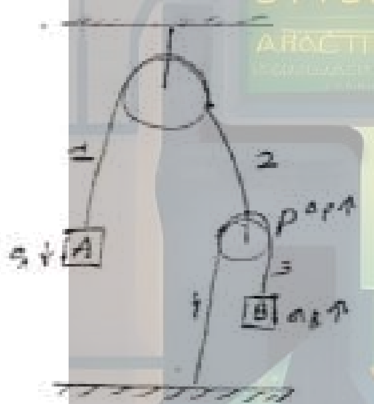
!! Chapter - 4 !!

Newton's Laws of Motion & Friction

Constraint Motions:

→ The equations showing the relation of motion of bodies in which motion of one body is ~~con~~ constrained by the other are called constraint relations.

1. Pulley constraint



Relation between acceleration of blocks

Δl_1 (change in length of rope 1) $= +x_A$
(जितना Block A निचे जाएगा)

$\Delta l_2 = -x_P$
(जितना pulley ऊपर जाएगा)

$\Delta l_1 + \Delta l_2 = 0$
(rope length remains same)

$+x_A - x_P = 0$

$$\boxed{x_A = x_P}$$

$\Delta l_3 = +x_P - x_B$
(जितना Pulley ऊपर जाएगा – जितना Block नीचे जाएगा)

$\Delta l_4 = x_P$

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$$\Delta l_3 + \Delta l_4 = 0$$

$$x_p + x_p - x_B = 0$$

$$2x_p = x_p$$

$$2x_A = x_B$$

$$2V_A = \cancel{3}V_B$$

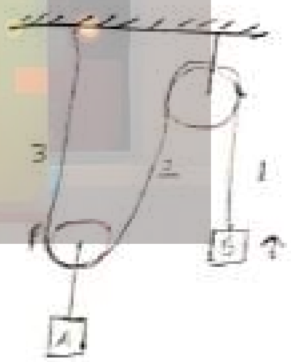
$$\boxed{2a_A = a_B}$$

Method II

Displacement of the block B will be $2x$
A will be x.

$$\boxed{2a_A = a_B}$$

Q Find relation between movement of blocks



~~$\Delta l_1 = x_B$~~

~~$\Delta l_2 = \ldots$~~

$\Delta l_3 = +x_A$

$\Delta l_2 = +x_A$

$\Delta l_1 = -x_B$

$$\Delta l_1 + \Delta l_2 + \Delta l_3 = 0$$

$$2x_A - x_B = 0$$

$$2x_A = x_B$$

$$2V_A = V_B$$

$$\boxed{2a_A = a_B}$$

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Q find constraint relation between acceleration of A & B

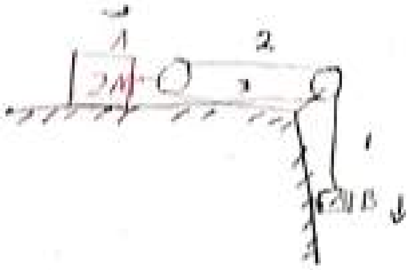
$\Delta l_1 = x_B$

$\Delta l_2 = -x_A$

$\cancel{\Delta l_1 + \Delta l_2 = 0}$

$\cancel{x_B = x_A}$

$\Delta l_3 = -x_A$



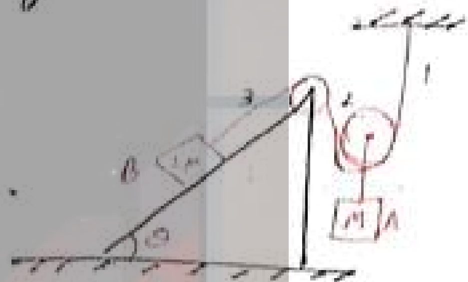
$\Delta l_1 + \Delta l_2 + \Delta l_3 = 0$

$x_B - 2x_A = 0$

$\boxed{2x_A = x_B}$

$\boxed{2a_A = a_B}$

Q find constraint relation between acceleration of A and B.



$\Delta l_1 = \Delta l_3 = x_B$

$\Delta l_2 = -x_A$

$\Delta l_4 = -x_A$

$\Delta l_1 + \Delta l_2 + \Delta l_3 = 0$

$x_B - x_A - x_A = 0$

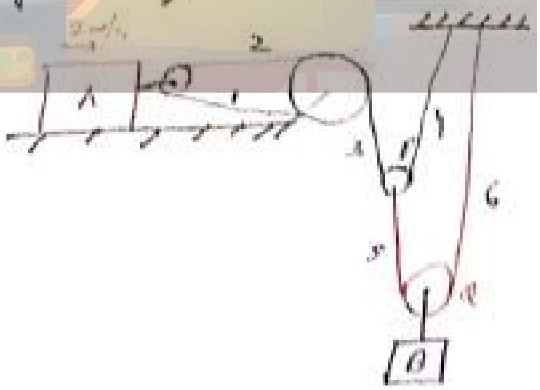
$x_B = 2x_A$

$2x_A = x_B$

$2V_A = V_B$

$\boxed{2a_A = a_B}$

Q find acceleration of block B, pulley P & Q. If acceleration of A is given



$\Delta l_1 = -x_A$

$\Delta l_2 = -x_A$

$\Delta l_3 = x_P$

$\Delta l_4 = x_P$

$\Delta l_1 + \Delta l_2 + \Delta l_3 + \Delta l_4 = 0$

$-2x_A + 2x_P = 0$

$\boxed{x_P = x_A}$

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$\Delta l_5 = +x_B \mp x_P$

$\Delta l_6 = +x_B$

$\Delta l_5 + \Delta l_6 = 0$

$+2x_B \mp x_P = 0$

$+x_P = +2x_B$

$x_A = 2x_P$

$V_A = 2V_B$

$\boxed{a_A = 2a_B}$

$a_A = 2\ m/s$

$2 = 2a_B$

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

Q Block A vel $= 0.6\ m/s$ to right, find V_B.

$\Delta l_1 = -x_A$

$\Delta l_2 = -x_{BA}$

$\Delta l_3 = -x_A$

$\Delta l_4 = x_B$

$\Delta l_1 + \Delta l_2 + \Delta l_3 + \Delta l_3 = 0$

$-3x_A + x_B = 0$

$x_B = 3x_A$

$V_B = 3V_A$

$V_B = 3(0.6)$

$\boxed{V_B = 1.8\ m/s}$

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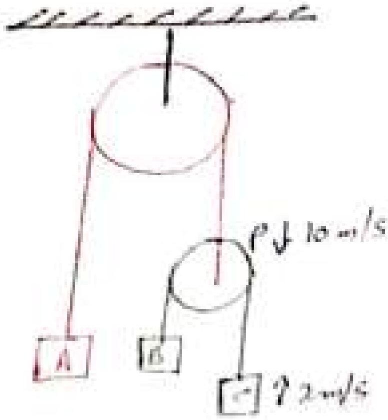
Q find velocities of A & B if velocity of P is 10 m/s downwards and velocity of C is 2 m/s upwards.



$V_A = -V_P$

$V_P = -10\hat{j}$

$\boxed{V_A = +10\hat{j}}$

$V_C = 2\hat{j}$

$V_B = ?$

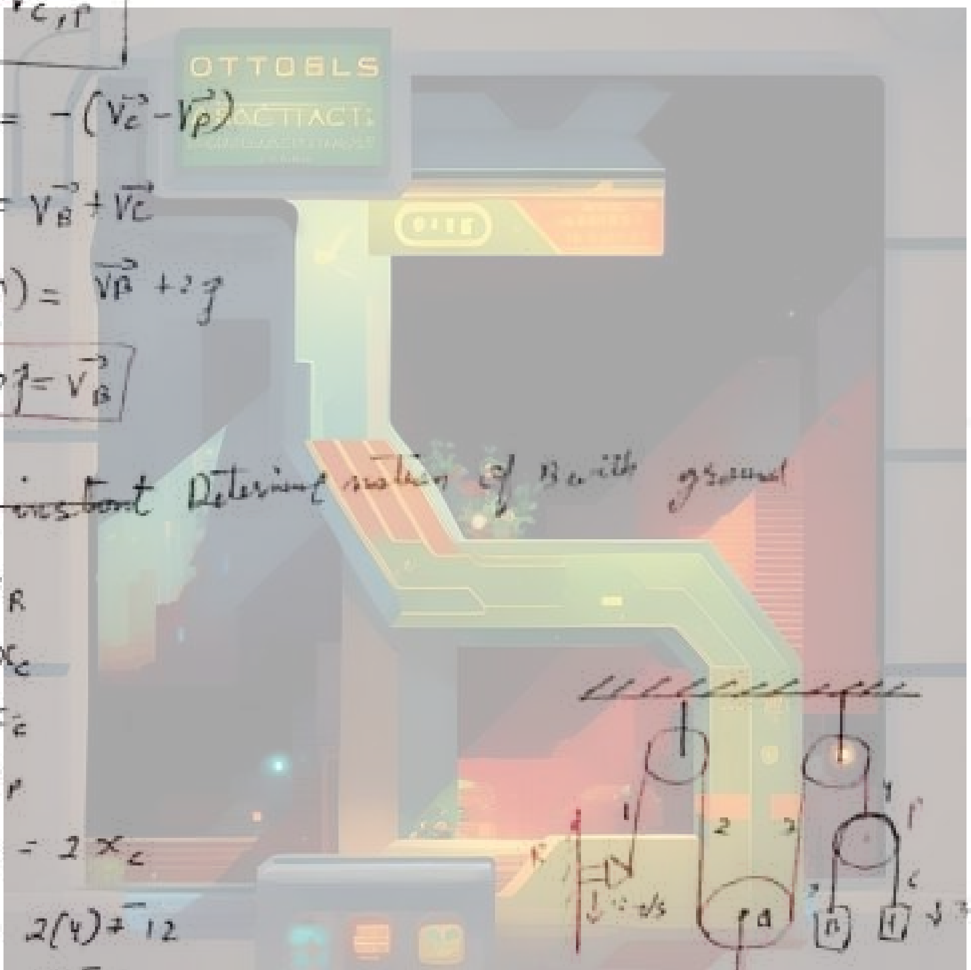
$\boxed{\vec{V}_{B,P} = -\vec{V}_{C,P}}$

$\vec{V}_B - \vec{V}_P = -(\vec{V}_C - \vec{V}_P)$

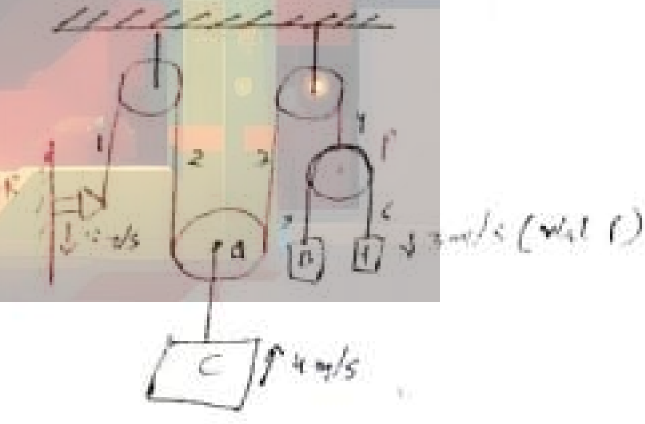
$2\vec{V}_P = \vec{V}_B + \vec{V}_C$

$2(-10\hat{j}) = \vec{V}_B + 2\hat{j}$

$\boxed{-22\hat{j} = \vec{V}_B}$



Q ~~At an instant~~ Determine motion of B with ground



$\Delta l_1 = x_R$

$\Delta l_2 = -x_C$

$\Delta l_3 = -x_C$

$\Delta l_4 = x_P$

$x_R + x_P = 2x_C$

$x_P = 2(4) \mp 12$

$= 8 \mp 12$

$\boxed{x_P = \cancel{20}\ 4\ m/s}$

$\cancel{x_{A,P} = x_A - x_P}$

$\cancel{-3 - 20}$

$\cancel{= -23}$

$\cancel{x_{B,P} =}$

$x_{A,P} = -3$

$x_{B,P} = x_B - x_P = (-3)$

$\cancel{x_P = +3 + 20}$

$\boxed{\cancel{x_B = -23\ m/s}}$

$x_B = -3 - 4$

$\boxed{x_B = -7\ m/s}$

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Q) Method II (P mirdoly Re based)

$\cancel{\vec{V}_R = 12\hat{j}}$

$\cancel{\vec{V}_C = 4\hat{j}}$

$\vec{V}_{A,P} = -3\hat{j}$

$\vec{V}_{B,P} = -\vec{V}_{A,P}$

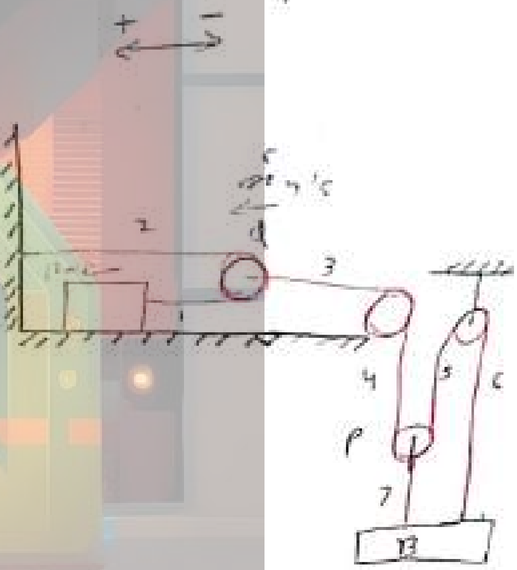
$\vec{V}_B - \vec{V}_P = 3\hat{j}$

$\vec{V}_B = 3\hat{j} + \vec{V}_P$

$\vec{V}_B = 3\hat{j} + 20\hat{j}$

$\boxed{= 23\hat{j}\ m/s}$

Q find B acc.



$\Delta l_1 + \Delta l_2 = 0$

$\cancel{\ddot{x}_A - \ddot{x}_Q = 0}$

$\ddot{x}_A - \ddot{x}_Q - \ddot{x}_Q = 0$

$\ddot{x}_A = 2\ddot{x}_Q$

$\boxed{6 = \ddot{x}_Q}$

$\cancel{\ddot{x}_Q = 12\ m/s^2}$

$\Delta l_3 + \Delta l_4 + \Delta l_5 + \Delta l_6 = 0$

$\ddot{x}_Q - \ddot{x}_P - \ddot{x}_P - \ddot{x}_P = 0$

$\ddot{x}_Q = 3\ddot{x}_P$

$6 = 3\ddot{x}_P$

$\ddot{x}_P = \frac{6}{3}$

$\boxed{\ddot{x}_P = 2\ m/s^2}$

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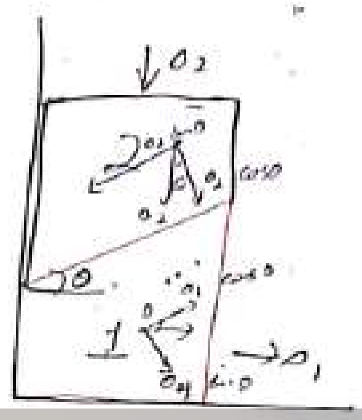
HW Q1-28 (O) 04-06-2024

Wedge constraint

→ Contact between the wedges is intact

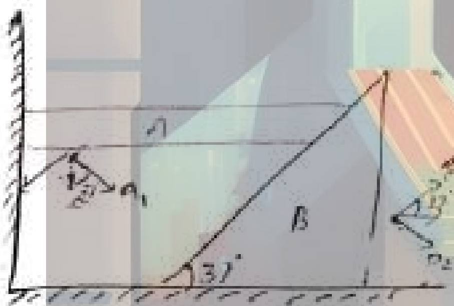
→ component of acceleration perpendicular to surface in contact is same for both.



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

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

Q find acceleration of A? ($\theta = 37°$)



~~$a_A \tan\theta = a_B$~~

~~$a_A \times \frac{3}{4} = 3$~~

~~$a_A = 3 \times \frac{4}{3}$~~

~~$\boxed{a_A = 4 \text{ m/s}^2}$~~

Or

$a_1 = \cos 37° \times a$

$a_2 = \sin 37° \times 3$

$= 3 \times \frac{3}{5}$

$= \frac{9}{5}$

$a_1 = a_2$

$a \times \frac{4}{5} = \frac{9}{5}$

$\boxed{a = \frac{9}{4} \text{ m/s}^2}$

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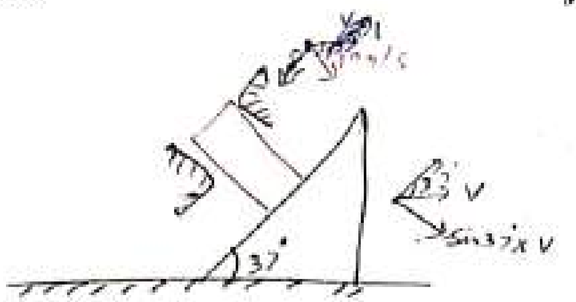
Q A rod is moving with speed 10m/s . find V



$V_{O_1} = 10 \cos 37$ $\quad \therefore \quad V \sin 37^\circ = 10$

$= 10 \times \frac{4}{5}$ $\quad V \times \frac{3}{5} = 10$

$= 8$ m/s

$V_2 = V \times \frac{3}{5}$ $\quad \boxed{V = \frac{50}{3} \text{ m/s}}$

$V_2 = \frac{3V}{5}$

$V_1 = V_2$

$8 = \frac{3V}{5}$

Q (m = 1kg) find acceleration of sphere

$V_1 = 5 \times \sin 53$ $\quad V_1 = \cos 53^\circ \times 5$

$= 5 \times \frac{4}{5}$ $\quad = 3 \text{ m/s}^2$

$= 4$ m/s

$V = \sqrt{9 + 2 \times \cancel{30} \times \frac{4}{5} c}$ $\quad V_2 = 3 \cos 53^\circ$

$V_2 = 24 \times \frac{4}{5}$

$V = \sqrt{34 - 24}$

$V_2 = \frac{12}{5}$

$V = \sqrt{10}$

70

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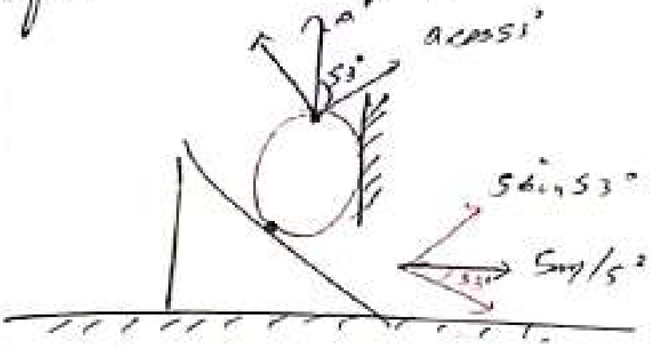
Q (find acceleration of sphere



$a\cos 53° = 5\sin 53°$

$a \times \frac{3}{5} = 5 \times \frac{4}{\cancel{5}}$

$a = \frac{4 \times 5}{3}$

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

Pulley & Wedge constraint

Q Determine block acceleration wrt wedge.

$\Delta l_1 = -x_M$

$\Delta l_2 = x_m$

$x_M = x_m$

$a_M = a_m$

$\boxed{a_m = A\ (\text{wrt wedge})}$

$a_{wrt\ ground} = \sqrt{A^2 + A^2 + 2A^2\cos(180-\theta)}$

$= \sqrt{2A^2 - 2A^2\cos\theta}$

$= \sqrt{2A^2(1-\cos\theta)}$

$= \sqrt{2A^2 \cdot 2\sin^2\frac{\theta}{2}}$

$\boxed{= 2A\sin\frac{\theta}{2}}$

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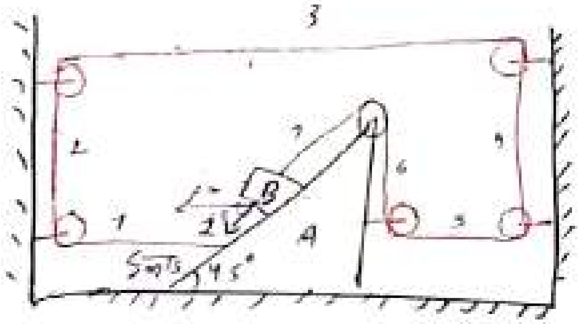
Q. vel B wrt ground



$$\cancel{x_A = x_B}$$

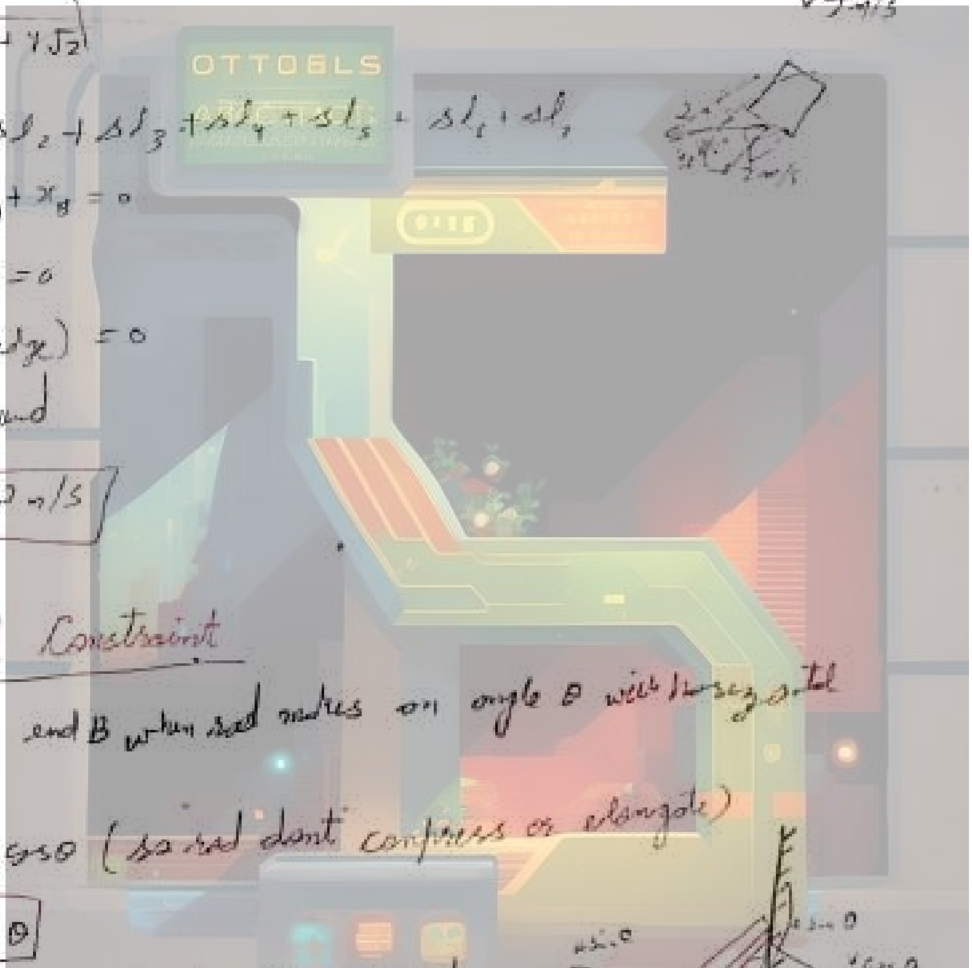
$$\cancel{V_A = V_B}$$

$$\cancel{V_B = 2(1) = 2\,m/s}$$

$$\cancel{V = \sqrt{v^2 + v^2 + 2v^2 \cos 45^\circ}}$$

$$\cancel{= \sqrt{8 + 8 \times \tfrac{1}{\sqrt{2}}}}$$

$$\cancel{= \sqrt{8 + 4\sqrt{2}}}$$



$$0 = \delta l_1 + \delta l_2 + \delta l_3 + \delta l_4 + \delta l_5 + \delta l_6 + \delta l_7$$

$$-x_A + x_A + x_B = 0$$

$$x_B = 0$$

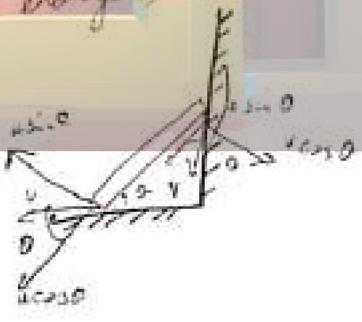
v_B (wrt wedge) $= 0$

wrt ground

$$\boxed{v_B = 2\,m/s}$$

General Constraint

Q Find vel of end B when rod makes an angle θ with horizontal



$v \sin\theta = u \cos\theta$ (so rod don't compress or elongate)

$$\boxed{v = u\cot\theta}$$

→ Component of velocity along the rod or string is equal for both ends.

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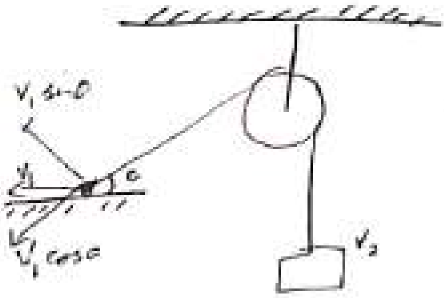
Q find relation btw v_1 & V_2

(the component along string to remain same.)

