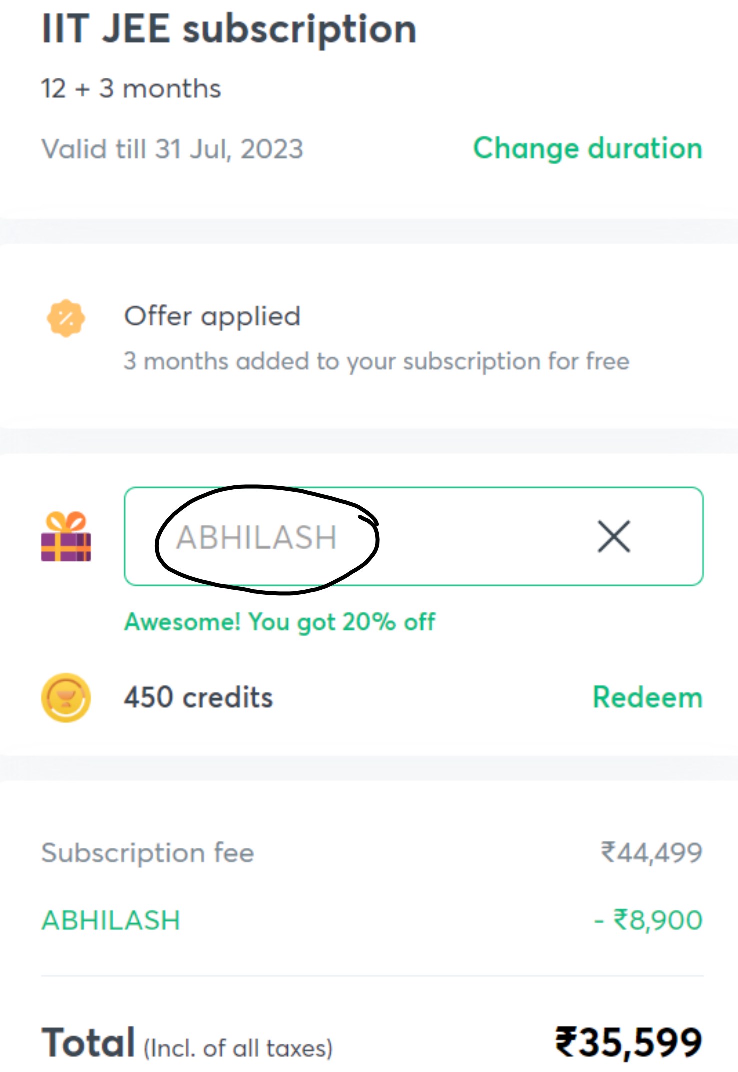

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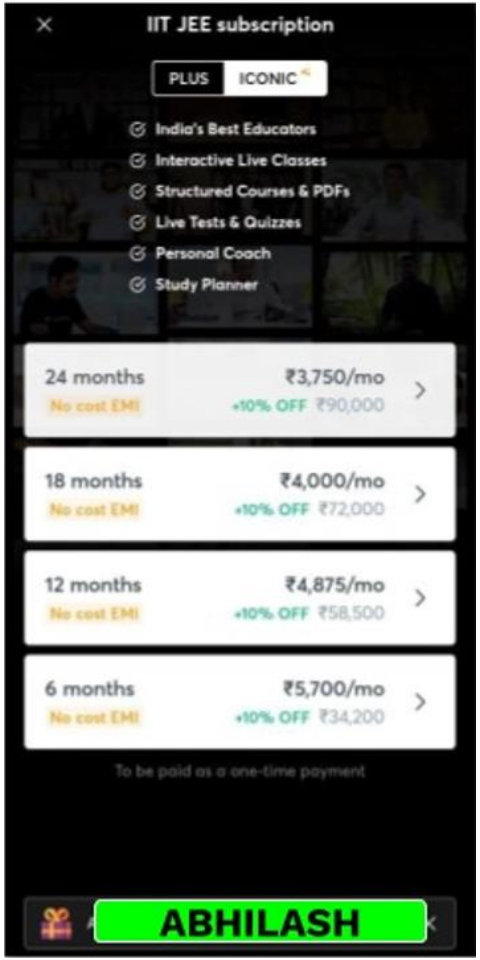

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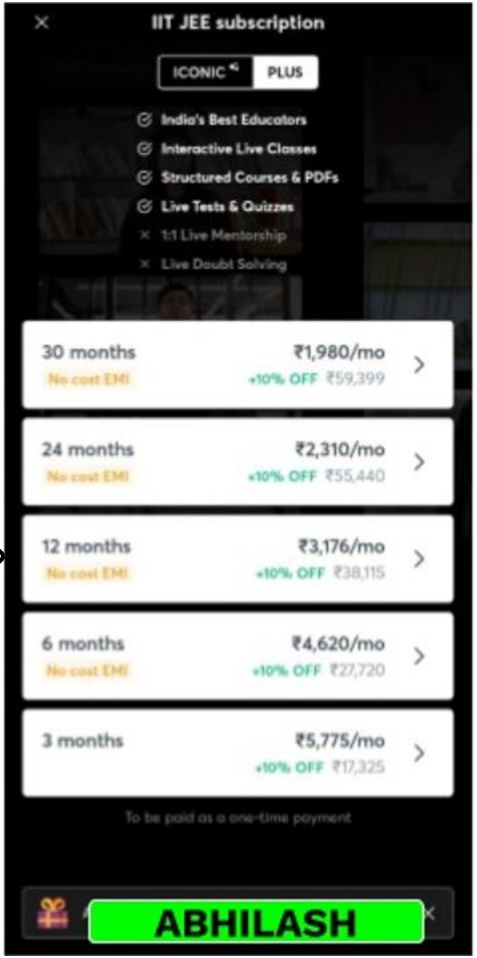

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