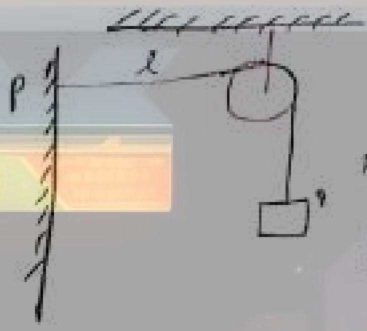
$$\boxed{V_1 \cos\theta = V_2}$$

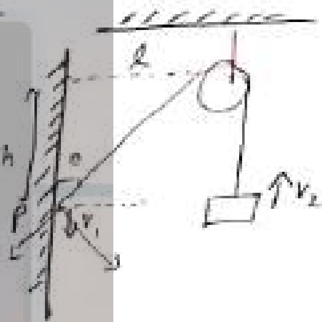


Q2. find relation btw v_1 & V_2 if distance moved by P is h.

$$v_1 \cos\theta = v_2$$

$$\boxed{\frac{v_1 h}{\sqrt{h^2+l^2}} = v_2}$$





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Newton's Laws of Motion

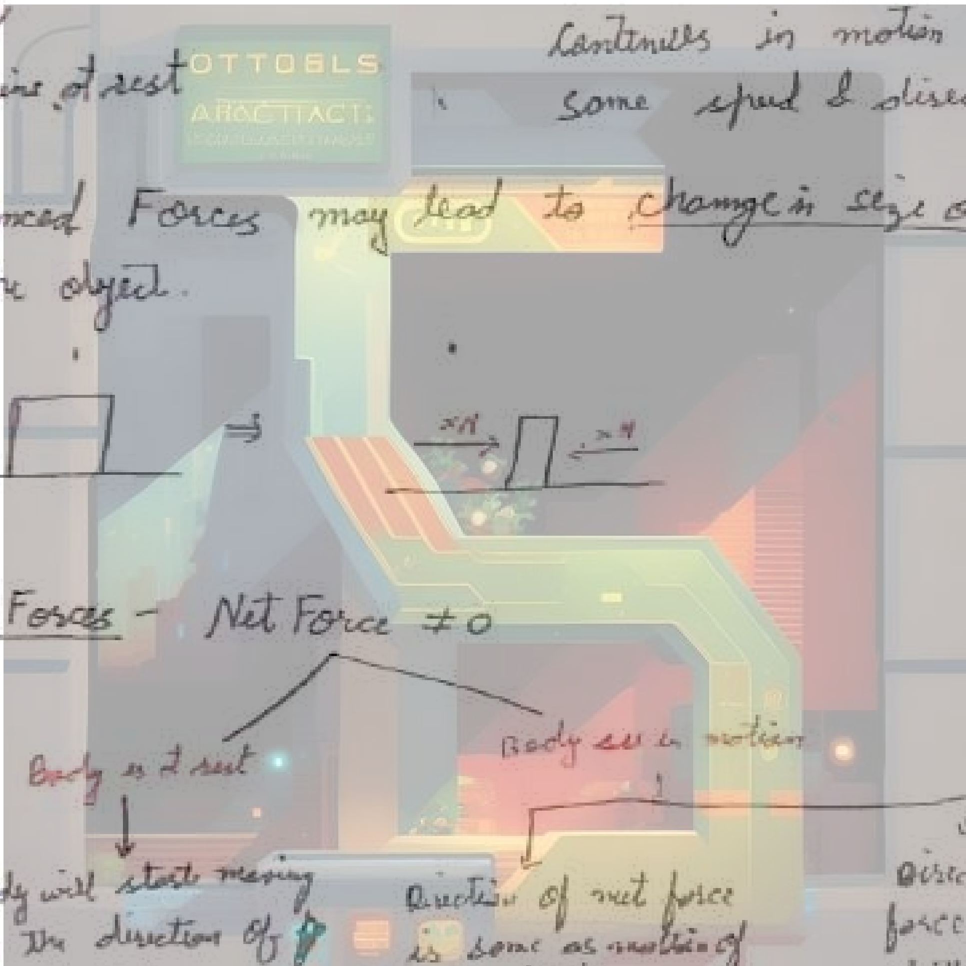
→ cause of motion :- forces → dynamics

Balanced Forces — Net Force = 0

If body at rest → Remains at rest

Body is in motion → Continues in motion with same speed & direction.

→ Balanced Forces may lead to change in size or shape of the object.



Unbalanced Forces — Net Force ≠ 0

Body is at rest → Body will start moving in the direction of resultant force

Body is in motion →
- Direction of net force is same as motion of the body → Body will speed up
- Direction of net force opp. to motion of the body → Body will slow down & finally stop

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~~Newton~~ Newton's First Law & Inertial Frame & non Inertial Frame.

→ Newton's First law / law of Inertia – defines a set of reference frames called inertial frames.

→ ~~Inder~~ Inertial Frame – Frames which do not have any acceleration.

→ Either the ~~Ro~~ frame is at rest or moving with a uniform velocity.

→ Newton's laws can be directly applied in such frames and dynamic equations can be written for objects in this frame. $\Sigma \vec{F} = m\vec{a}$

→ First Law – In the absence of external forces, when viewed from an inertial reference frame, every object continues to be in its state of rest or uniform motion.

Friction does not oppose the motion, It opposes the relative motion between two surfaces.

→ Inertial frames are also called as ~~Gall~~ 'Galilean Frames'.

→ Any reference frame that moves with constant relative velocity to an inertial frame is itself an inertial frame.

→ First law is a qualitative law. (does not tell about the quantity of forces)

→ Non-Inertial Frame – A Frame of reference which is a in accelerated motion with respect to a Inertial frame.

→ Newton's Laws cannot be ~~dired~~ directly ~~applied~~, same are applicable

→ Tendency of an object to resist any attempt to change its velocity is called Inertia.

→ Depends on mass,
more mass ↑ more Inertia ↑

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Linear Momentum & Newton's second Law.

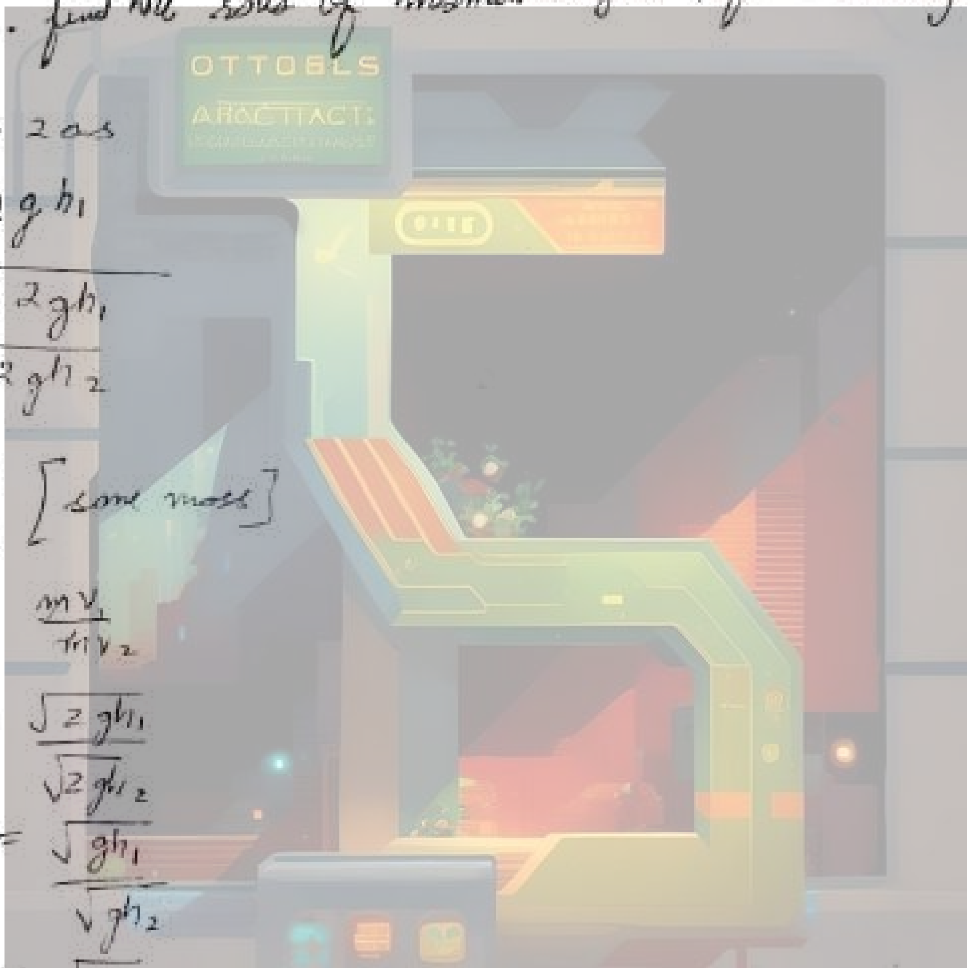
Linear Momentum (p) – The quantity of motion contained in the body.

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

SI unit :- kg m/s or Ns

It is a vector quantity

Q Two identical bodies are allowed to fall from two different heights h_1 & h_2. find the ratio of momentum just before striking the ground.



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

$$v_1^2 = 2gh_1$$

$$v_1 = \sqrt{2gh_1}$$

$$v_2 = \sqrt{2gh_2}$$

$p_1 = mv_1$

$p_2 = mv_2$ [same mass]

$$\frac{p_1}{p_2} = \frac{mv_1}{mv_2}$$

$$= \frac{\sqrt{2gh_1}}{\sqrt{2gh_2}}$$

$$= \frac{\sqrt{gh_1}}{\sqrt{gh_2}}$$

$$= \sqrt{\frac{h_1}{h_2}}$$

$p_1 : p_2$

$\sqrt{h_1} : \sqrt{h_2}$

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Q A ball of mass m is dropped from a height h on a smooth elastic floor, ~~such~~ such that it rebounds with same speed. What is the change in momentum of ball before & after striking the floor is: (take vertically downward as positive)

b) find magnitude of change in momentum

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

$v^2 = 2gh$

$v = \sqrt{2gh}$

$P_1 = m\sqrt{2gh}$

$v_2 = (-\sqrt{2gh})$

$P_2 = -m\sqrt{2gh}$

$|P_1| = m\sqrt{2gh}$

$|P_2| = m\sqrt{2gh}$

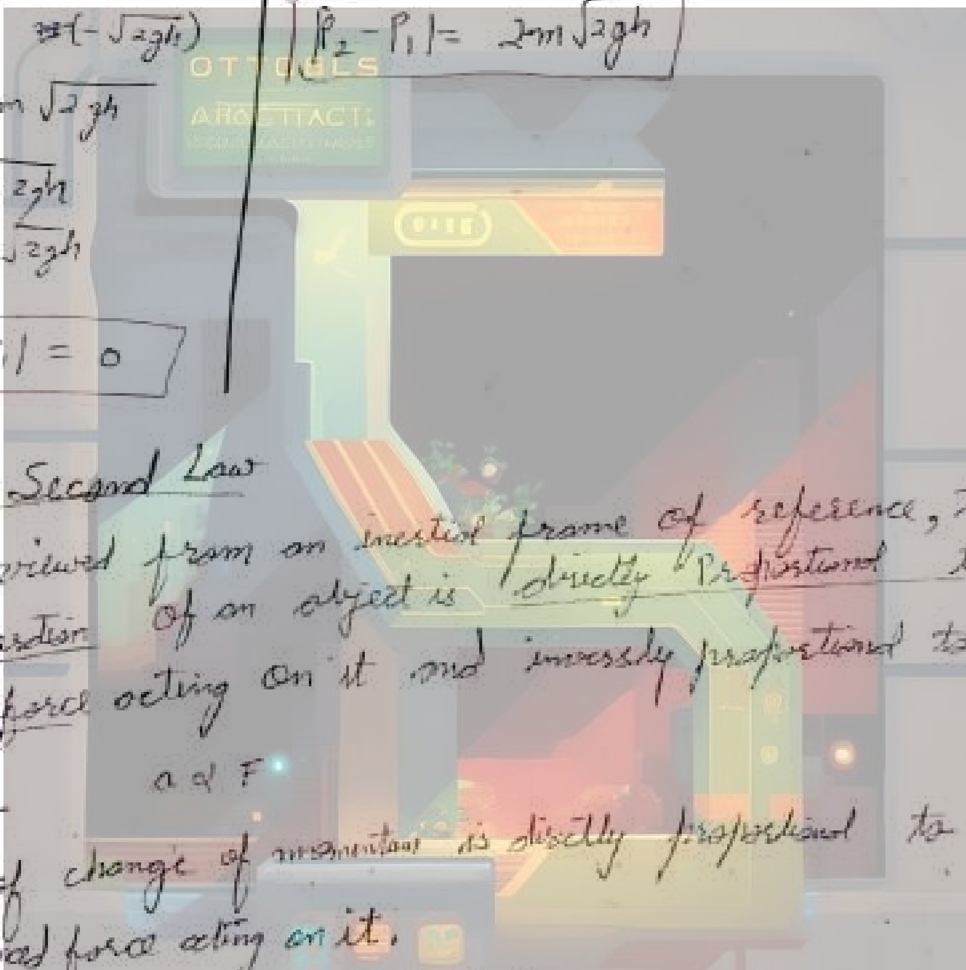
$\boxed{|P_2| - |P_1| = 0}$

$P_2 - P_1$

$-m\sqrt{2gh} - m\sqrt{2gh}$

$-2m\sqrt{2gh}$

$\boxed{|P_2 - P_1| = 2m\sqrt{2gh}}$



Newton's Second Law

→ When viewed from an inertial frame of reference, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

$a \propto \frac{1}{m}$ $\qquad a \propto F$

→ Rate of change of momentum is directly proportional to net unbalanced force acting on it.

$P_i = mu$

$P_f = mv$

$\Delta P = mv - mu$

$\boxed{\frac{\Delta P}{t} \propto F}$

$F \propto \frac{m(v-u)}{t}$

$F \propto ma$

$F = k\,ma \quad (k=1)$

$\boxed{F = ma}$

$\boxed{F = \frac{dP}{dt}}$ → Slope of P-T graph

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$$\int_{p_i}^{p_f} dp = \int_0^t F\,dt$$

change in momentum — area under F-t graph

Impulse (J):- It is the change in momentum of a body.

$J = \Delta P = mv - mu = Ft$

SI unit:- Ns or kg m/s

Q A machine gun has mass 5 kg. It fires 50 g bullets at the rate of 30 bullets per minute at a speed 400 m/s. What force is required to keep gun in position.

$F = m\frac{(v-u)}{t}$

$= \frac{50}{1000}\left[\frac{400-0}{2}\right]$

$= \frac{5}{100} \times 200$

$= 5 \times 2$

$\boxed{= 10 N}$

Q A dish of mass 10 g is kept horizontally in air by firing 5 g bullets 10/s. If bullets rebound with same speed, with what speed are bullets fired (g = 9.8 m/s²)

Force to keep dish in air $= \frac{10}{1000} \times 9.8$

$= \frac{98}{1000}$ N

~~$F = m\frac{(v-u)}{t}$~~

~~$= 5 \times \frac{(-u)}{1} \times 10$~~

~~$\frac{98}{1000} = -50u$~~

$F = m\frac{(v-u)}{t}$

$\frac{98}{1000} = \frac{5}{1000}\frac{(v-(-v))}{1} \times 10$

$\frac{98}{1000} = 50 \times 2v$

$\frac{98}{1000} = \frac{100v}{1000}$

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$v = \frac{98}{100}$

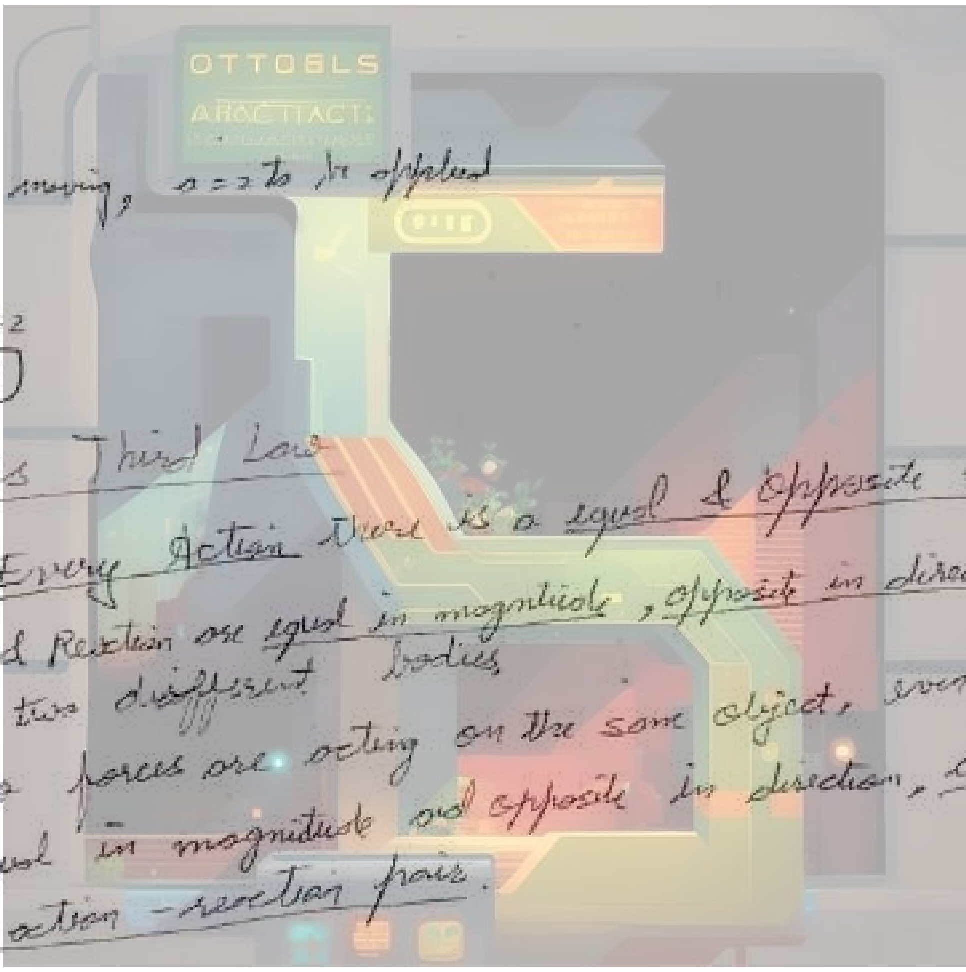
$\boxed{v = 0.98 \, m/s}$

Q A body of mass 4 kg moving on horizontal surface with initial velocity 6 m/s comes to rest after 3 s. If one wants to keep moving the body with same speed of 6 on same surface, find required force.

$u = 6$
$v = 0$

$t = 3s$

$a = \frac{v-u}{t}$



$= \frac{-6}{3}$

$= -2$

- to keep moving, $a = 2$ to be applied

$F = ma$

$F = 4 \times 2$

$\boxed{F = 8N}$

Newton's Third Law

→ To Every Action there is a equal & opposite reaction.

→ Action & Reaction are equal in magnitude, opposite in direction and acts on two different bodies

→ if two forces are acting on the same object, even if they are equal in magnitude and opposite in direction, cannot be an action - reaction pair.

Free Body Diagram

→ diagram of a body showing all the forces on it along with direction & magnitude.

→ Consider only the forces applied on that body & not the forces the body applies on any other body.

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Types of Forces

1. Contact forces - The force which acts between two bodies in contact are called contact forces.

$|F_{21}| = |F_{12}| = F_c$

$F = (m_1 + m_2)\, a$

$a = \frac{F}{(m_1 + m_2)}$

for m_2,

$F_c = m_2 a$

$\boxed{F_c = \frac{m_2 F}{m_1 + m_2}}$

for m_1,

$F - F_c = m_1 a$

$F - F_c = \frac{m_1 F}{m_1 + m_2}$

$F_c = F\left[1 - \frac{m_1}{m_1 + m_2}\right]$

$\boxed{F_c = \frac{m_2 F}{m_1 + m_2}}$

$\boxed{\Sigma \vec{F} = m \vec{a}}$ → Dynamic Equation

Q find acceleration & contact force b/w A & B.

$F = ma$

$10 = 5 \times a$

$a = \frac{10}{5}$

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

for, b

$F_c = 3 \times 2$

$\boxed{F_c = 6\ N}$

for, a

$F - F_c = 2 \times 2$

$10 - F_c = 4$

$F_c = 10 - 4$

$\boxed{F_c = 6\ N}$

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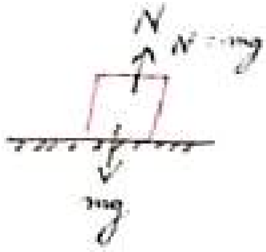
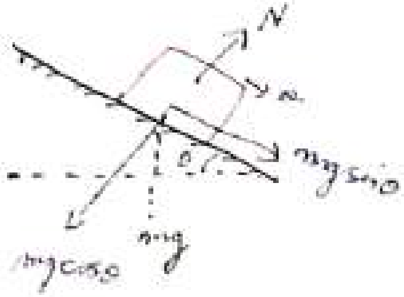
2. **Normal Force & Weight of body** – Normal force is a special type of contact force which always act ⊥ to surface in contact





$$N = mg\cos\theta$$

$$mg\sin\theta = ma$$

$$\boxed{g\sin\theta = a} \text{ (along incline)}$$

Eg

$$N_1 = mg$$

Note

→ when external force is applied on a object, the normal force shifts towards the direction of applied force.

→ on the verge of toppling, normal reaction passes through edge of the block.

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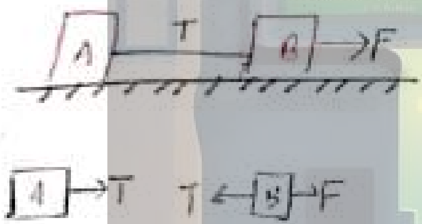
3. Tension Force – ~~The~~ The force with which elements of a string pull each other is called tension force.

→ An Ideal string is considered to be massless, inextensible, pulls at any point on the string can pull but not push.

→ An Ideal pulley is assumed to be massless, frictionless. Action of pulley is to change the direction of force. Tension is same in the pulley on both sides of it.

→ Tension force is always directed away from point of contact.

Eg.



$T_2 = m_2 g$ (for body at rest)

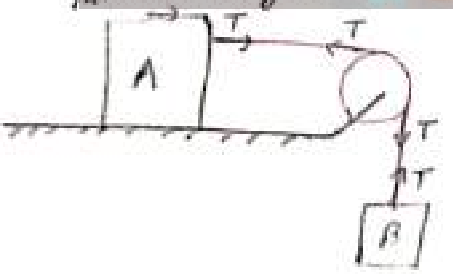
$T_2 = m_2 g$

$T_1 = m_1 g + T_2$

$T_1 = m_1 g + m_2 g$

$\boxed{T_1 = (m_1 + m_2) g}$

massless string and frictionless pulley & string



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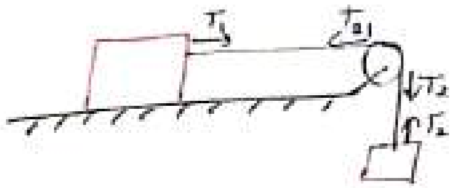
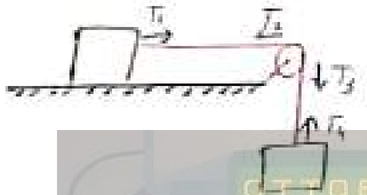
Massless String & pully is not frictionless



Massive String & Pulley is not frictionless



Eg

$g = 10\,m/s^2$

find ~~...~~ tension at A, B, C
└ midpoint

at A, $T = mg$

$T = (2+1) \times 10$

$= 3 \times 10$

$\boxed{T_A = 30N}$

$T_B = mg$

$= (1+1) \times 10$

$\boxed{T_B = 20N}$

$T_C = mg$

$= 1 \times 10$

$\boxed{T_C = 10N}$

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Q A rope of uniform mass distribution of mass m & length l, find ~~tension at~~ tension at distance x from bottom.

length till $x = x$

$$\text{mass} = \cancel{\frac{m(l-x)}{l}} = \frac{mx}{l}$$

$$T = mg$$

$$= \cancel{\frac{m(l-x)}{l}g}$$

$$\boxed{T = \frac{mxg}{l}}$$

H.W.
Ch-3
S-1 (1-20)

Q Find acceleration of blocks & Tension in string connecting A, B.

$$\cancel{F = ma}$$
$$\cancel{16 = 18a}$$
$$\cancel{a = \frac{8}{9}}$$

$$F = ma$$
$$16 = 8a$$
$$a = \frac{16}{8}$$
$$\boxed{a = 2}\ m/s^2$$

$$F_1 = 3 \times 2$$
$$\boxed{F_1 = 6N}$$

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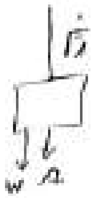
Q with what min acceleration can a fireman slide down a rope whose breaking strength is of his 2/3 weight.



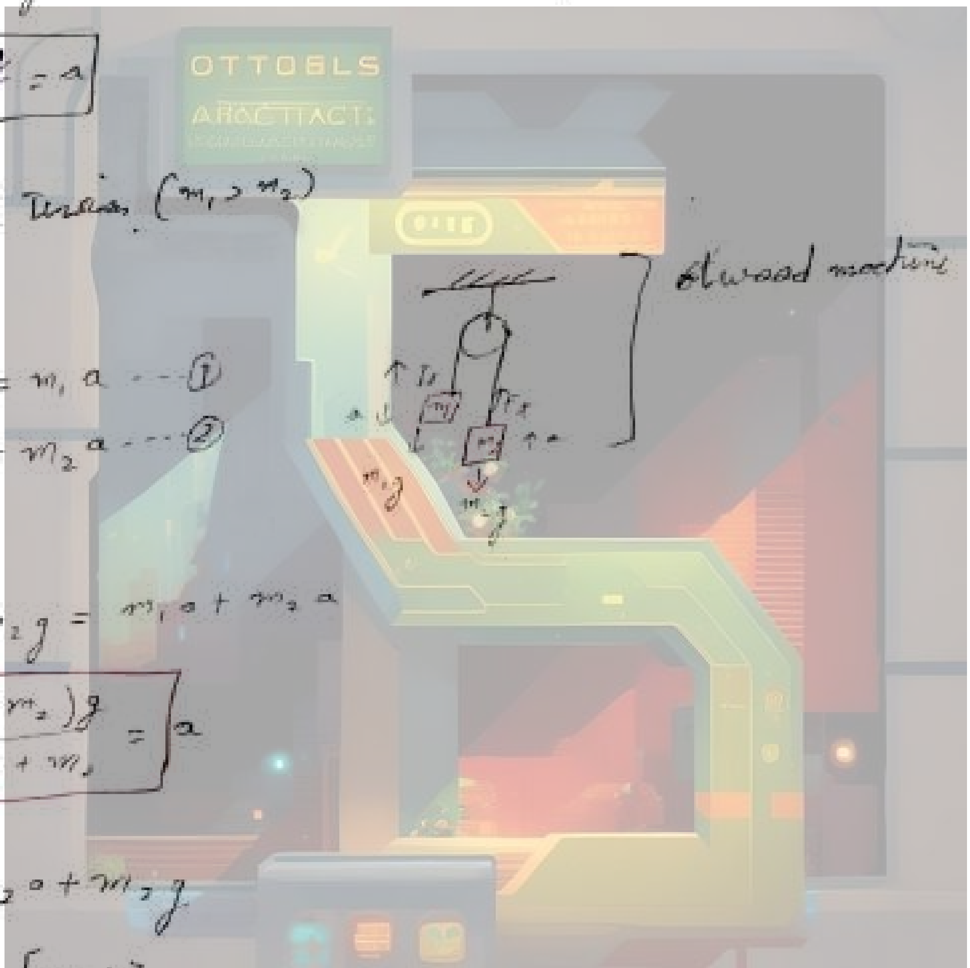
$\frac{2}{3}w$ $F_t - F = mga$

$w - \frac{2}{3}w = \frac{w}{g} \cdot a$

$1 - \frac{2}{3} = \frac{a}{g}$

$\frac{1}{3} = \frac{a}{g}$

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



Q Find acc & Tension $(m_1 > m_2)$

Atwood machine

acc = g

$m_1 g - F_t = m_1 a$ ---- ①

$F_t - m_2 g = m_2 a$ ---- ②

① + ②

$m_1 g - m_2 g = m_1 a + m_2 a$

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

$F_t = m_2 a + m_2 g$

$= m_2 [a + g]$

$= m_2 \left[\frac{(m_1 - m_2)g}{m_1 + m_2} + g\right]$

$= m_2 g$

$= m_2 g \left[\frac{m_1 - m_2 + m_1 + m_2}{m_1 + m_2}\right]$

$$\boxed{F_t = \frac{2 m_1 m_2 g}{m_1 + m_2}}$$

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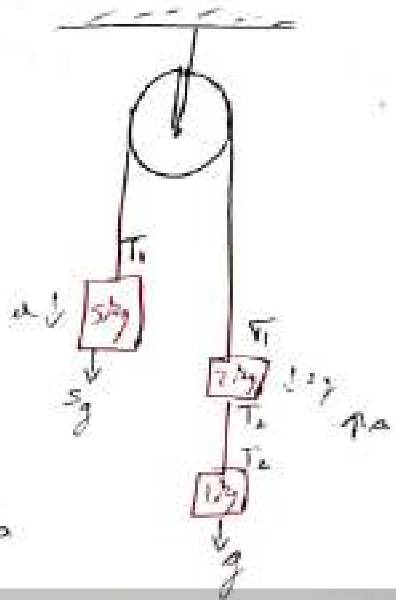
Q find acc & Tention



$5g - T_1 = 5a$ ---(1)

$T_1 - (2g + T_2) = 2a$ ---(2)

$T_2 - g = a$ ---(3)

(3) − (2)

$-g + 2g - T = 0$

$\boxed{T_1 = g}$

$g - 2g + T_2 = a$

$T_2 - g = a$

$-2g + 2T_2 = 2a$

$5g - g = a$

$\boxed{a = 4g}$

$T_2 = a + g$

$= 4g + g$

$\boxed{T_2 = 5g}$

(3) + (2)

$T_1 - 2g - g = 3a$

$T_1 - 3g = 3a$

$5g - T_1 = 5a$

$2g = 8a$

$a = \frac{g}{4}$

$a = \frac{10}{4}$

$\boxed{a = 2.5\,m/s^2}$

$5g - T_1 = 5a$

$T_1 = 5g - 5a$

$T_1 = 5g - \frac{5g}{4}$

$T_1 = \frac{15g}{4}$

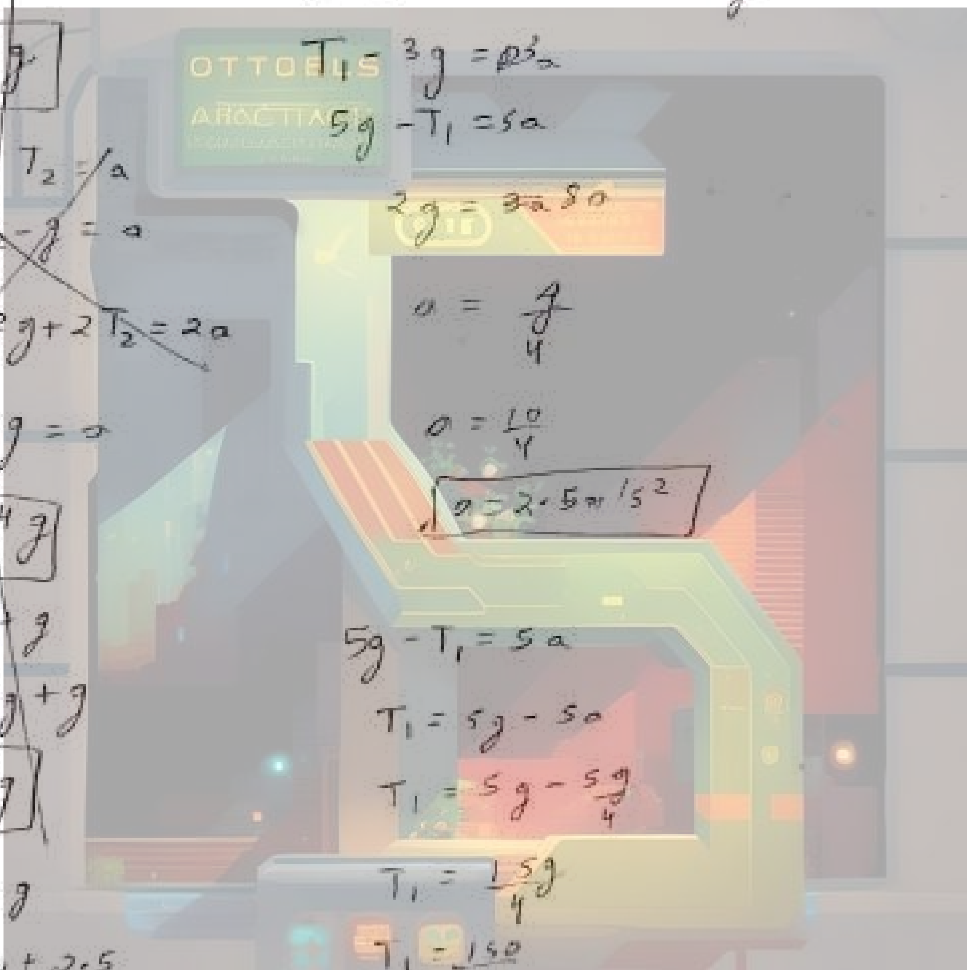
$T_1 = \frac{150}{4}$

$\boxed{T_1 = \frac{75}{2} N}$

$T_2 = a + g$

$T_2 = 10 + 2.5$

$\boxed{T_2 = 12.5 N}$



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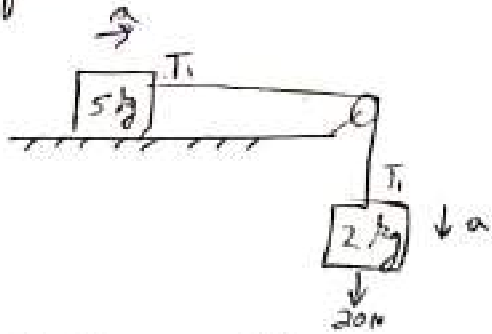
Q find acc & Tension.



$T_1 = 5a \quad \text{---} \ (1)$

$\cancel{T_1 - 20 = 2a \quad \text{---} \ (2)}$

$\cancel{20 = 3a}$

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

$20 - T_1 = 2a$

$20 = 7a$

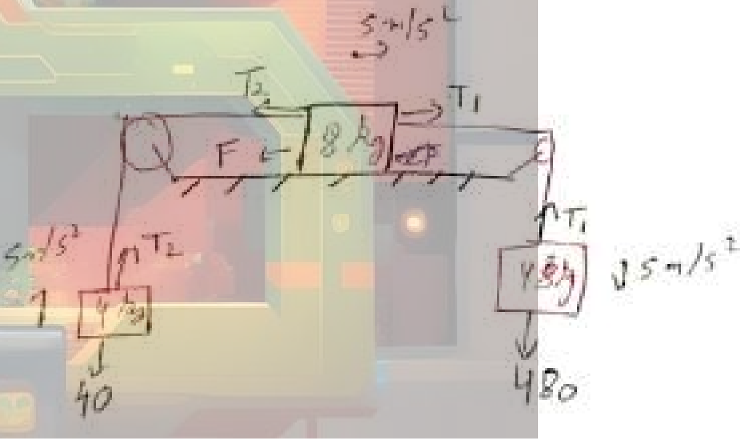
$\boxed{a = \frac{20}{7}\ m/s^2}$

$T = 5a$

$T = 5 \times \frac{20}{7}$

$\boxed{T = \frac{100}{7}\ N}$

Q. $a = 5\ m/s^2$
find friction of 8kg block



for 48kg

$480 - T_1 = 5 \times 48$

$480 - T_1 = 240$

$T_1 = 480 - 240$

$\boxed{T_1 = 240N}$

for 4kg

$T_2 - 40 = 5 \times 4$

$\cancel{T_2 = 45N}$

$T_2 - 40 = 20$

$\boxed{T_2 = 60N}$

for 8kg

$T_1 - T_2 - F = 8 \times 5$

$240 - 60 - F = 40$

$F = 240 - 100$

$\boxed{F = 140N}$

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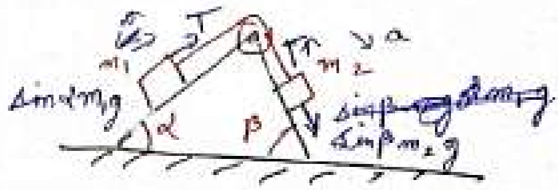
Q find acc.



$\sin\beta\, m_2 g - T = m_2 a$ --- (1)

$T - \sin\alpha\, m_1 g = m_1 a$ ---- (2)

$\sin\beta\, m_2 g - \sin\alpha\, m_1 g = m_2 a + m_1 a$

$$\boxed{\frac{g(\sin\beta\, m_2 - \sin\alpha\, m_1)}{(m_2 + m_1)} = a}$$

Q acceleration of blocks & tension in strings.

$\Delta l_1 + \Delta l_2 + \Delta l_3 = 0$

$x_{B_A} + x_{B_A} - x_B = 0$

$\boxed{2x_A = x_B}$

for A,

$-T' + mg = 3a_A$

$mg - T' = 3a_A$

$mg - 2T = 3a_A$

$30 - 2T = 3a_A$ — (1)

~~for B,~~

~~$mg - T = a_B$~~

~~$mg - T = 2a_A$ -- (2)~~

~~$10 - T = 2a_A$~~

for B,

$T - mg = a_B$

$T - 10 = 2a$

$2T - 20 = 4a$ — (2)

(1) + (2)

$10 = 7a$

$\boxed{a_A = \frac{10}{7}}$

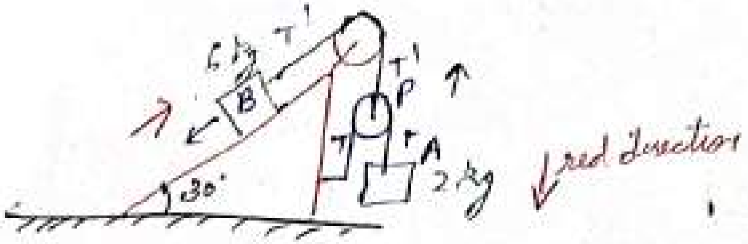
$\boxed{a_B = \frac{20}{7}}$

$T = \frac{20}{7} + 10$

$\boxed{T = \frac{90}{7}\ N}$

(88)

Q find acceleration ($m_1 > m_2$)



$x_B = x_P$

$x_P + x_P - x_A = 0$

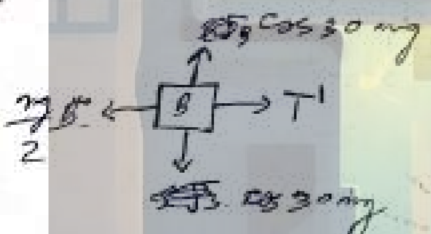
$\boxed{2x_A = x_B}$ $\boxed{T' = 2T}$

for A.

$T - 20 = 2a_A$ --- (1)

$2T - 40 = 4a_A$ --- (1)

for B.



$30 - T' = 6a_B$

$30 - 2T = 12a_A$ --- (2)

(1) + (2)

$-10 = 16a_A$

~~$a_A = -\frac{5}{8}$ m/s²~~ ~~$a_B = -\frac{5}{7}$ m/s²~~ ~~$a_A = -\frac{5}{4}$ m/s²~~

$a_A = \frac{-10}{7}$

$a_B = \frac{-5}{7}$

~~$T - 20 = -\frac{20}{7}$~~

~~$T = 20 - \frac{20}{7}$~~

~~$T = \frac{140-20}{7}$~~

~~$\boxed{T = \frac{120}{7} N}$~~

~~$\boxed{T' = \frac{240}{7} N}$~~

~~$T - 20 = 2 \times -\frac{5}{8}$~~

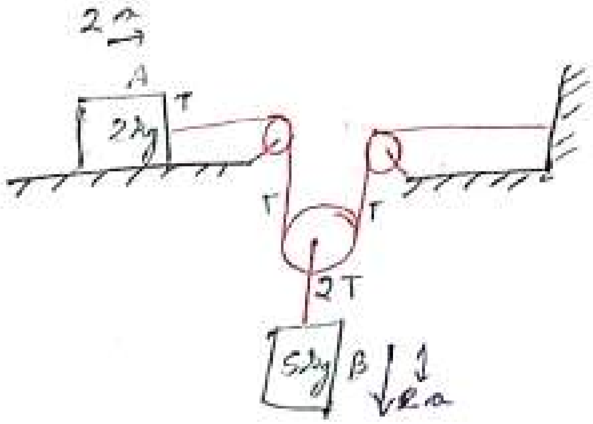
~~$T = 20 - \frac{5}{4}$~~

~~$T = \frac{80-5}{4}$~~

~~$\boxed{T = \frac{75}{4} N}$~~

~~$\boxed{T' = \frac{75}{2} N}$~~

l. find acceleration.



$-x_A + 2x_B = 0$

$\boxed{2x_B = x_a}$

for A,

$T = \overset{4}{\cancel{2}}a$ --- (1)

$2T = 8a$ --- (1)

for B

$50 - 2T = \overset{5}{\cancel{10}}a$ --- (2)

(1) + (2)

$50 = \overset{3}{\cancel{19}}a$

$\cancel{a = \frac{25}{7}}$ $A = \frac{50}{13}$

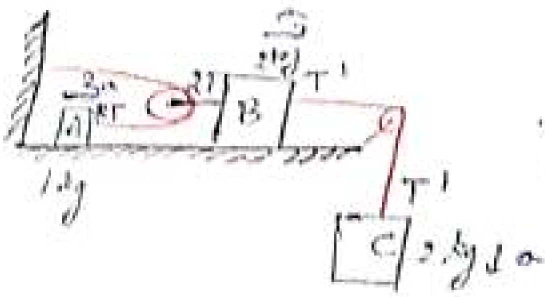
$\cancel{\boxed{a_A = \frac{25}{7}}}$

$\cancel{\boxed{a_B = \frac{50}{7}\ m/s^2}}$

$\boxed{a_B = \frac{50}{13}\ m/s^2}$

$\boxed{a_A = \frac{100}{13}\ m/s^2}$

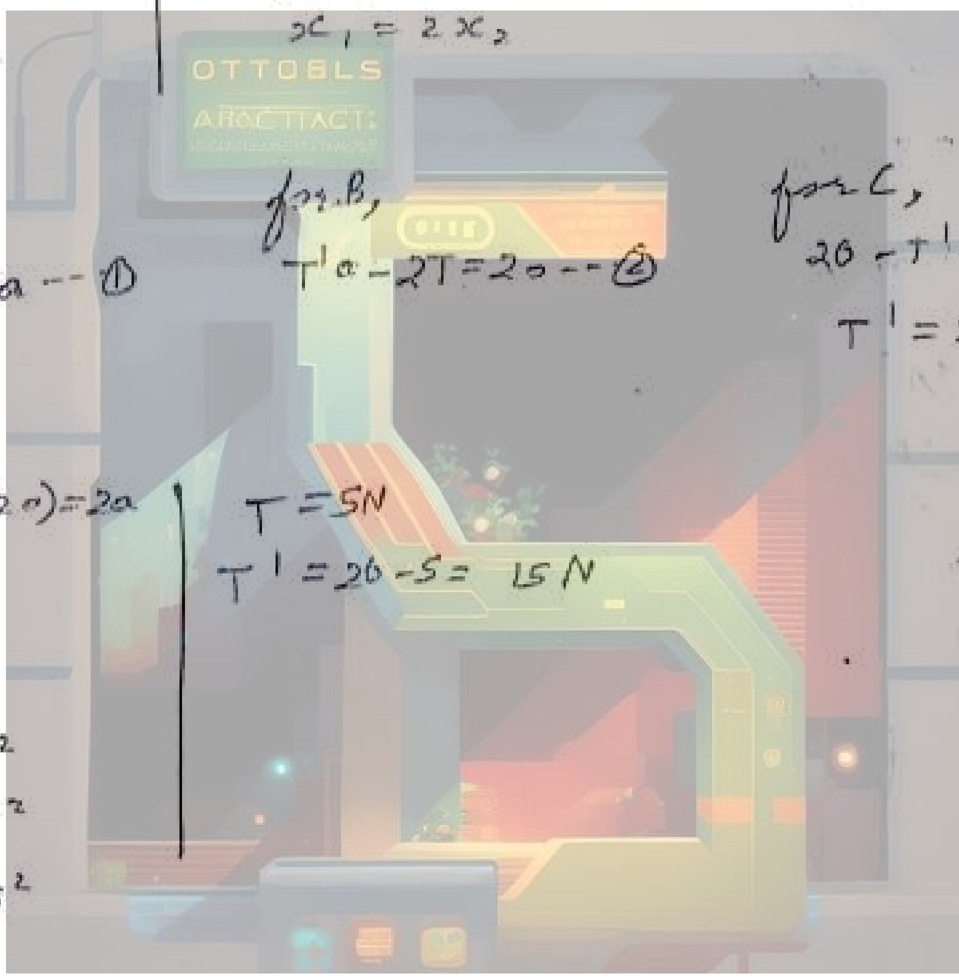
Q find acceleration & Tension



sol^n

$x_3 - x_2 = 0$ | $x_2 - x_1 + x_2 = 0$

$x_3 = x_2$ | $x_1 = 2x_2$



for A,

$T = 2a$ --- (1)

for B,

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

for C,

$20 - T' = 2a$

$T' = 20 - 2a$

$20 - 2a - 2(2a) = 2a$

$20 = 8a$

$a = \frac{5}{2}$

$T = 5N$

$T' = 20 - 5 = 15N$

$a_A = 5 \ m/s^2$

$a_B = 5/2 \ m/s^2$

$a_C = 5/2 \ m/s^2$

Q25. Pg 103

$x_A = x_P$

$-x_B + x_A + x_A = 0$

$2x_A = x_B$

$mg - 2T = m a x_A$

$\cancel{mg - 2T = 2m x_A}$

$T - mg = 2m x_A$

$2T - 2mg = 4m x_A$

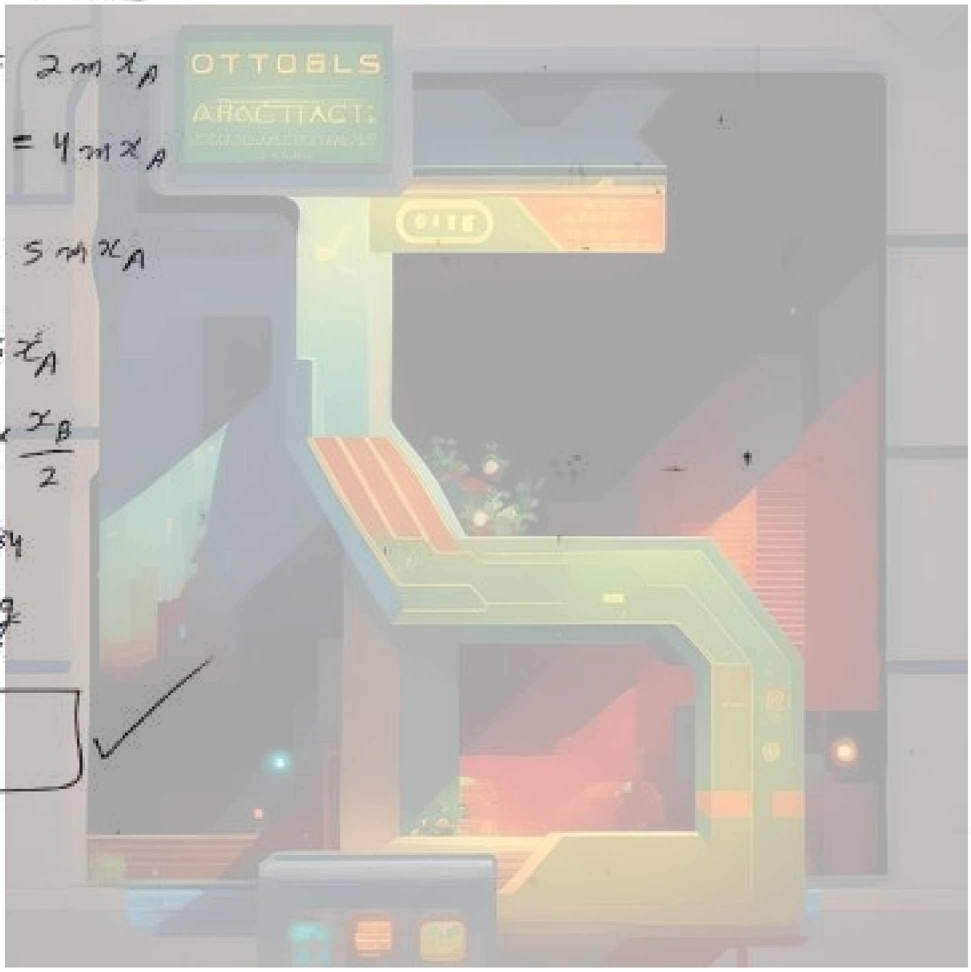
$-mg = 5m x_A$

$-g = 5 x_A$

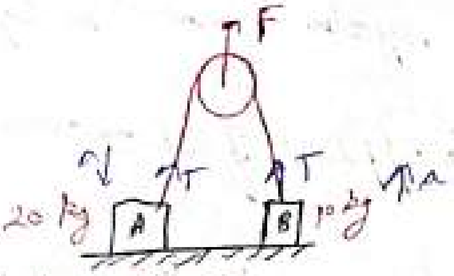
$-g = 5 \times \frac{x_B}{2}$

$x_B = \frac{2g}{5}$

$\boxed{C}$ ✓



Q



find acc if F:-

a) 124 N b) 294 N c) 424 N

~~a) T = 62 N~~

~~for A~~

~~mg 200 − T = 20 a~~

for B

T − 100 = 10 a

~~① + ②~~

~~100 = 30 a~~

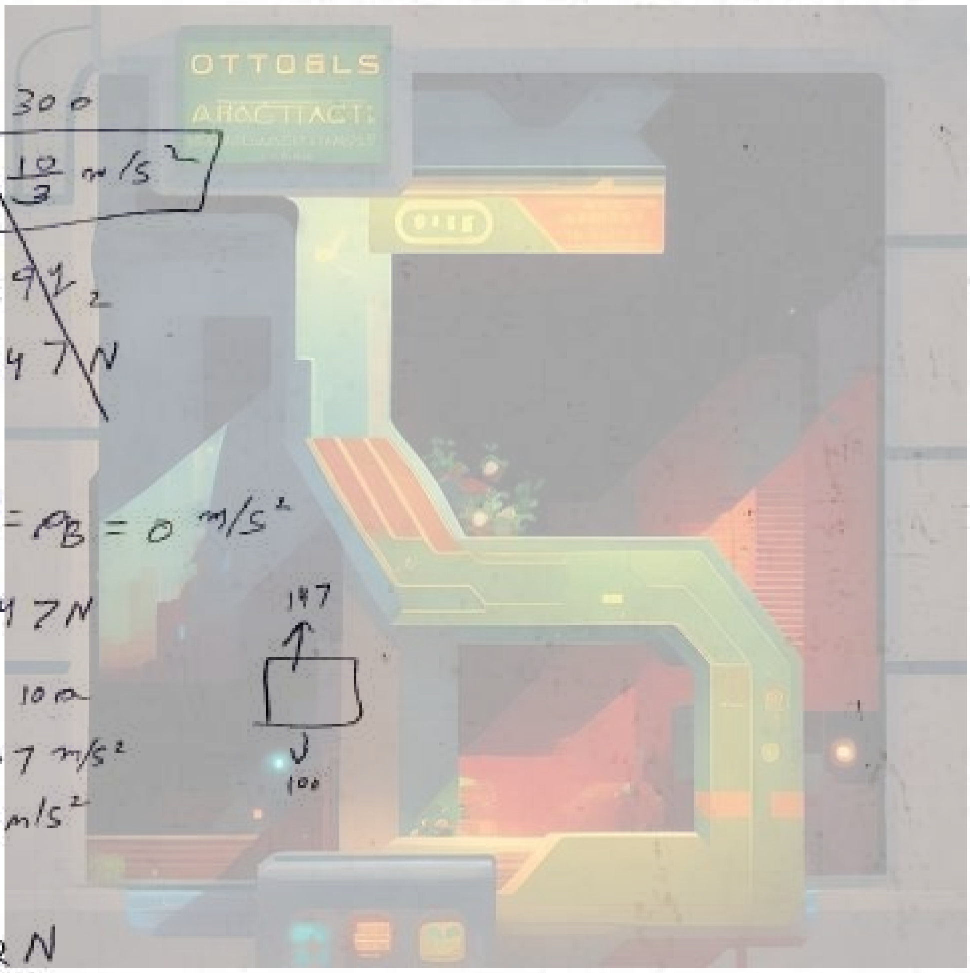
~~$\boxed{a = \frac{10}{3}\ m/s^2}$~~

~~c) T = 294/2~~

~~= 147 N~~

for A

a) acc of A = a_B = 0 m/s²



b) T = 147 N

147 − 100 = 10 a

$a_B = 4.7\ m/s^2$

$a_A = 0\ m/s^2$

c) T 212 N

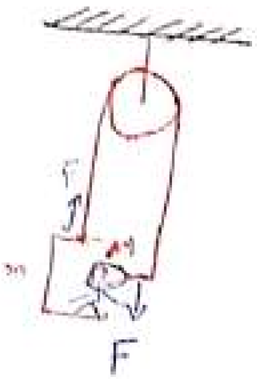
12 = 20 a

112 = 10 a

$a_A = \frac{3}{5}\ m/s^2 = 0.6\ m/s^2$

$a_B = 11.2\ m/s^2$

1)



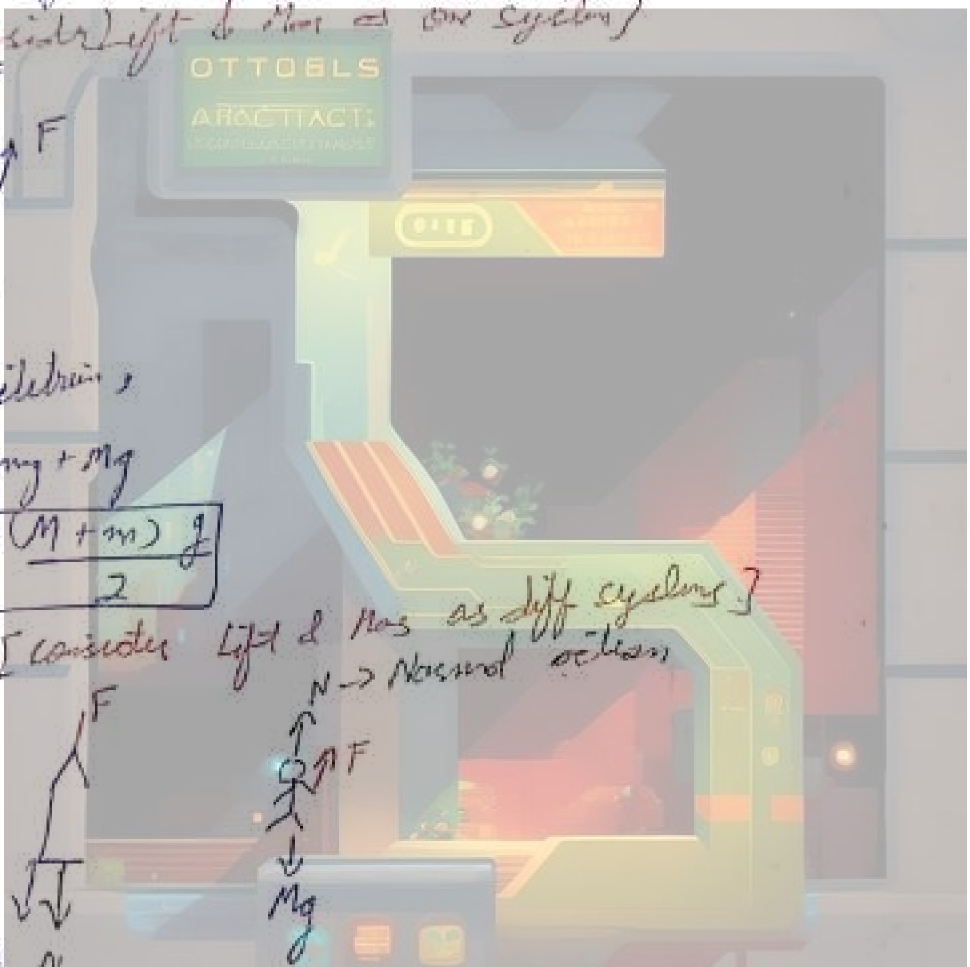
a) find F for which if system remains in equilibrium

b) If force F' (>F) is applied find acceleration of system

c) Find Normal Reaction on man in (b)

on Lift,

Method I [consider Lift & Man as one system]



for equilibrium,

$2F = mg + Mg$

$$\boxed{F = \frac{(M+m)}{2} g}$$

Method II [consider Lift & Man as diff systems]

N -> Normal action

Normal reaction

$F + N = Mg$

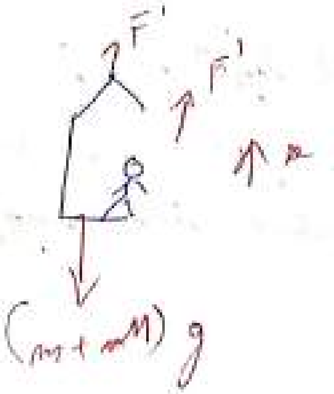
$N = Mg - F$

$F = mg + N$

$F = mg + Mg - F$

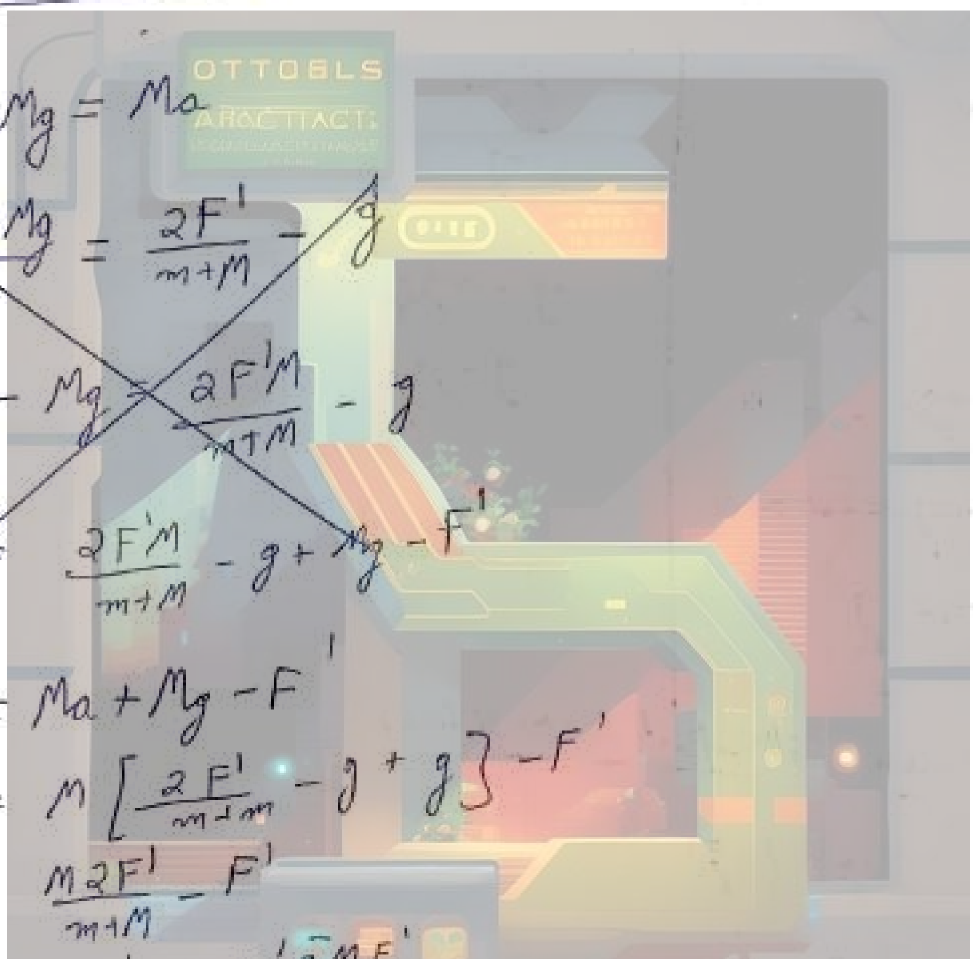
$2F = (m+M) g$

$$F = \frac{(m+M) g}{2}$$

b) 

$$2F' - (m+M)g = (m+M)a$$

$$\boxed{a = \frac{2F'}{m+M} - g}$$



c) $N + F' - Mg = Ma$

$$\frac{N+F'-Mg}{M} = \frac{2F'}{m+M} - g$$

$$N + F' - Mg = \frac{2F'M}{m+M} - g$$

$$N = \frac{2F'M}{m+M} - g + Mg - F'$$

$$N = Ma + Mg - F'$$

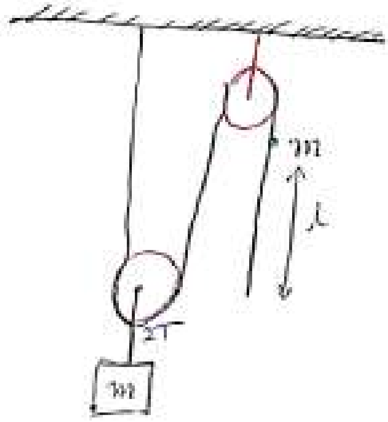
$$N = M\left[\frac{2F'}{m+M} - g + g\right] - F'$$

$$N = \frac{M2F'}{m+M} - F'$$

$$N = \frac{M2F' - mF' - MF'}{m+M}$$

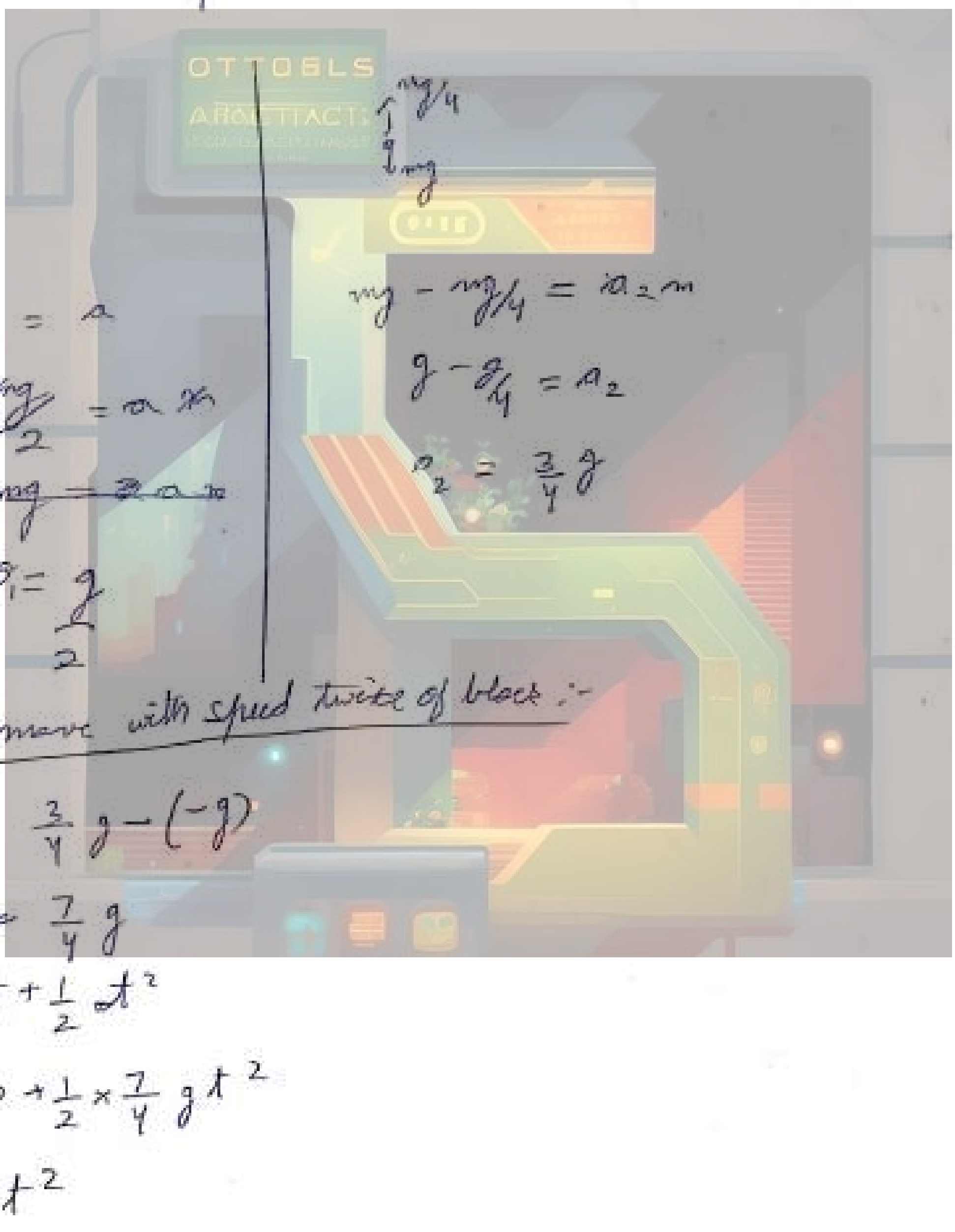
$$\boxed{N = \frac{F'(M-m)}{(M+m)}}$$

Q



friction between bead & light string is $mg/4$. System is released from rest. Find time taken by string to lost contact with string.

Tension $T = mg/4$



$mg/2$ ↑, m, ↓ mg, a

$mg - mg/2 = a$

$\cancel{mg}\ \frac{mg}{2} = a\,m$

$\cancel{mg = 2am}$

$a_1 = \frac{g}{2}$

↑ $mg/4$, ↓ mg

$mg - mg/4 = a_2 m$

$g - g/4 = a_2$

$a_2 = \frac{3}{4}g$

* rope will move with speed twice of block :-

$a_{rel} = \frac{3}{4}g - (-g)$

$= \frac{7}{4}g$

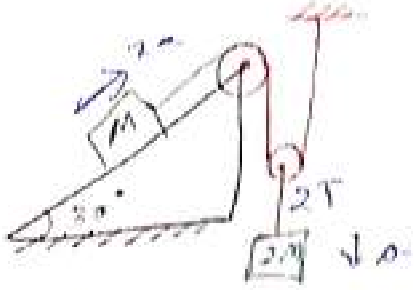
$s = ut + \frac{1}{2}at^2$

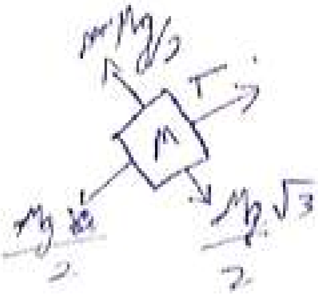
$l = 0 + \frac{1}{2} \times \frac{7}{4} g t^2$

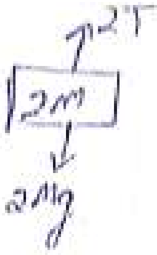
$\frac{8l}{7g} = t^2$

$\boxed{t = 2\sqrt{\frac{2l}{7g}}}$

Q. find acc of M





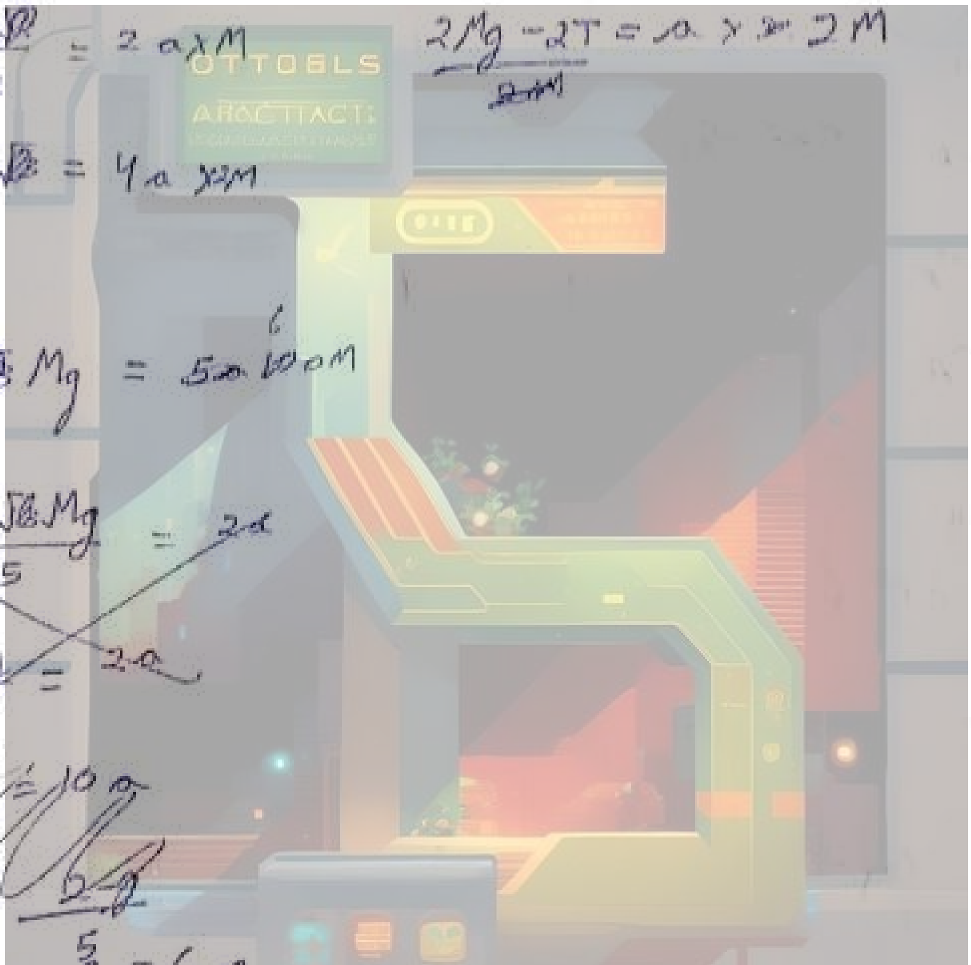


$T - \frac{Mg}{2} = 2a \times M$

$2Mg - 2T = a \times 2M$

$2T - Mg = 4a \times 2M$

$2Mg - Mg = 5a\ 6aM$



$\frac{4Mg - 2Mg}{5} = 2a$

$\frac{2Mg}{5} = 2a$

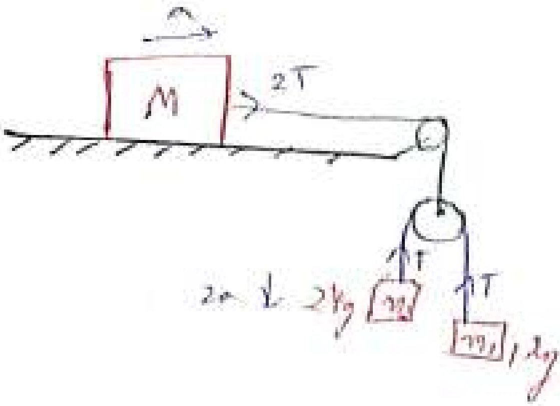
$2a = \frac{g}{5}$

$2g - g = 6a$

$\frac{g}{6} = a$

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

Q ..



$a_{m_1} = 0$

$a_{2,p} = -a_{m_1,p}$

$a_{m_2} - a_{mp} = a_{mp} - a_{m_1}$

$a_{m_2} = 2a_p$

$a_{m_2} = 2a_M$

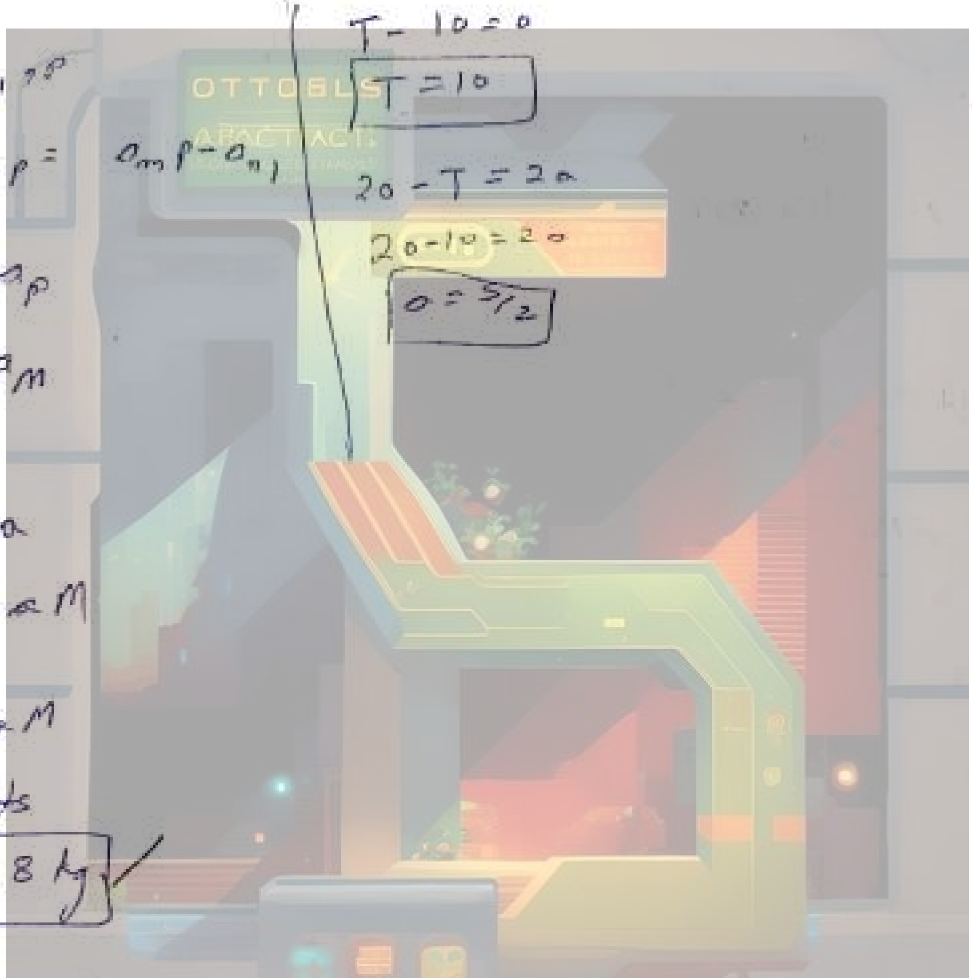
$T - 10 = 0$

$\boxed{T = 10}$

$20 - T = 2a$

$20 - 10 = 2a$

$\boxed{a = 5/2}$



$2T = Ma$

$\frac{20}{5/2} = aM$

$\frac{40}{5} = aM$

$\cancel{a = 8\ m/s}$

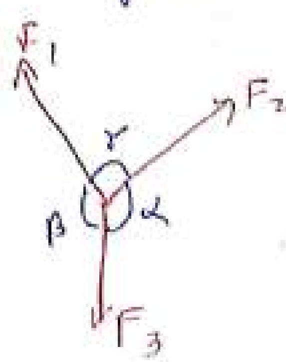
$\boxed{M = 8\ kg}$

Q Static Equilibrium

→ Vector sum of all the forces acting on a body is zero.

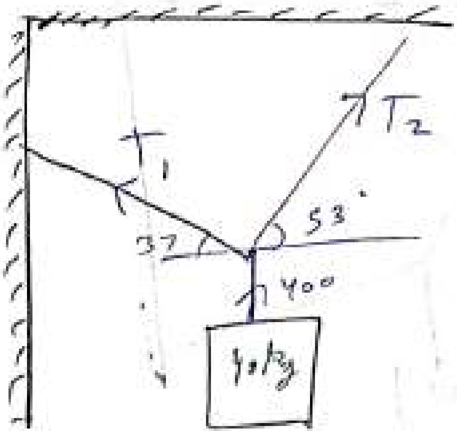
1) Lami's ~~rule~~ Theorem

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



2) Take component vectors of forces

Q find tension in three cords



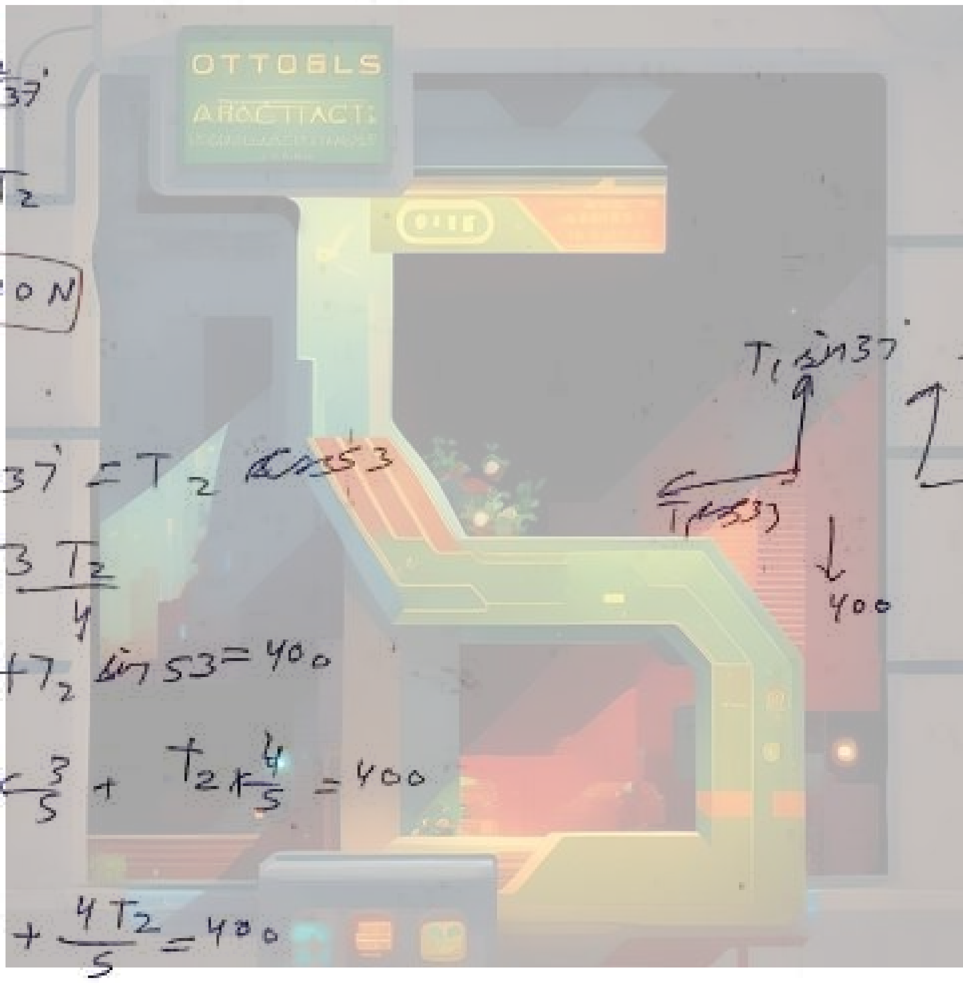
MI

$$\frac{400}{\sin 90} = \frac{T_1}{\sin(90+53)} = \frac{T_2}{\sin(90+37)}$$

$$400 = \frac{T_1}{\cos 53}$$

$$400 \times \frac{3}{5} = T_1$$

$$\boxed{T_1 = 240\,N}$$



$$400 = \frac{T_2}{\cos 37}$$

$$400 \times \frac{4}{5} = T_2$$

$$\boxed{T_2 = 320\,N}$$

MII

$$T_1 \cos 37° = T_2 \cos 53$$

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

$$T_1 \sin 37° + T_2 \sin 53 = 400$$

$$\frac{3T_2}{4} \times \frac{3}{5} + T_2 \times \frac{4}{5} = 400$$

$$\frac{9T_2}{20} + \frac{4T_2}{5} = 400$$

$$\frac{9T_2 + 16T_2}{20} = 400$$

$$25T_2 = 8000$$

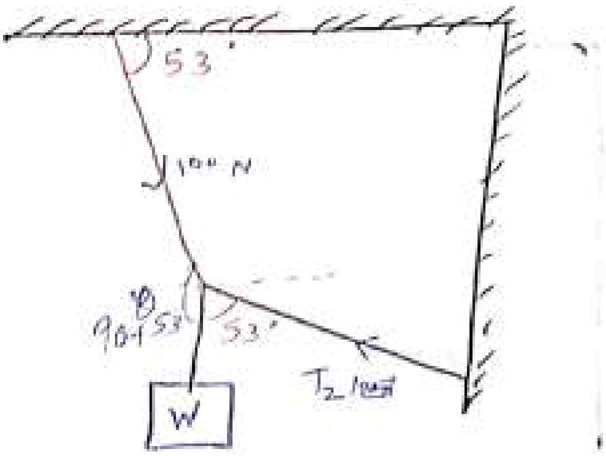
$$T_2 = \frac{8000}{25}$$

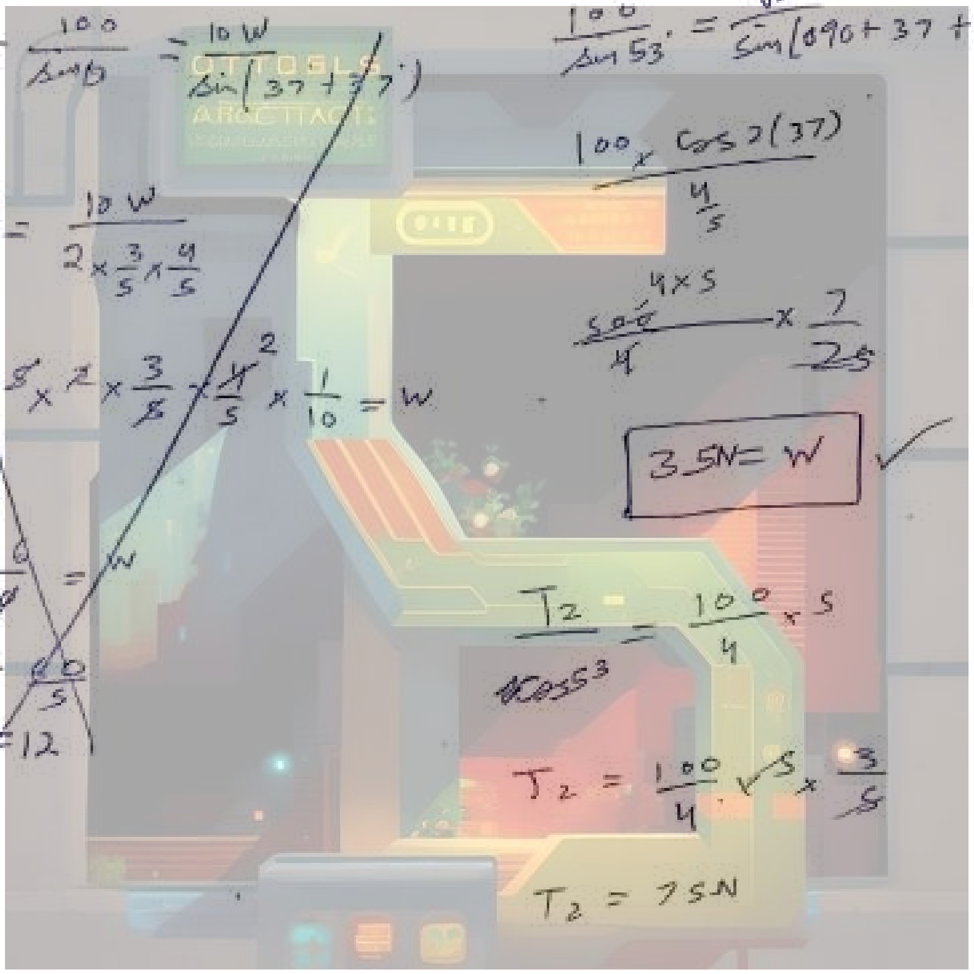
$$\boxed{= 320\,N}$$

$$T_1 = \frac{3}{4} \times 320$$

$$\boxed{= 240\,N}$$

Q max tension 100 N, which the ropes can withstand, find the maximum value of W.





$$\frac{100}{\sin 53} = \frac{100}{\sin\theta} = \frac{10W}{\sin(37+37)}$$

$$\frac{100}{4}\times 5 = \frac{10W}{2\times\frac{3}{5}\times\frac{4}{5}}$$

$$\frac{100}{4}\times 5\times 2\times\frac{3}{5}\times\frac{4}{5}\times\frac{1}{10} = W$$

$$\frac{100\times 6}{5\times 10} = W$$

$$W = \frac{60}{5}$$

$$W = 12$$

$$\frac{100}{\sin 53} = \frac{W}{\sin(90+37+37)}$$

$$\frac{100\times\cos 2(37)}{\frac{4}{5}}$$

$$\frac{500}{4}\times\frac{7}{25}$$

$$\boxed{35N = W}$$

$$\frac{T_2}{\cos 53} = \frac{100}{4}\times 5$$

$$T_2 = \frac{100}{4}\times 5\times\frac{3}{5}$$

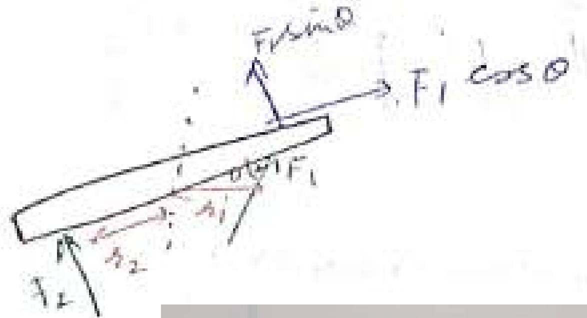
$$T_2 = 75N$$

1

(100)

Torque (τ)

→ Torque measures the turning effect of a force on the body.
→ Magnitude is given by the product of force & $\perp$ distance from the axis of rotation.



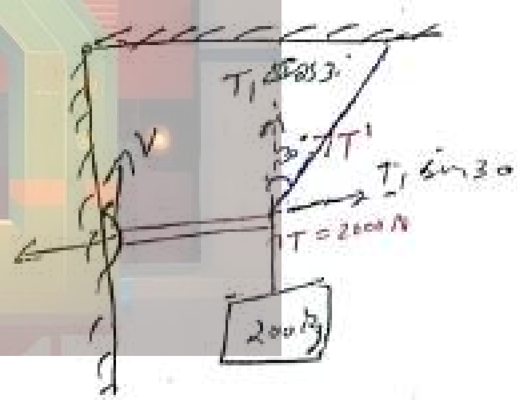
$\tau_{F_1} = (F_1 \sin\theta)(r_1)$ (ACW) → Anti-clockwise

$\tau_{F_2} = F_2 r_2$ (CW)

$\tau_{net} = \tau_{dF_1} - \tau_{F_2}$ (ACW)

Q ~~for~~ find Tension T in string ($g = 10$)
find force exerted by ~~string and~~ rod on hinge

$\Sigma \vec{F} = 0$ translatory equilibrium



$T_1 \sin 30 = H$

$\frac{T_1}{2} = H$ --- ①

~~$T_1 = 2H$~~

$V + \frac{\sqrt{3}T'}{2} = 2000$ --- ②

rotational equilibrium

$\Sigma \vec{\tau} = 0 \qquad \vec{\tau}_P = 0$

$T' \cos 30\, L = 2000 \times L$

$T\frac{\sqrt{3}}{2} = 2000$

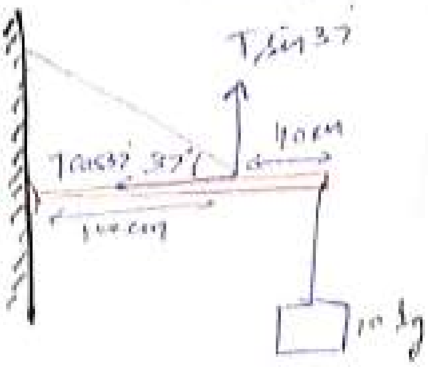
$\boxed{T' = \frac{4000}{\sqrt{3}}}$

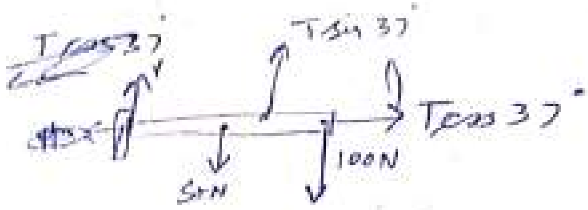
$\boxed{H = \frac{2000}{\sqrt{3}}}$

$\boxed{V = 0}$

F_{net} on hinge → $\sqrt{H^2+V^2} = \frac{2000}{\sqrt{3}}\,N$

Q Mass of rod = 5 kg
find tension & force exerted by hinge on rod.





$\tau_1 = 100 \times \frac{140}{100}$

$= 140$ Nm

$\tau_2 = T \times \frac{3}{5} \times \frac{100}{100}$

$= \frac{60T}{100}$

$\tau_3 = 50 \times \frac{70}{100}$

$= 35$ N

$\tau_3 + \tau_1 = \tau_2$

$140 + 35 = \frac{6T}{10}$

$\frac{1400 + 350}{6} = T$

$\boxed{T = \frac{1750}{6} \text{ N}}$

$50 + 100 = T \sin 37° + V$

$150 = T \times \frac{3}{5} + V$

$150 = \frac{1750}{6} \times \frac{3}{5} + V$

$150 = 175 + V$

$\boxed{V = -25 \text{ N}} \rightarrow$ down

$H = T \cos 37$

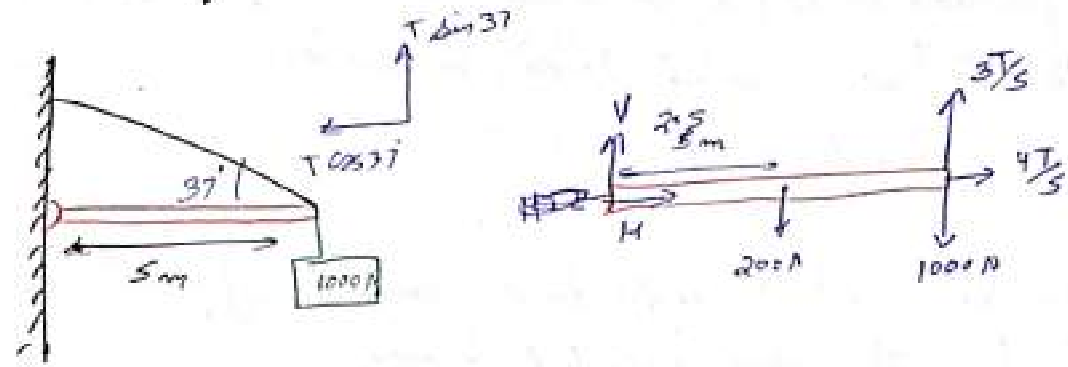
$= \frac{4T}{5}$

$= 4 \times \frac{1750}{6} \times \frac{1}{5}$

$\boxed{H = \frac{700}{3} \text{ N}}$

102

weight of rod = 200 N
find tension & force exerted by hinge on rod.



$\tau_1 = \frac{3T}{5} \times 5$

$= 3T$ Nm

~~$\tau_2 = \frac{4T}{5} \times 5$~~

~~$= 4T$ Nm~~

$\tau_2 = 1000 \times 5$

$= 5000$ Nm

$\tau_3 = 200 \times 2.5$

$= 500$ Nm

$\tau_3 + \tau_2 = \tau_1$

~~$500 + 4T = 3T$~~

~~$500 =$~~

$5000 + 500 = 3T$

$\frac{5500}{3} = T$ N

$\boxed{T = \frac{5500}{3} N}$ ✓

$200 + 1000 = V + \frac{3T}{5}$

$1200 - 1100 = V$

$\boxed{V = 100 N}$ ✓

$H = \frac{4T}{5}$

$\boxed{H = \frac{4400}{3} N}$ ✓

force on rod by hinge $= \sqrt{H^2 + V^2}$

$= \sqrt{10000 + \frac{19360000}{9}}$

$= \sqrt{\frac{90000 + 19360000}{9}}$

$= \frac{100}{3}\sqrt{1945}$ N

Pseudo Force

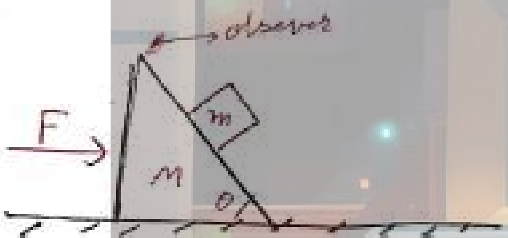
→ Apply a pseudo force on an object if and only if it is placed on another object (non-inertial frame) accelerating w.r.t. some inertial frame of reference.

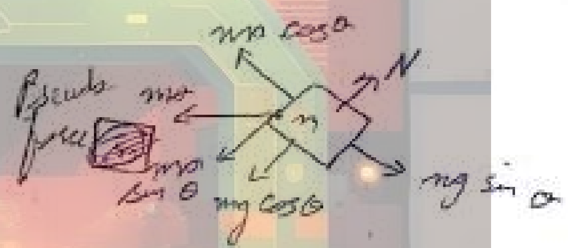
→ The direction of Pseudo force must be opposite to direction of acceleration of non-inertial frame.

→ Pseudo Force = mass of Body × acceleration of non-inertial frame.

→ After applying Pseudo force on a body, all equations and results associated with it become relative to respective non-inertial frame.

Q. All surfaces are smooth. find F such that m remains at rest w.r.t wedge





$F = (m+M)a$

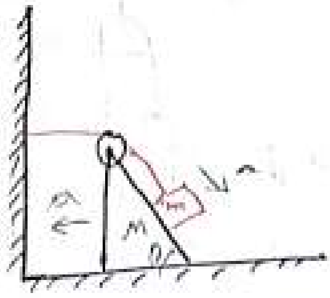
$a = \frac{F}{m+M}$

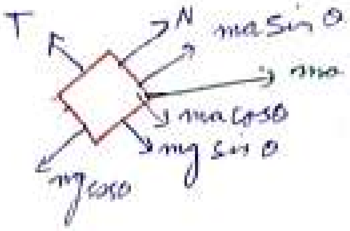
$ma\cos\theta = mg\sin\theta$ (at rest)

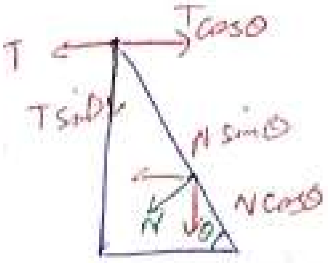
$a = g\tan\theta$

$$\boxed{F = (m+M)\,g\tan\theta}$$

Q find acceleration of M.







$N + ma\sin\theta = mg\cos\theta$ (block has no vertical velocity)

$N = mg\cos\theta - ma\sin\theta$ ---- (1) (block's horizontal vel)

$mg\cos\theta + mg\sin\theta - T = am$

$T = mg\cos\theta + mg\sin\theta - ma$ ---- (2)

$T + N\sin\theta - T\cos\theta = Ma$ ---- (3)

$mg\cos\theta + mg\sin\theta - ma + mg\cos\theta\sin\theta - mg\sin^2\theta - mg\cos^2\theta - mg\sin\theta\cos\theta$

$+ ma\cos\theta = Ma$

$mg\cos\theta + mg\sin\theta - ma - mg + ma\cos\theta = Ma$

~~$mg(\sin\theta\cos\theta - 1) = Ma + ma - ma\cos\theta$~~

~~$a(M + m - m\cos\theta)$~~

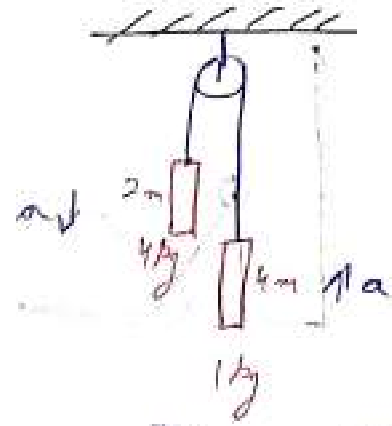
~~$a = \frac{mg(\sin\theta\cos\theta - 1)}{(M + m - m\cos\theta)}$~~

$mg\sin\theta - mg = Ma + ma - 2ma\cos\theta$

$$a = \frac{mg\sin\theta - mg}{M + m - 2m\cos\theta}$$

$$\boxed{a = \frac{g(m\sin\theta - m)}{M + m - 2m\cos\theta}}$$

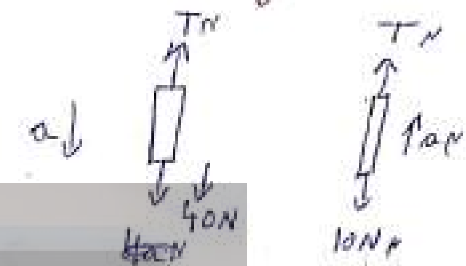
Q released from rest. find time to across each other



~~$40N + 4a - T = 4a$~~

~~$40N = T$~~

~~$10 - T = a$~~



$40 - T = 4a$

$T - 10 = a$

$\boxed{40 = a}$

$30 = 5a$

$\boxed{a = 6\ m/s^2}$

$a_{rel} = 12\ m/s^2$

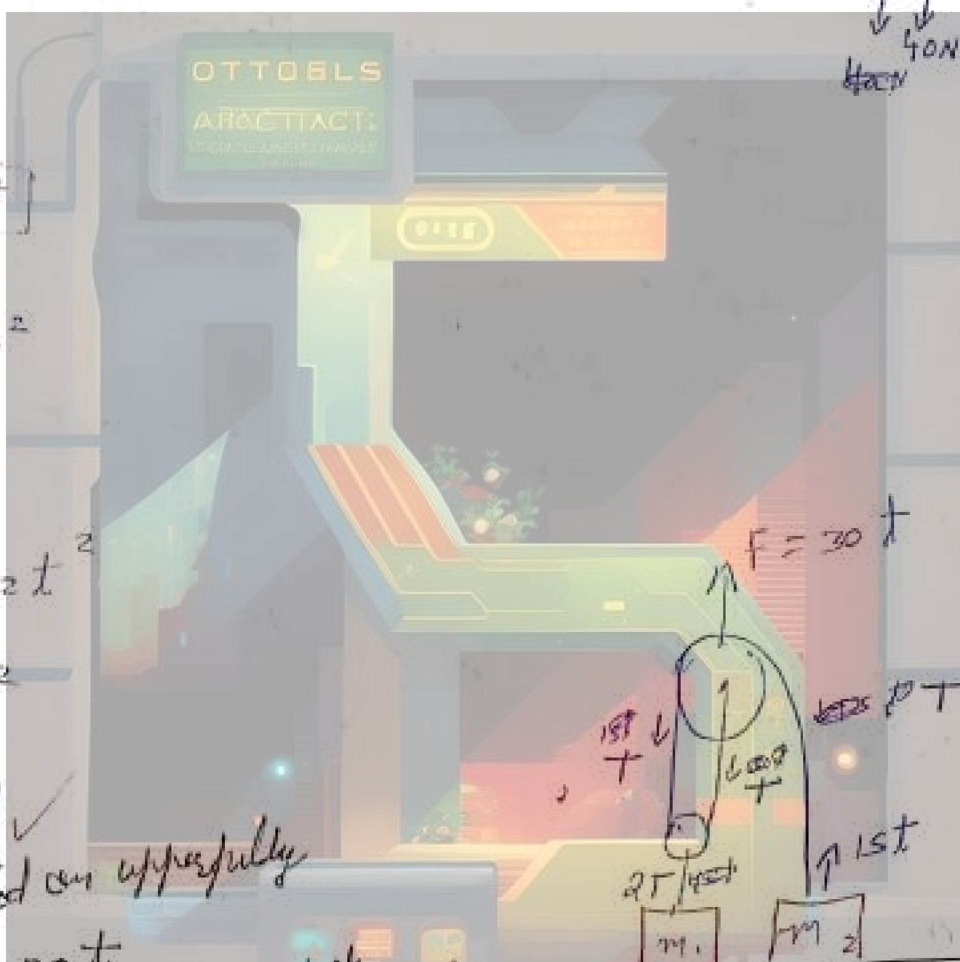
$s_{rel} = 6\ m$

$u = 0$

$6 = \frac{1}{2} \times 12 t^2$

$\frac{12}{12} = t^2$

$\boxed{t = 1\ s}$



Q F is applied on upper pully

$F = 30t$

find t when m_1 lose contact

$3T = 30t$

$T = 10t$

~~$4.8t = 40$~~

~~$t = \frac{8}{9}$~~

$2T = 40$

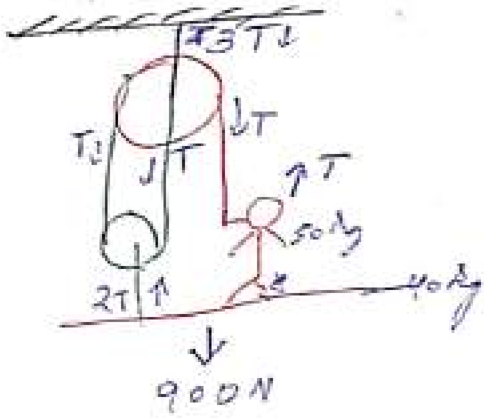
$20t = 40$

$\boxed{t = 2\ s}$

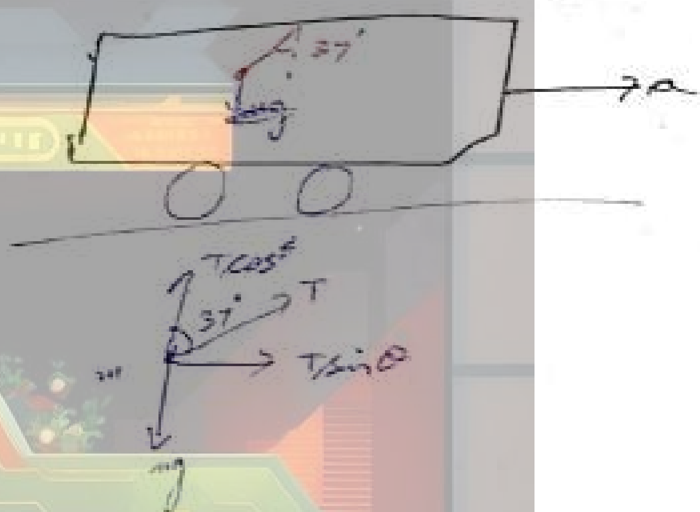
Q force man to apply to keep plat form in equation

$$900\,N = \cancel{3T}\ 2T + T$$

$$\therefore \boxed{T = 300\,N}$$



Q what would be acceleration will string make 37° with vertical



a) Ground Frame

$T\cos\theta = mg$

$T = \dfrac{mg}{\cos\theta}$

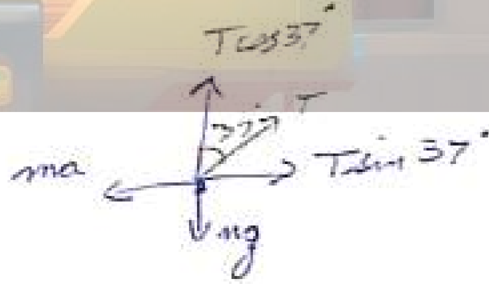
$T\sin\theta = ma$

$\dfrac{mg}{\cos\theta} \times \sin\theta = ma$

$g\tan 37° = a$

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

b) Non-Inertial Frame



$T\sin\theta = ma$

$T\cos\theta = mg$

$T = \dfrac{mg}{\cos\theta}$

$\dfrac{mg}{\cos\theta} \times \sin\theta = ma$

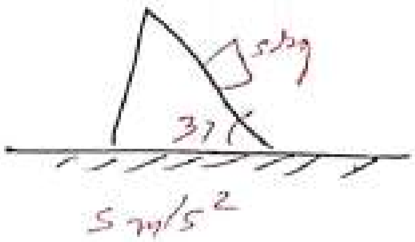
$g\tan\theta = a$

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

Q Inclined plane is ~~move~~ moved to right $5\ m/s^2$. find force exerted by 5 kg block on inclined Plane.

~~$N = 5 \times \frac{3}{5}$~~

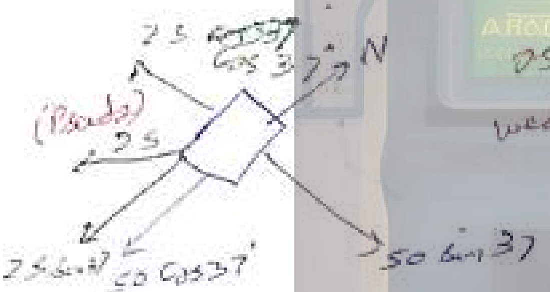
~~$N = 3$ Newton~~

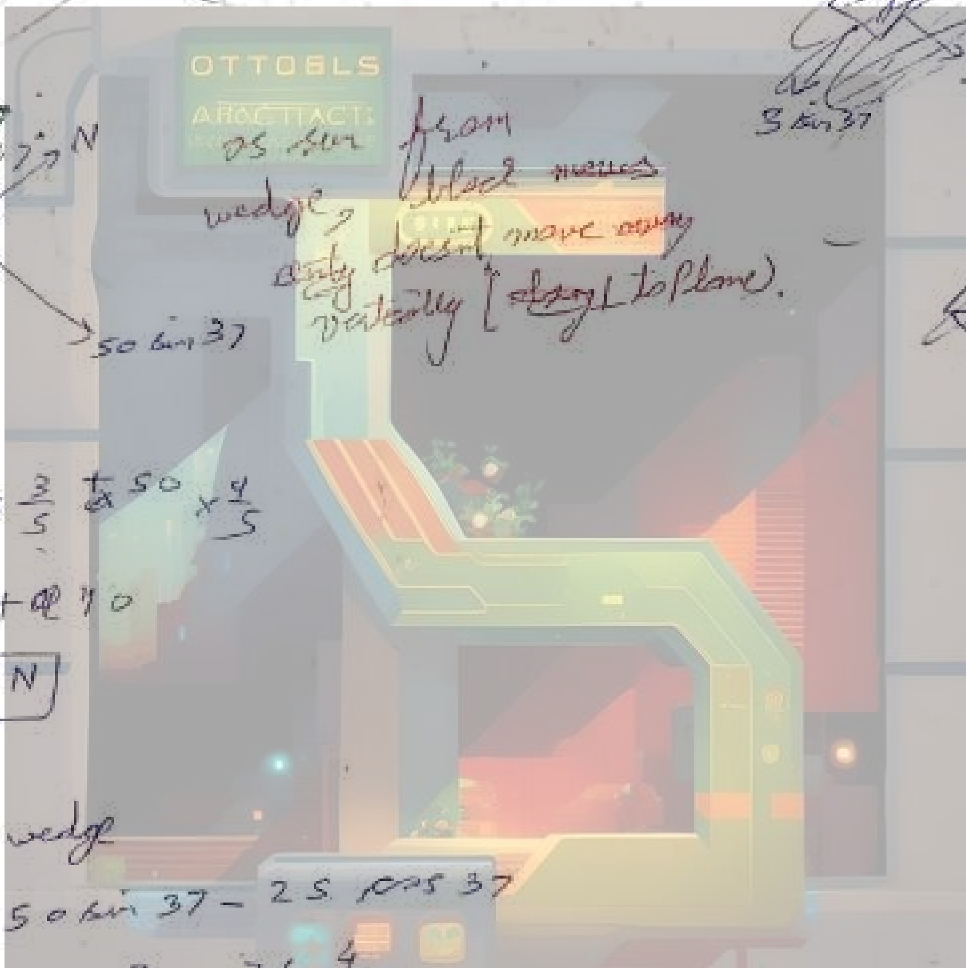


~~N~~

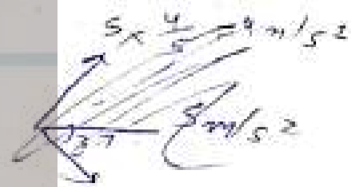
~~$N - 3 = 5 \times 4$~~

~~$N = \ldots$~~





as seen from wedge, block moves only down vertically [along ⊥ to plane].



$$N = 25 \times \frac{3}{5} + 50 \times \frac{4}{5}$$

$$= 15 + 40$$

$$\boxed{= 55\ N}$$

acceleration

as seen from wedge

$$5a = 50 \sin 37 - 25 \cos 37$$

$$= 50 \times \frac{3}{5} - 25 \times \frac{4}{5}$$

$$= 30 - 20$$

$$5a = 10$$

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

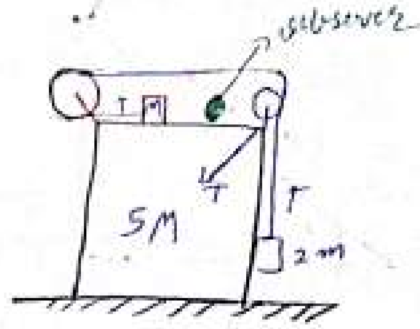
$$a_{net}\ (\text{from ground}) = \sqrt{(2)^2 + (5)^2 + 2 \times 2 \times 5 \cos 37}$$

$$= \sqrt{4 + 25 + 20 \times \frac{4}{5}}$$

$$= \sqrt{45}$$

$$\boxed{= 3\sqrt{5}\ m/s^2}$$

Q. find initial acceleration of wedge.



$N = 2Ma' \quad \text{--- (1)}$

$20M - T = 2Ma \quad \text{--- (2)}$ non-inertial frame

$T + Ma' = Ma \quad \text{--- (3)}$

$T - N = 5Ma'$ Ground --- (4)

Put (1) in (4)

$T - 2Ma' = 5Ma'$

$T = 7Ma' \quad \text{--- (5)}$

put (5) in (3)

$8Ma' = Ma$

$8a' = a \quad \text{--- (6)}$

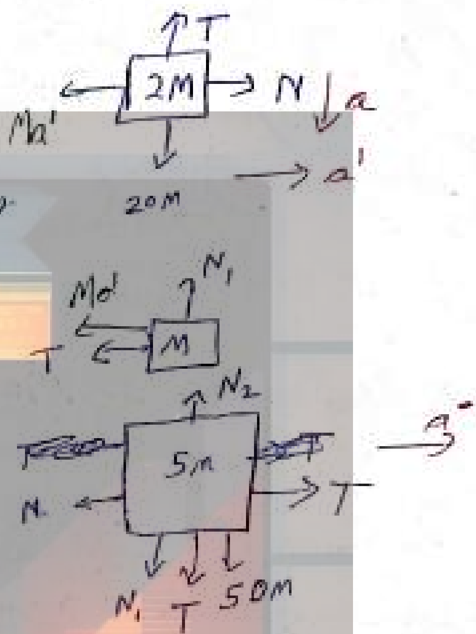
put (6) in (2) and (3)

$20M - 7Ma' = 2M(8a')$

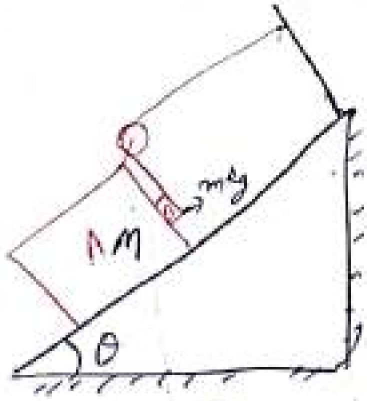
$20 - 7a' = 16a'$

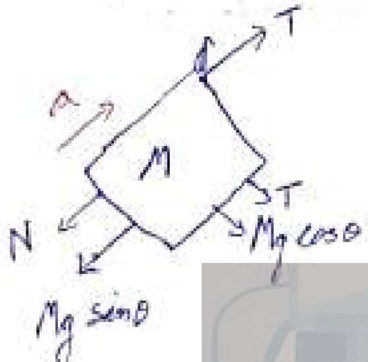
$20 = 23a'$

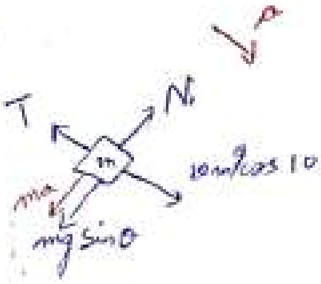
$\boxed{a' = \frac{20}{23}}$



Q. Find acceleration of A & B.







for A

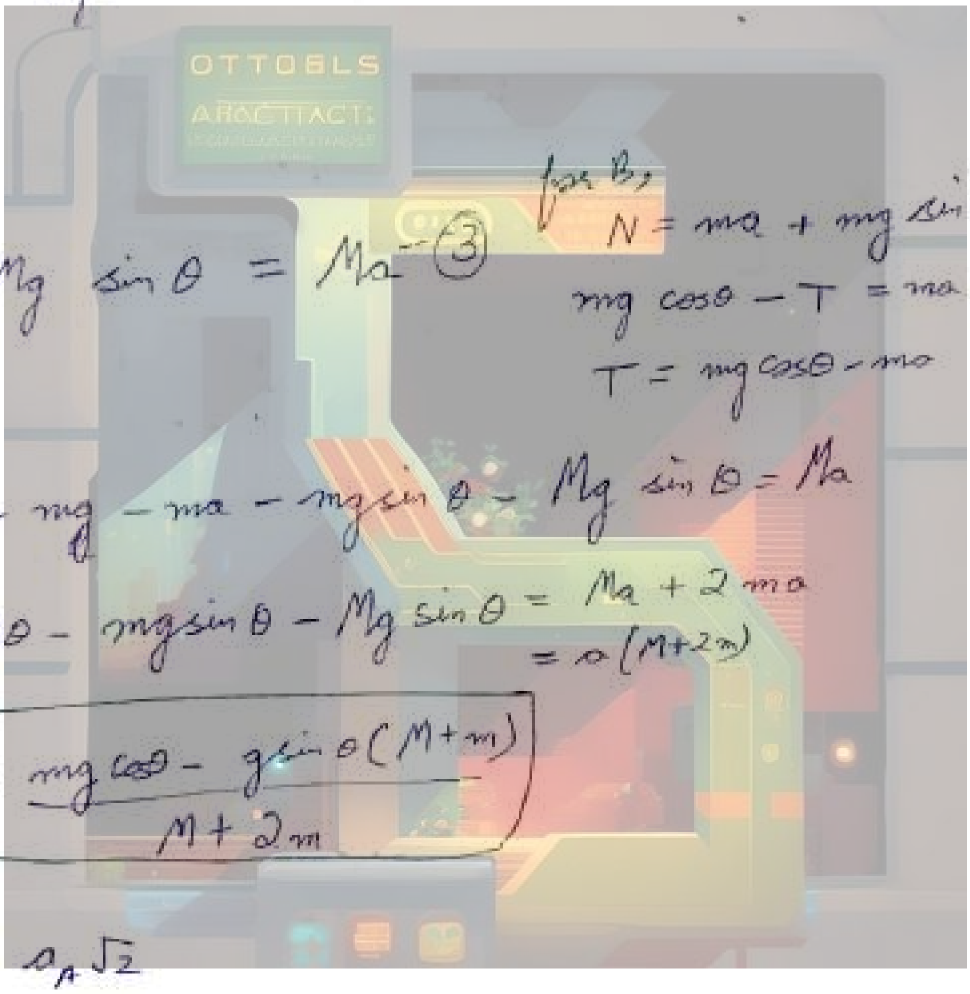
$$T - N - Mg\sin\theta = Ma \quad \text{--- (3)}$$

for B,

$$N = ma + mg\sin\theta \quad \text{--- (1)}$$

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

$$T = mg\cos\theta - ma \quad \text{--- (2)}$$



$$mg\cos\theta - ma - ma - mg\sin\theta - Mg\sin\theta = Ma$$

$$mg\cos\theta - mg\sin\theta - Mg\sin\theta = Ma + 2ma$$

$$= a(M+2m)$$

$$\boxed{a_A = \frac{mg\cos\theta - g\sin\theta(M+m)}{M+2m}}$$

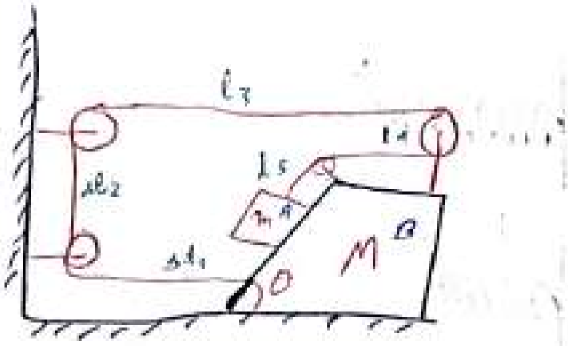
$$a_B = a_A\sqrt{2}$$

Q find acceleration of M.

$x_A - x_B - x_B = 0$

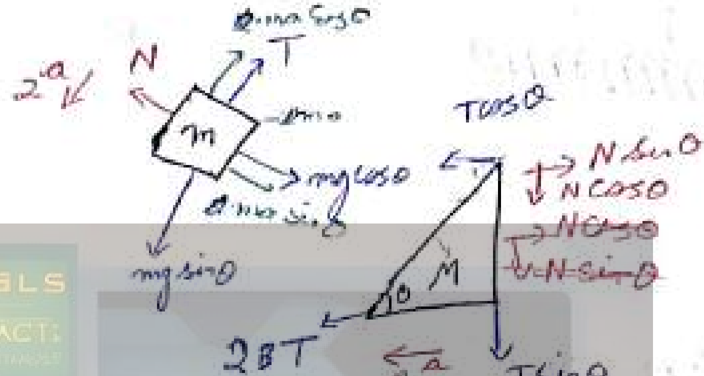
$\cancel{x_A - 2x_B}$

$x_A = 2x_B$



for M,

$2T + T\cos\theta - \cancel{N\cos\theta}\ N\sin\theta = \cancel{2}Ma$ — ①



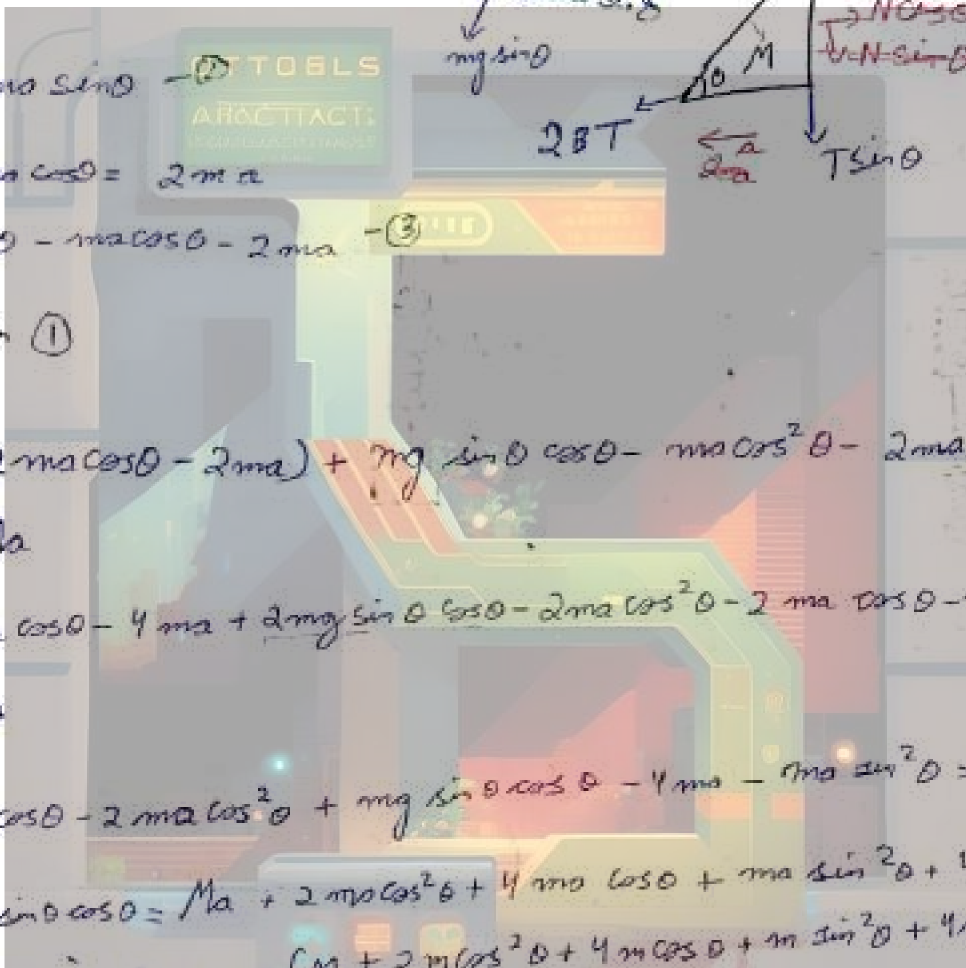
for m,

$N = mg\cos\theta + ma\sin\theta$ — ②

$mg\sin\theta - T - ma\cos\theta = 2ma$

$T = mg\sin\theta - ma\cos\theta - 2ma$ — ③

let ③ & ② in ①



$2(mg\sin\theta - \cancel{2}ma\cos\theta - 2ma) + mg\sin\theta\cos\theta - ma\cos^2\theta - 2ma\cos\theta - mg\cos\theta\sin\theta$
$- ma\sin^2\theta = Ma$

$2mg\sin\theta - 2ma\cos\theta - 4ma + 2mg\sin\theta\cos\theta - 2ma\cos^2\theta - 2ma\cos\theta - mg\cos\theta\sin\theta$
$- ma\sin^2\theta = Ma$

$2mg\sin\theta - 4ma\cos\theta - 2ma\cos^2\theta + mg\sin\theta\cos\theta - 4ma - ma\sin^2\theta = Ma$

$2mg\sin\theta + mg\sin\theta\cos\theta = Ma + 2ma\cos^2\theta + 4ma\cos\theta + ma\sin^2\theta + 4ma$

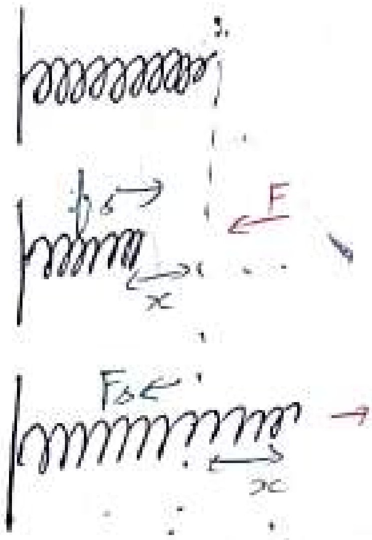
$2mg\sin\theta + mg\sin\theta\cos\theta = a(M + 2m\cos^2\theta + 4m\cos\theta + m\sin^2\theta + 4m)$

$2mg\sin\theta + mg\sin\theta\cos\theta = a(M + m\cos^2\theta + 4m\cos\theta + 5m)$

$mg(2\sin\theta + \sin\theta\cos\theta) = a(M + m\cos^2\theta + 4m\cos\theta + 5m)$

$$a = \frac{mg\sin\theta(2+\cos\theta)}{(M + m\cos^2\theta + 4m\cos\theta + 5m)}$$

☆ Spring Force



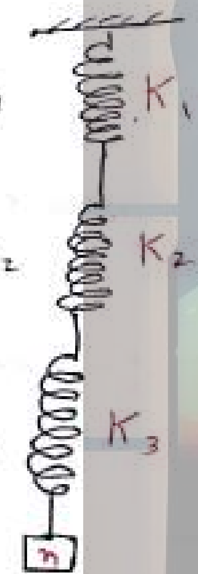
Spring Force, $f_s \propto x$

$$\boxed{F_s = -Kx}$$

K = Spring Constant (stiffness of spring)

$$K \propto \frac{1}{\text{length of spring}}$$

① Springs in series



⇒ $(x_1+x_2+x_3)$ K_{eq} m

$K_1 x_1 = K_2 x_2 = K_3 x_3 = mg$ (Tension at any point is equal if springs are massless).

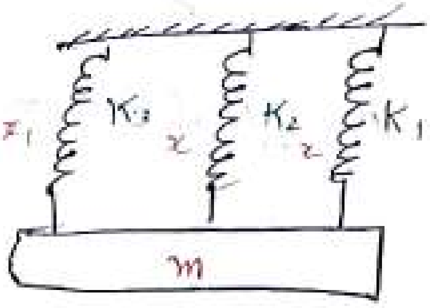
$$K_{eq}(x_1+x_2+x_3) = mg$$

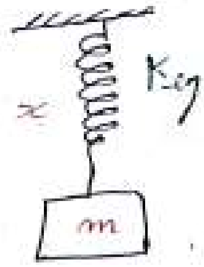
$$K_{eq}\left(\frac{mg}{K_1}+\frac{mg}{K_2}+\frac{mg}{K_3}\right) = mg$$

$$\cancel{\frac{1}{K_{eq}} = \frac{1}{x_1}+\frac{1}{x_2}+\frac{1}{x_3}}$$

$$\boxed{\frac{1}{K_{eq}} = \frac{1}{K_1}+\frac{1}{K_2}+\frac{1}{K_3}}$$

(2) Springs in parallel

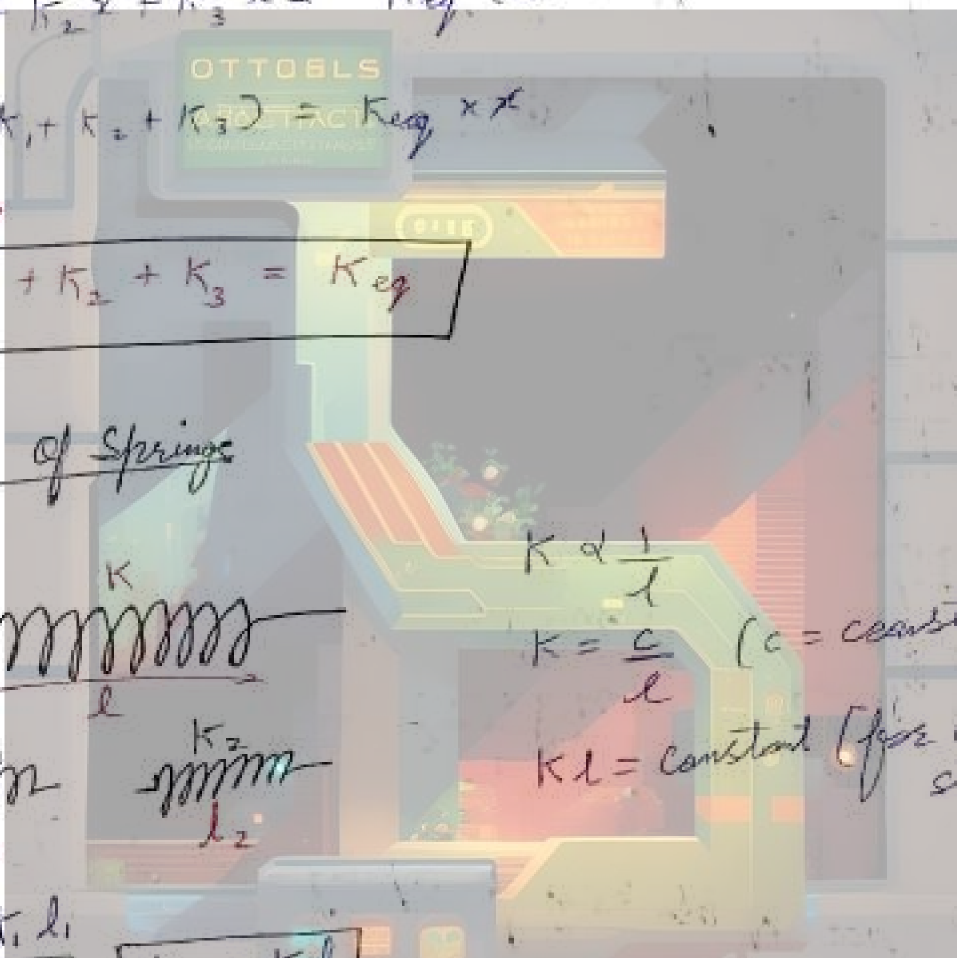




$K_1 x + K_2 x + K_3 x = mg$

$K_{eq}(x) = mg$

$K_1 x + K_2 x + K_3 x = K_{eq}(x)$



$x(K_1 + K_2 + K_3) = K_{eq} \times x$

$$\boxed{K_1 + K_2 + K_3 = K_{eq}}$$

(3) Cutting of Springs

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

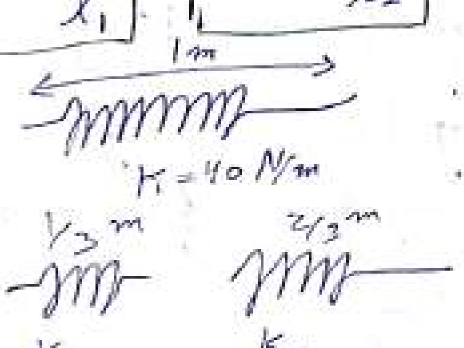
$K = \frac{c}{l}$ (c = constant)

Kl = constant (for an particular string)

$Kl = K_1 l_1$

$$\boxed{K_1 = \frac{Kl}{l_1}} \quad \boxed{K_2 = \frac{Kl}{l_2}}$$

eg.



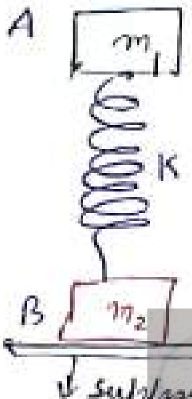
$K_1 = \frac{40 \times 1}{1/3} = 120\ N/m$

$K_2 = \frac{40 \times 1}{2/3} = \frac{120}{2} = 60\ N/m$

Breaking of Supports

→ The spring force do not change Instantaneously.

Q Find acceleration of blocks instantly after the support is removed.



$\uparrow f_s$ $\downarrow m_1 g$ $\boxed{f_s = m_1 g}$

$N = m_2 g + f_s$

$\uparrow N$ $\downarrow m_2 g$ $\downarrow f_s$ $\boxed{N = m_2 g + m_1 g}$

After removing is removed, $N = 0$

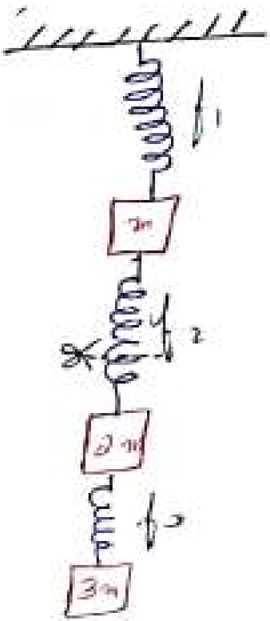
m_1: $\uparrow f_s$, $\downarrow mg$ $\boxed{a_1 = 0}$

m_2: $\uparrow N = 0$, $\downarrow m_2 g$, $\downarrow f_s = m_1 g$

$m_2 g + m_1 g = m_2 a$

$$\boxed{\frac{m_2 g + m_1 g}{m_2} = a}$$

Q find initial acc of blocks if spring - 2 is cut.



m: $\uparrow f_1$, $\downarrow mg$, $\downarrow f_2$ $2m$: $\uparrow f_2$, $\downarrow 2mg$, $\downarrow f_3$ $3m$: $\uparrow f_3$, $\downarrow 3mg$

$f_1 = mg + f_2$ $f_2 = 2mg + f_3$ $f_3 = 3mg$

$f_1 = 6mg$ $f_2 = 5mg$

$f_1 = 6mg$ ↑ [m] ↓ mg, ↓ $f_2 = 0$

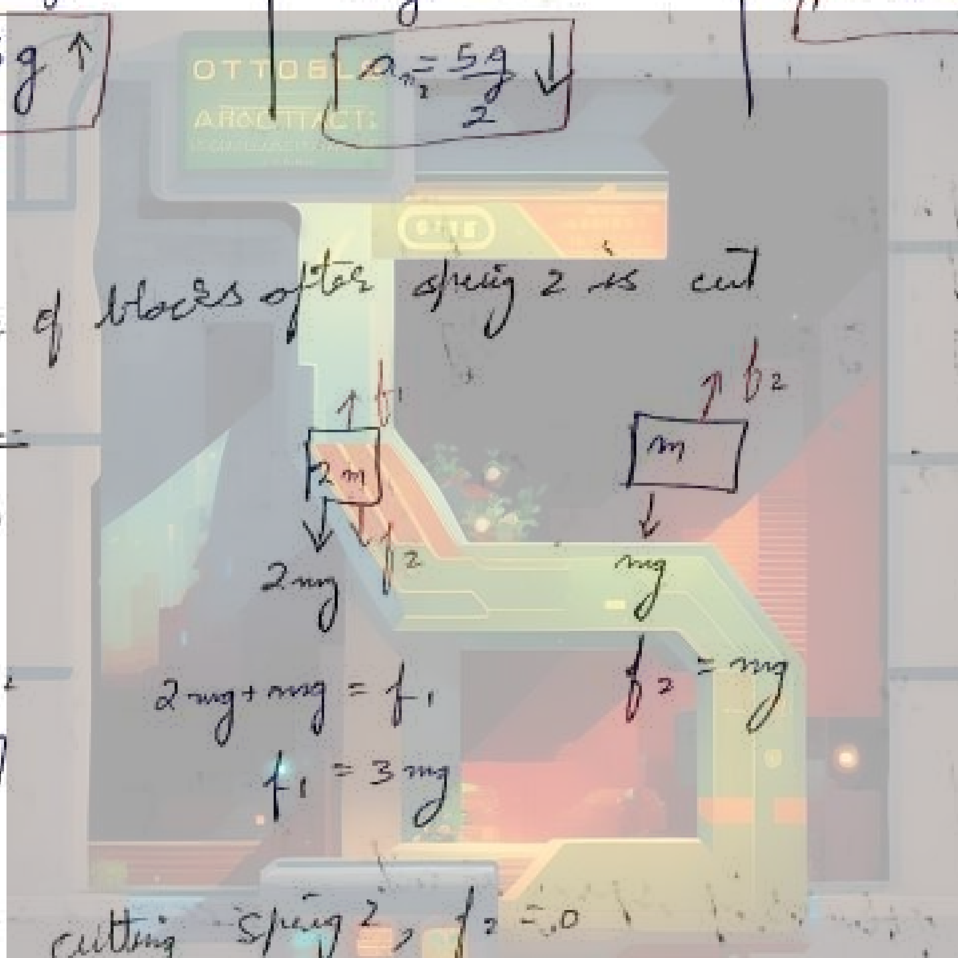
$f_2 = 0$ ↑ [$2m$] ↓ $2mg$, ↓ $f_3 = 3mg$

$f_3 = 3mg$ ↑ [$3m$] ↓ $3mg$

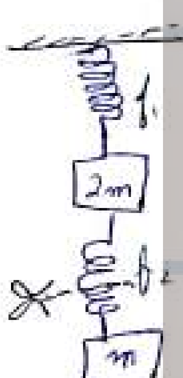
when the spring 2 is cut, $f_2 = 0$

f_1 & f_3 = same

$6mg - mg = ma$	$3mg + 2mg = 2ma$	$3mg - 3mg = 3ma$
$5mg = ma$	$5g = 2a$	$\boxed{a_{m_3} = 0}$
$\boxed{a_m = 5g \uparrow}$	$\boxed{a_{m_2} = \frac{5g}{2} \downarrow}$	



Q Find acc of blocks after spring 2 is cut



f_1 ↑ [$2m$] ↓ $2mg$, ↓ f_2

f_2 ↑ [m] ↓ mg

$2mg + mg = f_1$

$f_1 = 3mg$

$f_2 = mg$

After cutting spring 2, $f_2 = 0$

$f_1 = 3mg$ ↑ [$2m$] a_1, ↓ $2mg$, ↓ 0

0 ↑ [m] a_2, ↓ mg

$3mg - 2mg = 2ma_1$

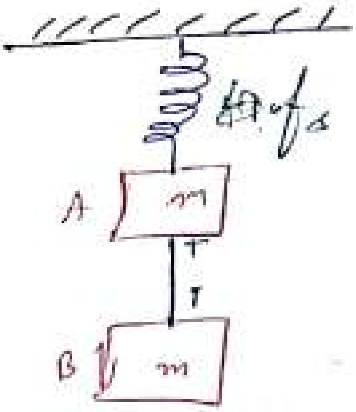
$g = 2a_1$

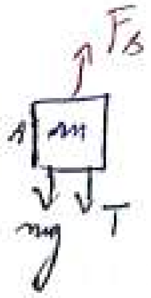
$\boxed{a_1 = \frac{g}{2}} \uparrow m/s^2$ ✓

$mg = ma_2$

$\boxed{a_2 = g \downarrow} m/s^2$ ✓

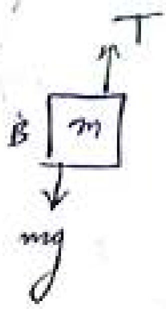
Q acc of Blocks after spring is cut





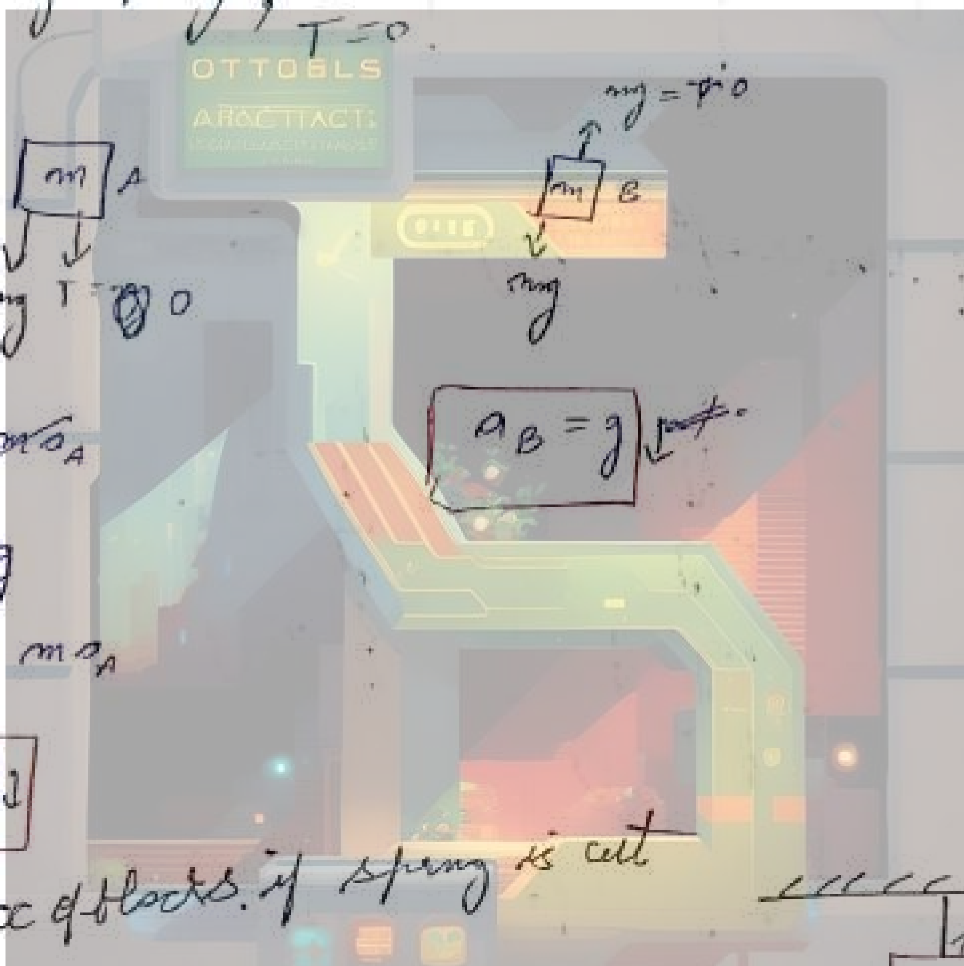
$mg + T = F_s$

$2mg = F_s$



$T = mg$

After cutting spring, $F_s = 0$
$T = 0$



~~$2mg = ma_A$~~

~~$a_A = 2g$~~

$mg = ma_A$

$\boxed{a_A = g}$

$\boxed{a_B = g}$

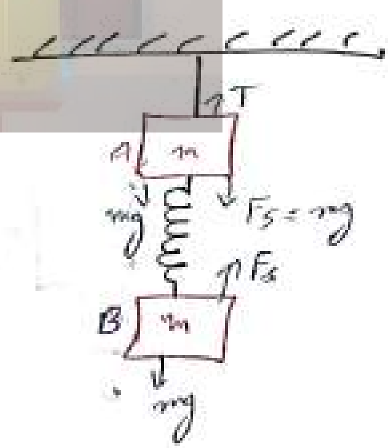
Q find acc of blocks if spring is cut

$F_s = 0$

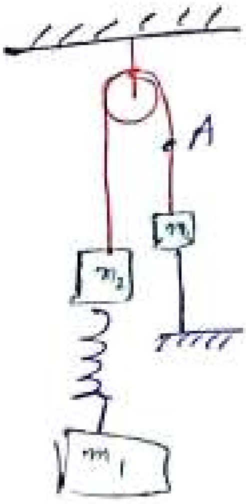
$mg = ma$

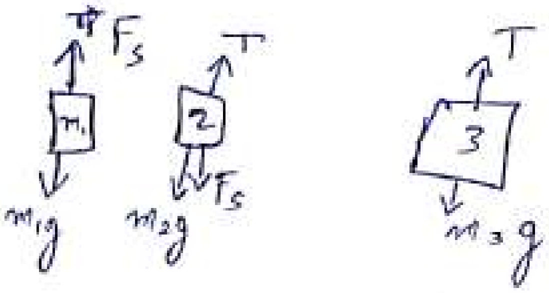
$a_B = g$

$a_A = 0$



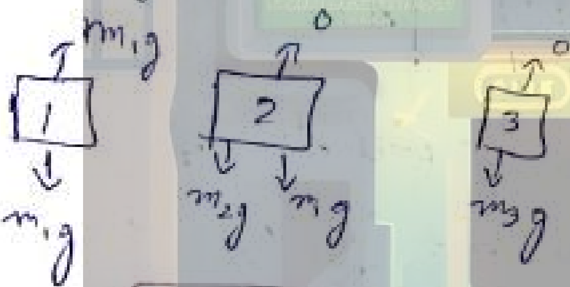
Q find acc if string is cut at A?





$F_s = m_1 g$ $\quad m_2 g + m_1 g = m_3 g$ $\quad T = m_3 g$

After cutting. $T = 0$



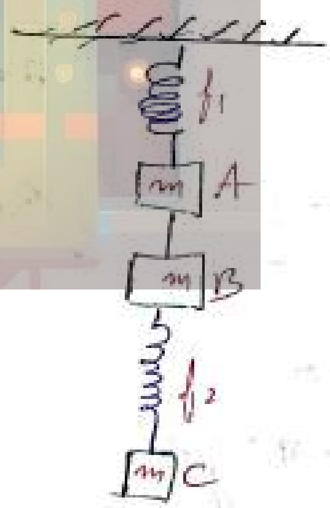
$\boxed{a_1 = 0}$ $\quad \boxed{a_2 = \frac{(m_1 + m_2)g}{m_2} \downarrow}$ $\quad \boxed{a_3 = g} \downarrow$

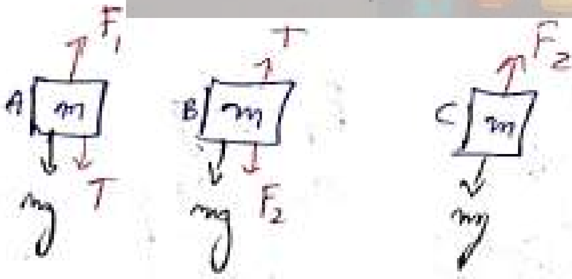
Q find acc of blocks

a) spring f_1 is cut

b) ~~spring~~ string is cut

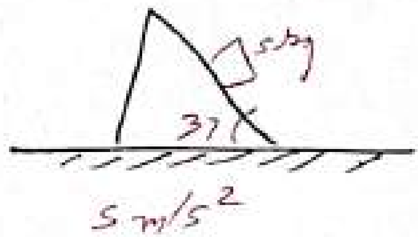
c) spring f_2 is cut.





$F_1 = 3mg$ $\quad T = 2mg$ $\quad F_2 = mg$

Q Inclined plane is ~~moving~~ moved to right $5\, m/s^2$. find force exerted by 5 kg block on inclined Plane.

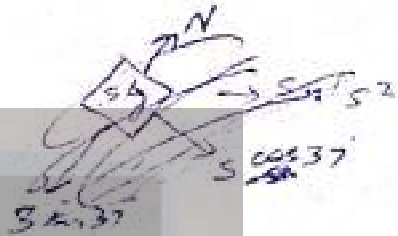


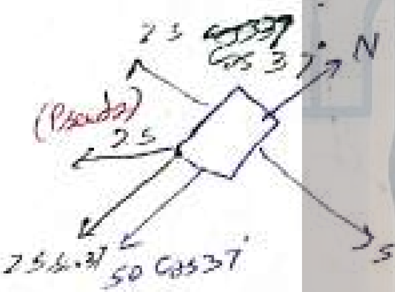
~~$N = 5 \times \frac{3}{5}$~~

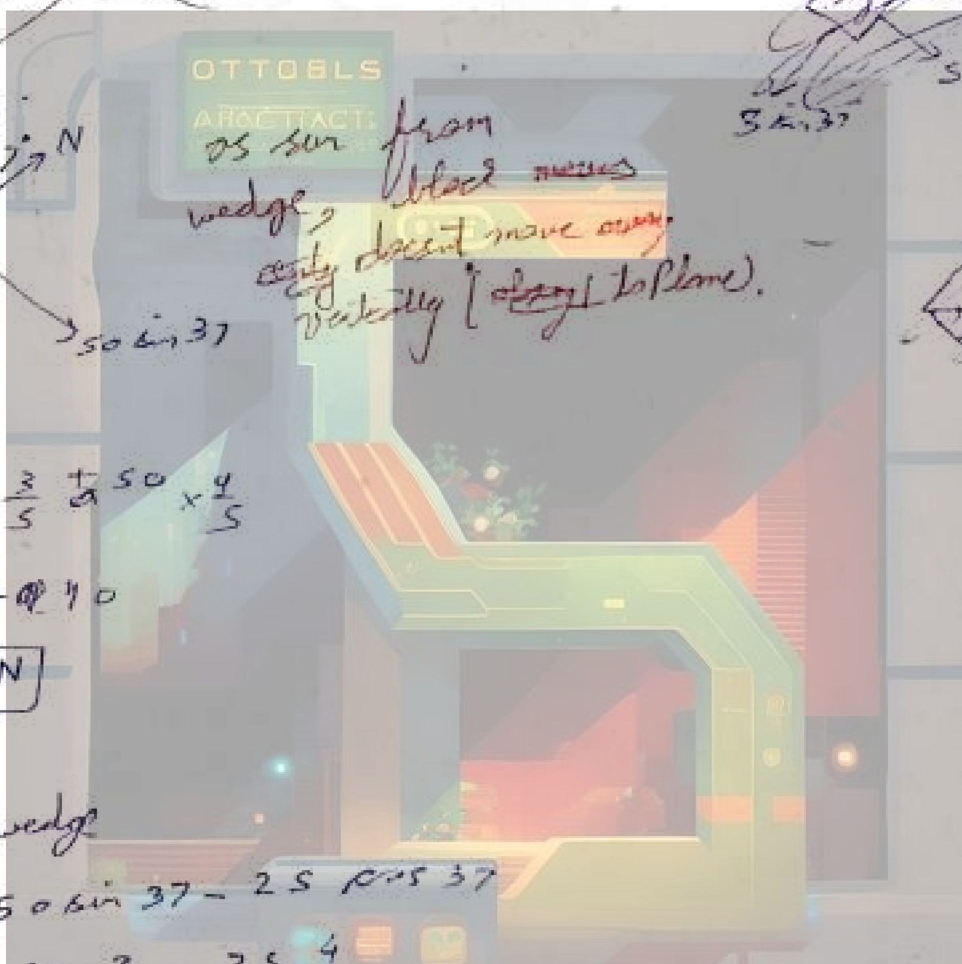
~~N = 3 Newton~~

~~FBD~~

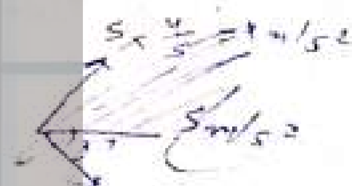
~~$N - 3 = 5 \times 4$~~







as seen from wedge, block ~~moves~~ only doesn't move away vertically [~~along~~ $\perp$ to Plane].



$N = 25 \times \frac{3}{5} + 50 \times \frac{4}{5}$

$= 15 + 40$

$\boxed{= 55\,N}$

acceleration as seen from wedge

$5a = 50 \sin 37 - 25 \cos 37$

$= 50 \times \frac{3}{5} - 25 \times \frac{4}{5}$

$= 30 - 20$

$5a = 10$

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

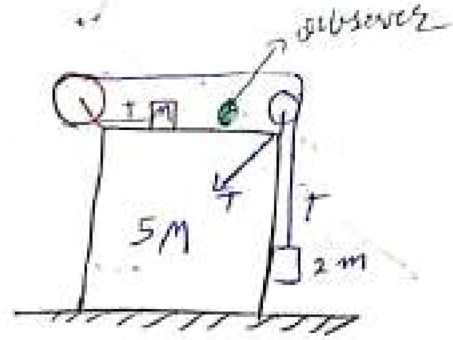
A_{net} (from ground) $= \sqrt{(2)^2 + (5)^2 + 2 \times 2 \times 5 \cos 37}$

$= \sqrt{4 + 25 + 20 \times \frac{4}{5}}$

$= \sqrt{45}$

$\boxed{= 3\sqrt{5}\, m/s^2}$

Q- find initial acceleration of wedge.



$N = 2Ma'$ --- (1)

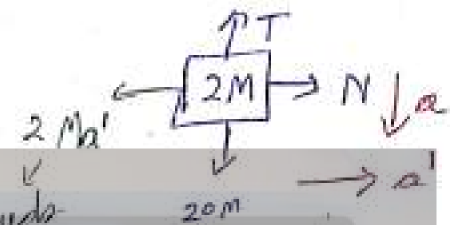
$20M - T = 2Ma$ --- (2) non-inertial frame

$T + Ma' = Ma$ --- (3)

$T - N = 5Ma'$ Ground --- (4)

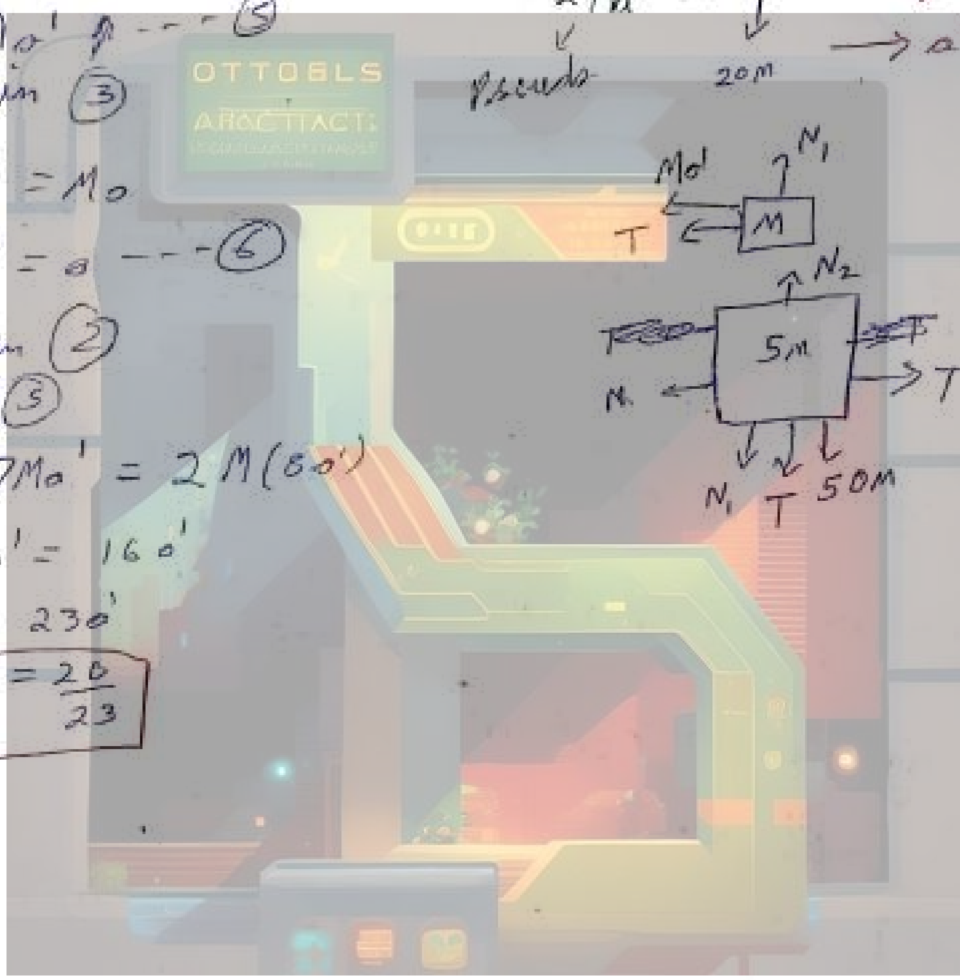
Put (1) in (4)

$T - 2Ma' = 5Ma'$



$T = 7Ma'$ --- (5)

put (5) in (3)



$8Ma' = Ma$

$8a' = a$ --- (6)

put (6) in (2) and (5)

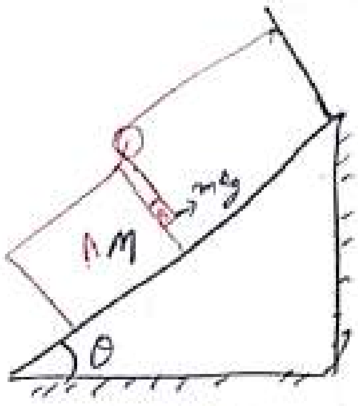
$20M - 7Ma' = 2M(8a')$

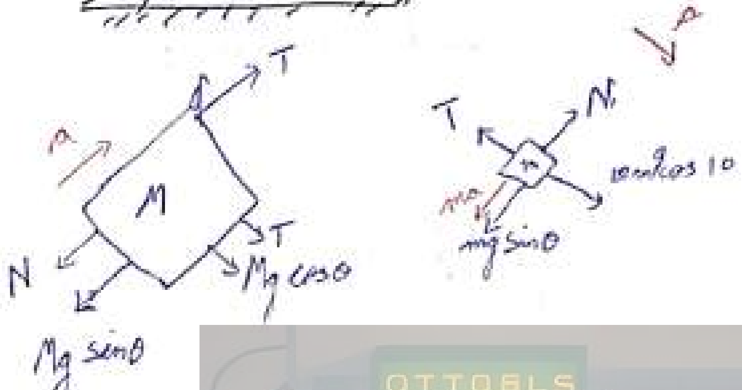
$20 - 7a' = 16a'$

$20 = 23a'$

$\boxed{a' = \frac{20}{23}}$

Q. Find acceleration of A & B





for A

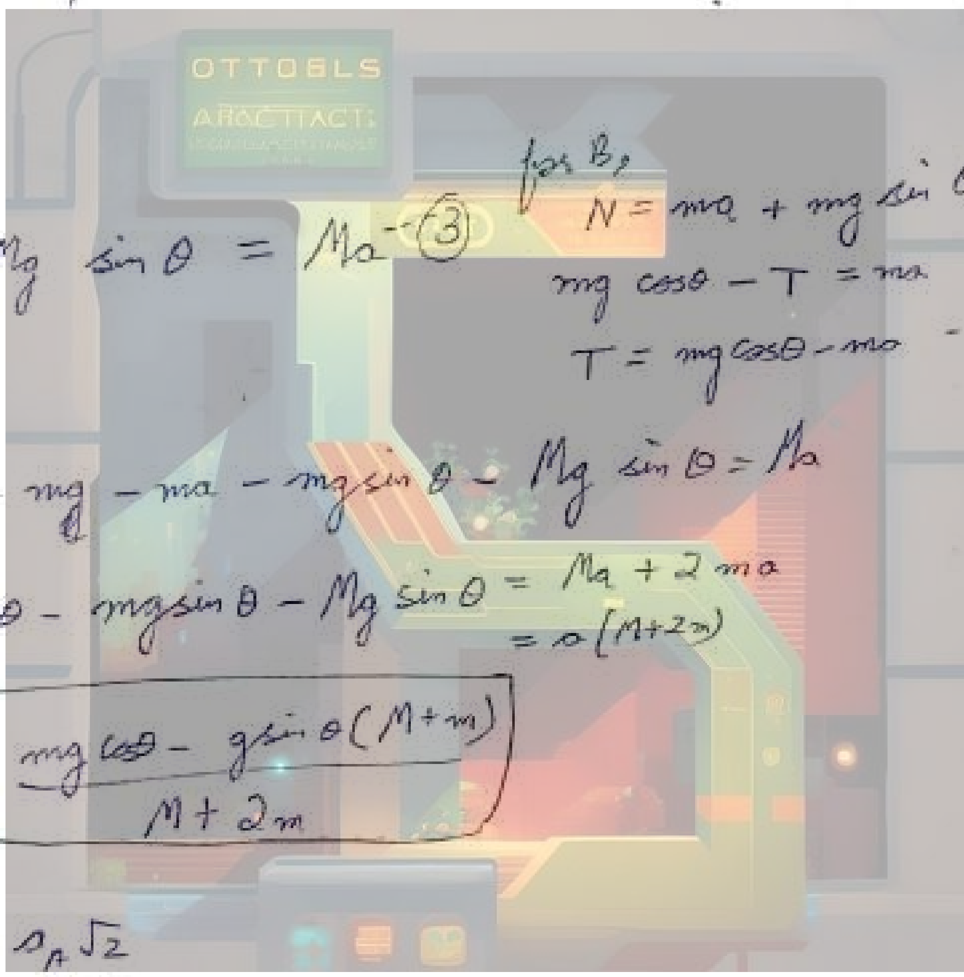
$$T - N - Mg\sin\theta = Ma \quad \text{--(3)}$$

for B,

$$N = ma + mg\sin\theta \quad \text{--(1)}$$

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

$$T = mg\cos\theta - ma \quad \text{--(2)}$$



$$mg\cos\theta - mg - ma - mg\sin\theta - Mg\sin\theta = Ma$$

$$mg\cos\theta - mg\sin\theta - Mg\sin\theta = Ma + 2ma$$

$$= a(M+2m)$$

$$\boxed{a_A = \frac{mg\cos\theta - g\sin\theta(M+m)}{M+2m}}$$

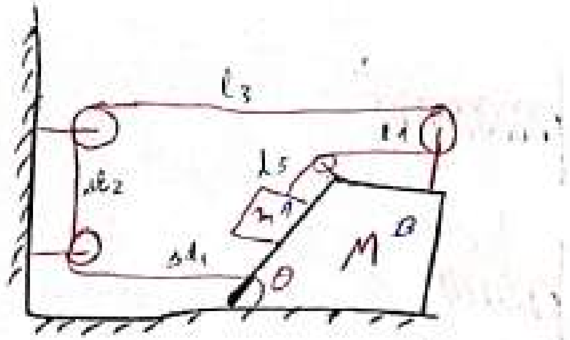
$$a_B = a_A\sqrt{2}$$

Q find acceleration of M.

$x_A - x_B - x_B = 0$

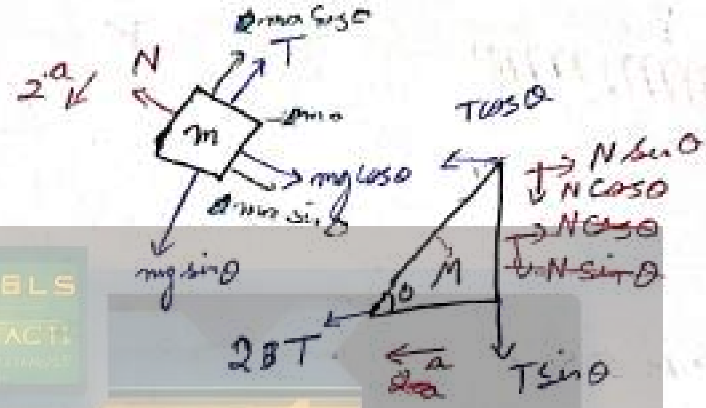
$\cancel{x_A = 2x_B}$

$x_A = 2x_B$



for M,

$2T + T\cos\theta - \cancel{N\cos\theta}\ N\sin\theta = \cancel{2}Ma$ —(1)



for m,

$N = mg\cos\theta + ma\sin\theta$ —(2)

$mg\sin\theta - T - ma\cos\theta = 2ma$

$T = mg\sin\theta - ma\cos\theta - 2ma$ —(3)

Put (3) & (2) in (1)

$2(mg\sin\theta - \cancel{2}ma\cos\theta - 2ma) + mg\sin\theta\cos\theta - ma\cos^2\theta - 2ma\cos\theta - mg\cos\theta\sin\theta$
$- ma\sin^2\theta = Ma$

$2mg\sin\theta - 2ma\cos\theta - 4ma + 2mg\sin\theta\cos\theta - 2ma\cos^2\theta - 2ma\cos\theta - mg\cos\theta\sin\theta$
$- ma\sin^2\theta = Ma$

$2mg\sin\theta - 4ma\cos\theta - 2ma\cos^2\theta + mg\sin\theta\cos\theta - 4ma - ma\sin^2\theta = Ma$

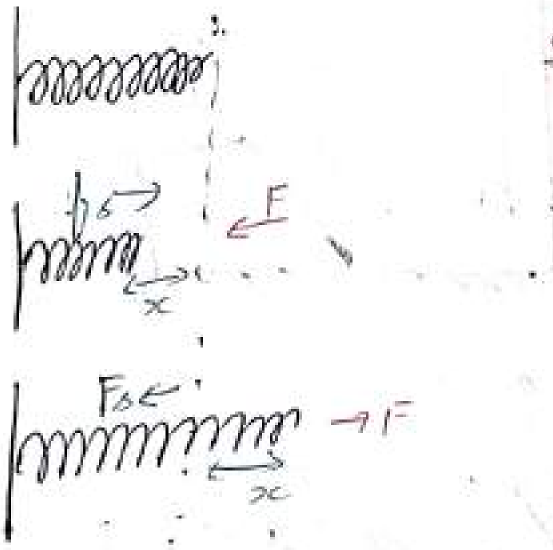
$2mg\sin\theta + mg\sin\theta\cos\theta = Ma + 2ma\cos^2\theta + 4ma\cos\theta + ma\sin^2\theta + 4ma$

$2mg\sin\theta + mg\sin\theta\cos\theta = a(M + 2m\cos^2\theta + 4m\cos\theta + m\sin^2\theta + 4m)$

$mg(2\sin\theta + \sin\theta\cos\theta) = a(M + m\cos^2\theta + 4m\cos\theta + 5m)$

$$a = \frac{mg\sin\theta(2+\cos\theta)}{(M + m\cos^2\theta + 4m\cos\theta + 5m)}$$

Spring Force



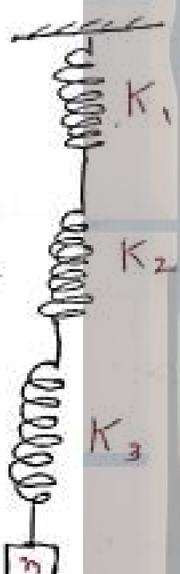
Spring Force, $f_s \propto x$

$$\boxed{F_s = -Kx}$$

K = spring constant (stiffness of spring)

$$K \propto \frac{1}{\text{length of spring}}.$$

① Springs in series



$\Rightarrow$

$K_1 x_1 = K_2 x_2 = K_3 x_3 = mg$ (Tension at any point is equal if springs are massless).

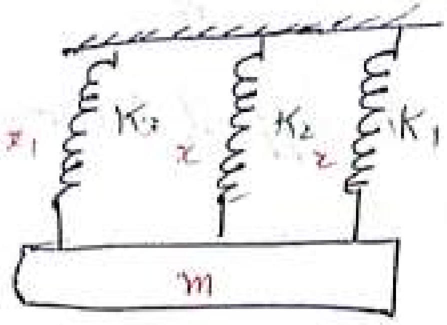
$$K_{eq}(x_1+x_2+x_3) = mg$$

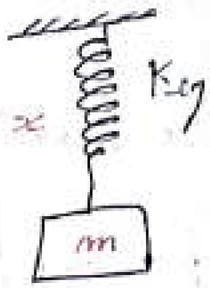
$$K_{eq}\left(\frac{mg}{K_1}+\frac{mg}{K_2}+\frac{mg}{K_3}\right) = mg$$

$$\cancel{\frac{1}{K_{eq}} = \frac{1}{x_1}+\frac{1}{x_2}+\frac{1}{x_3}}$$

$$\boxed{\frac{1}{K_{eq}} = \frac{1}{K_1}+\frac{1}{K_2}+\frac{1}{K_3}}$$

② Springs in parallel





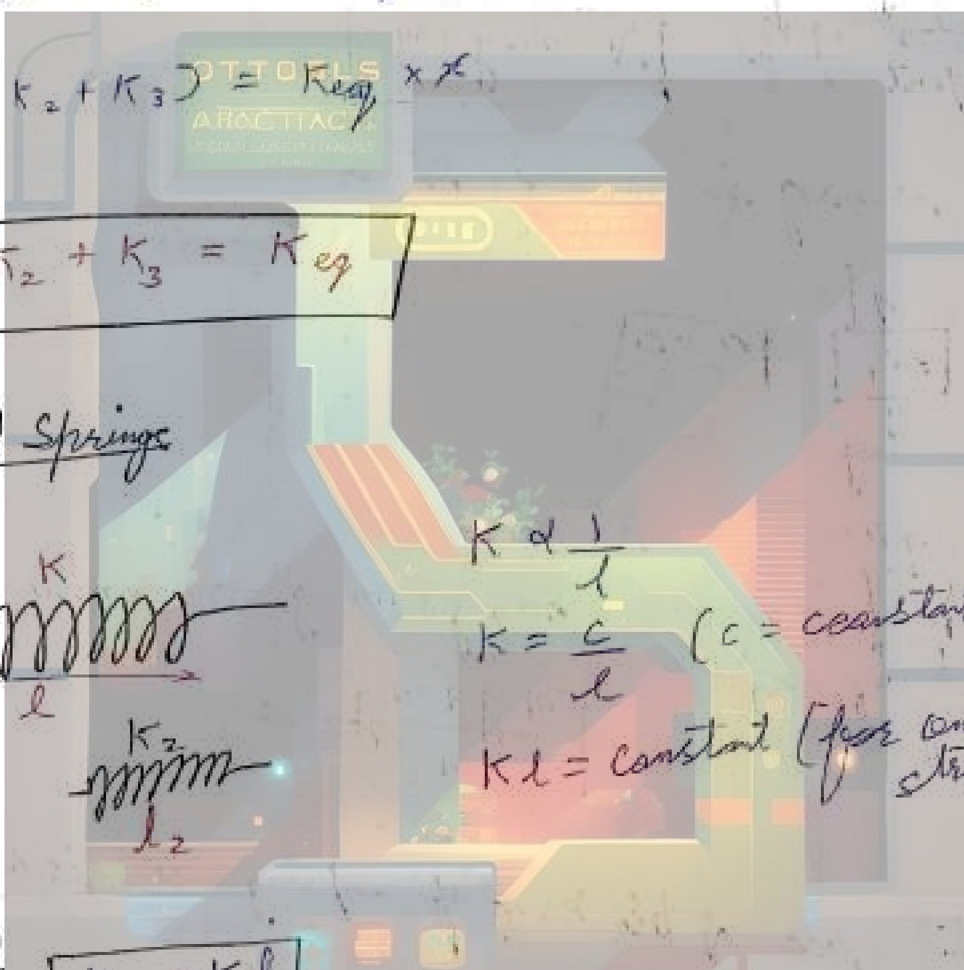
$K_1x + K_2x + K_3x = mg$

$K_{eq}(x) = mg$

$K_1x + K_2x + K_3x = K_{eq}(x)$

$x(K_1 + K_2 + K_3) = K_{eq} \times x$

$\boxed{K_1 + K_2 + K_3 = K_{eq}}$



③ Cutting of Springs

K

l

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

$K = \frac{c}{l}$ (c = constant)

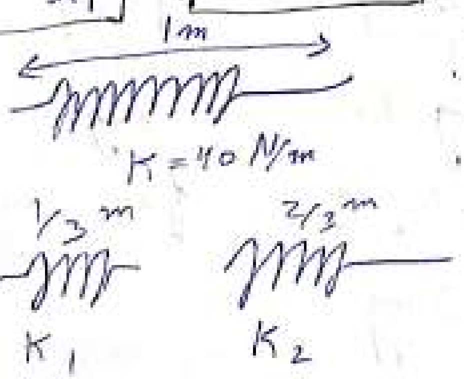
Kl = constant (for an particular string)

K_1, l_1 K_2, l_2

$Kl = K_1 l_1$

$\boxed{K_1 = \frac{Kl}{l_1}}$ $\boxed{K_2 = \frac{Kl}{l_2}}$

eg.



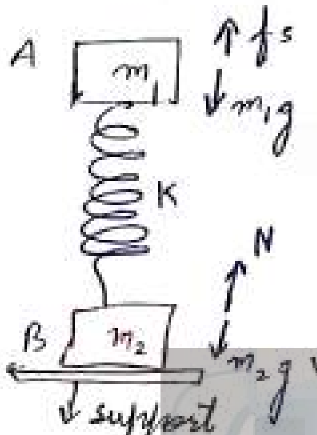
$K_1 = \frac{40 \times 1}{1/3} = 120$ N/m

$K_2 = \frac{40 \times 1}{2/3} = \frac{120}{2} = 60$ N/m

Breaking of Supports

→ The spring force do not change Instantaneously.

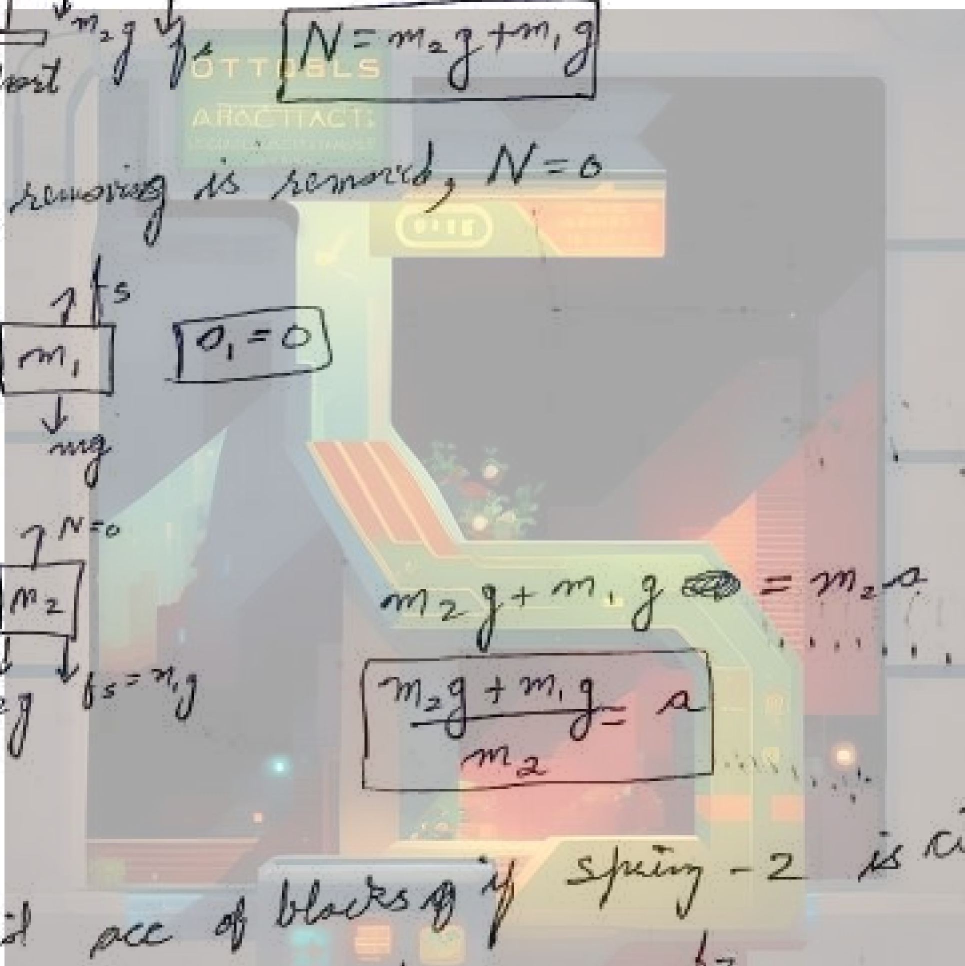
Q Find acceleration of blocks instantly after the support is removed.



$$\boxed{f_s = m_1 g}$$

$$N = m_2 g + f_s$$

$$\boxed{N = m_2 g + m_1 g}$$



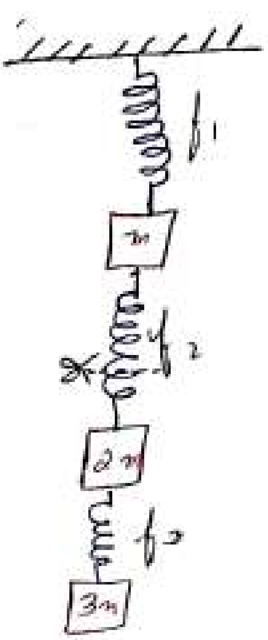
After removing is removed, $N = 0$

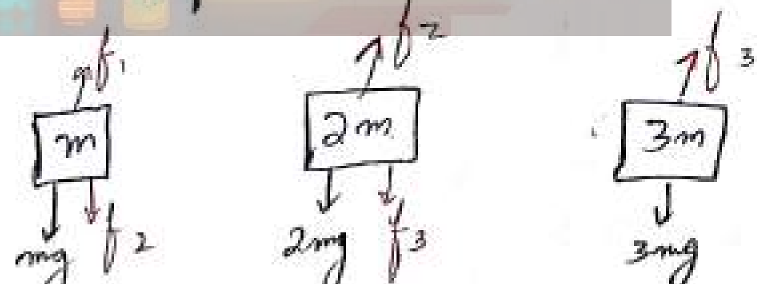
$$\boxed{a_1 = 0}$$

$$m_2 g + m_1 g = m_2 a$$

$$\boxed{\frac{m_2 g + m_1 g}{m_2} = a}$$

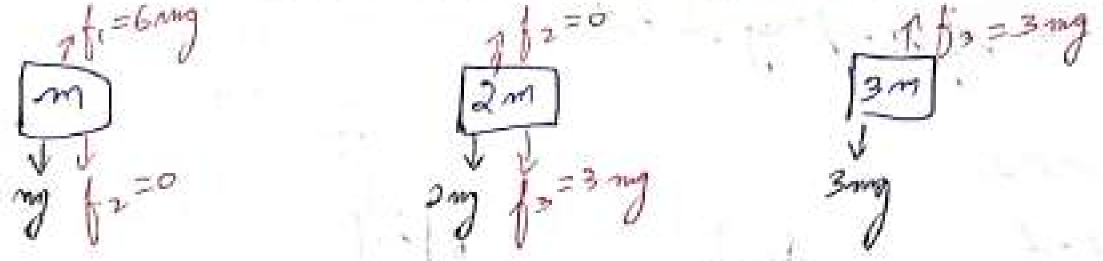
Q find initial acc of blocks if spring - 2 is cut.





$f_1 = mg + f_2$ $\quad$ $f_2 = 2mg + f_3$ $\quad$ $f_3 = 3mg$

$f_1 = 6\,mg$ $\quad$ $f_2 = 5mg$



when the spring 2 is cut, $f_2 = 0$

f_1 & f_3 = same

~~mg~~ $6mg - mg = ma$

$5mg = ma$

$\boxed{a_m = 5g \uparrow}$

$3mg + 2mg = 2ma$

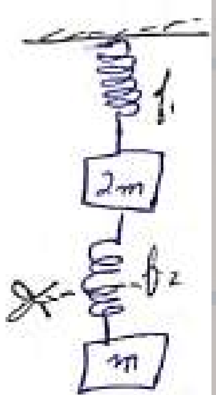
$5g = 2a$

$\boxed{a_{m_2} = \frac{5g}{2} \downarrow}$

$3mg - 3mg = 3ma$

$\boxed{a_{m_3} = 0}$

Q Find acc of blocks after spring 2 is cut



$2mg + mg = f_1$

$f_1 = 3mg$

$f_2 = mg$

After cutting spring 2, $f_2 = 0$

$3mg - 2mg = 2ma_1$

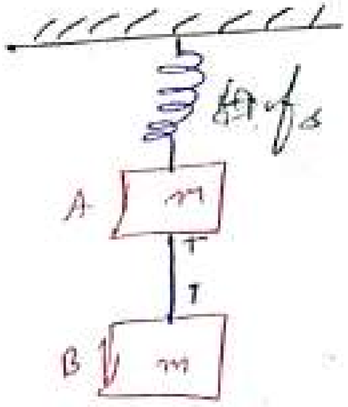
$g = 2a_1$

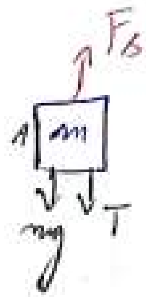
$\boxed{a_1 = \frac{g}{2}} \uparrow m/s^2$

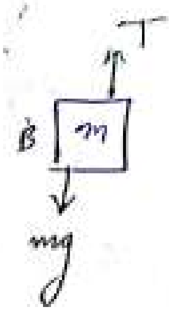
$mg = ma_2$

$\boxed{a_2 = g \downarrow} m/s^2$

Q acc of Blocks after the spring is cut





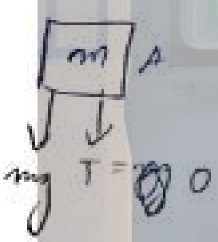


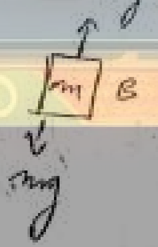
$mg + T = F_s$

$2mg = F_s$

$T = mg$

After cutting spring, $F_s = 0$, $T = 0$





$mg = T \neq 0$

$\boxed{a_B = g}$

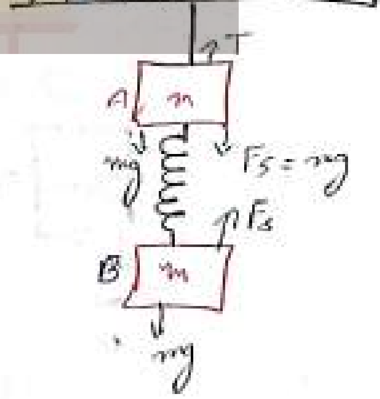
$\cancel{2mg = ma_A}$

$\cancel{a_A = 2g}$

$mg = ma_A$

$\boxed{a_A = g}$

Q find acc of blocks if spring is cut



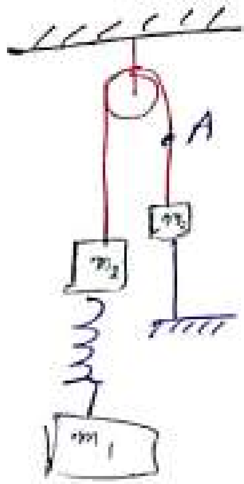
$F_s = 0$

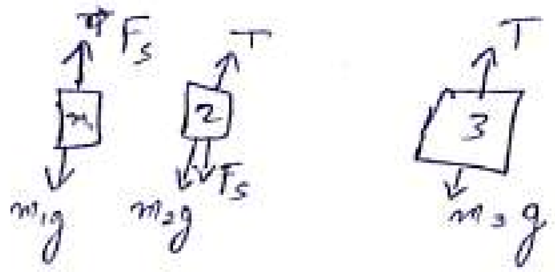
$mg = ma$

$a_B = g$

$a_A = 0$

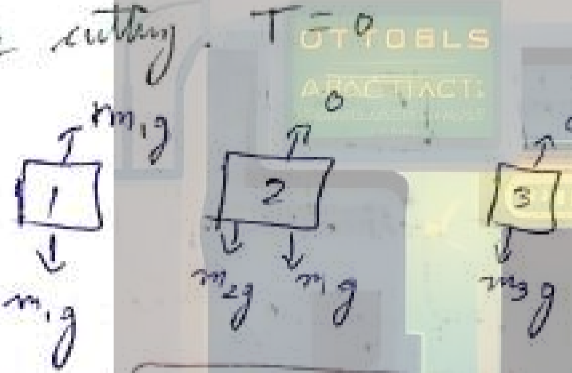
Q find acc if string is cut at A?





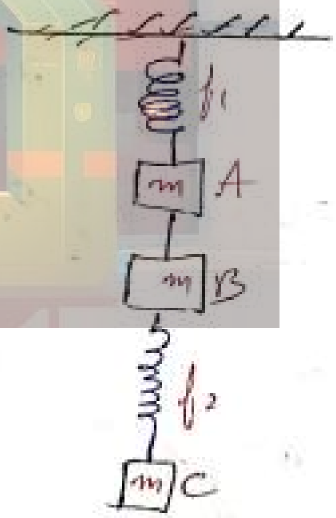
$F_s = m_1 g \quad m_2 g + m_1 g = m_3 g \quad T = m_3 g$

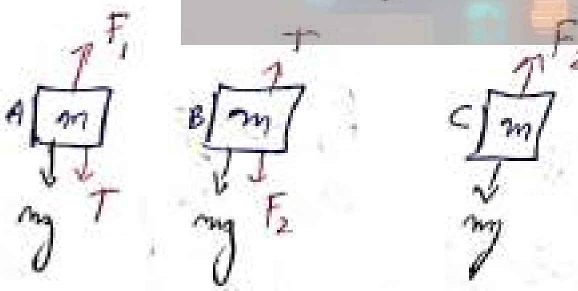
After cutting. $T = 0$



$\boxed{a_1 = 0}$ $\boxed{a_2 = \frac{(m_1 + m_2) g}{m_2}} \uparrow$ $\boxed{a_3 = g} \downarrow$

Q find acc of blocks
a) spring f_1 is cut
b) ~~spring~~ string is cut
c) spring f_2 is cut.





$F_1 = 3mg \quad T = 2mg \quad F_2 = mg$

~~a) $f_1 = 0$~~

~~$3mg = m a_A$~~

~~$\boxed{a_A = 3g}$~~

~~c) $f_2 = 0$~~

~~$a_C = g$~~

a) $f_1 = 0$

$T = 0$

$\boxed{a_A = g \downarrow}$ $\boxed{a_B = 2g \downarrow}$ $\boxed{a_C = 0}$

~~b) $T = 0$~~ But $a_B > a_1$ so T will develop

They should have been moving together

so,

$\boxed{2m}$ A+B

$2mg$ $f_2 = mg$

$\boxed{a_C = 0}$ $\boxed{a_A = a_B = \frac{3}{2} g \downarrow}$

b) $T = 0$

$\boxed{a_A = 2g \uparrow}$

$\boxed{a_B = 2g \downarrow}$

$\boxed{a_C = 0}$

c) $f_2 = 0$

$\boxed{a_C = g} \downarrow$

$F_1 = 3mg$

$a_A = a_B$, $F_1 = 3mg$

$\boxed{A+B}$

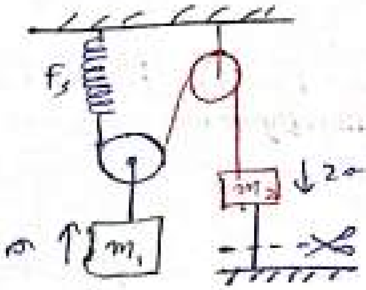
$2mg$

~~$a_A = a_B = g \downarrow$~~

$a_A = a_B = \frac{3mg - 2mg}{2mg}$

$\boxed{a_A = a_B = \frac{g}{2} \uparrow}$

Q find initial acceleration of m_2 $(m_1 > 2m_2)$ $\left(\frac{m_1 - 2m_2}{2m_2} g\right)$ Ans



$2T + \cancel{F_s}$

m_1 : $m_1 g$ downward

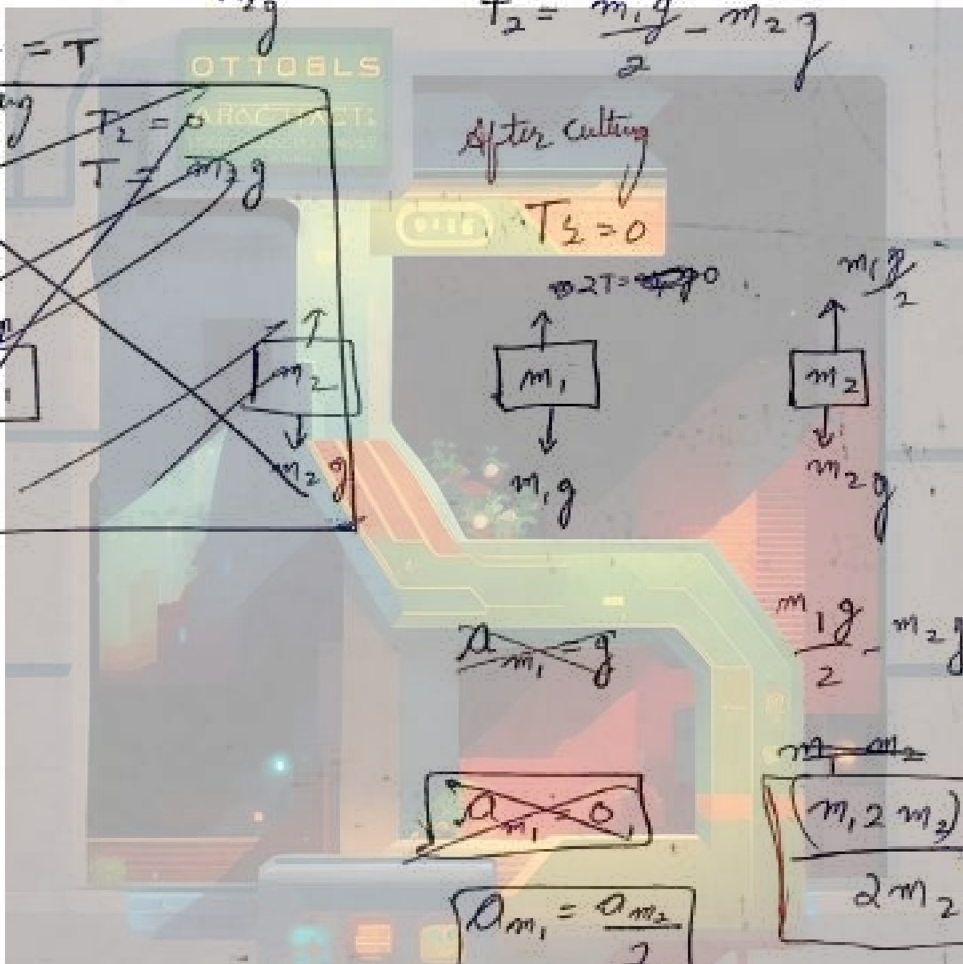
m_2 : T upward, $m_2 g$ and T_2 downward

$F_s = T$

$m_1 g = 2T$

$T = \frac{m_1 g}{2}$

$T_2 = \frac{m_1 g}{2} - m_2 g$



~~After cutting~~

~~$T_2 = 0$~~

~~$T = m_1 g$~~

After cutting

$T_2 = 0$

$2T = \cancel{m_1 g}\ 0$

m_1 : $m_1 g$ downward

m_2 : $\frac{m_1 g}{2}$ upward, $m_2 g$ downward

$\cancel{a_{m_1} = g}$

$\frac{m_1 g}{2} - m_2 g = m_2 a$

$\boxed{\frac{(m_1 - 2m_2) g}{2m_2} = a}$

$\cancel{a_{m_1} = a_1}$

$\boxed{a_{m_1} = \frac{a_{m_2}}{2}}$

Friction

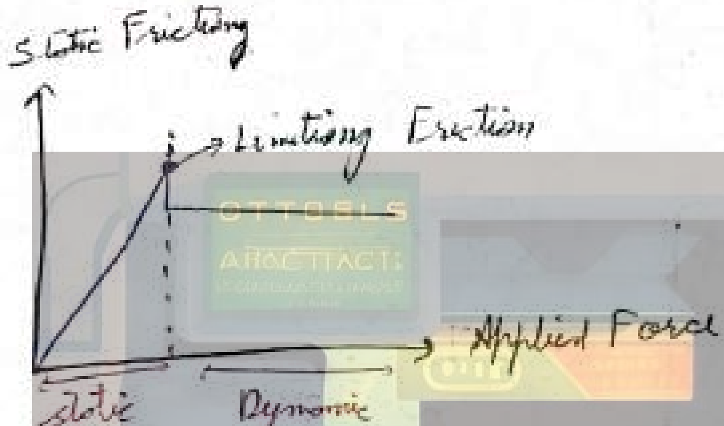
Static Friction (greater than Dynamic)

→ Self-Adjusting
(equal to Force applied)

→ Max-Value → Limiting Friction

Dynamic Friction (Kinetic Friction)
~~greater than Dynamic~~

Sliding > Rolling



Laws of Limiting Friction :-

→ The Limiting Friction is directly proportional to normal reaction by surface in contact.

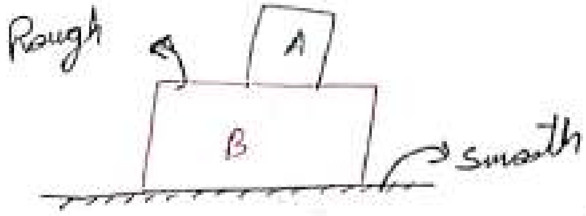
$f_L \propto N$

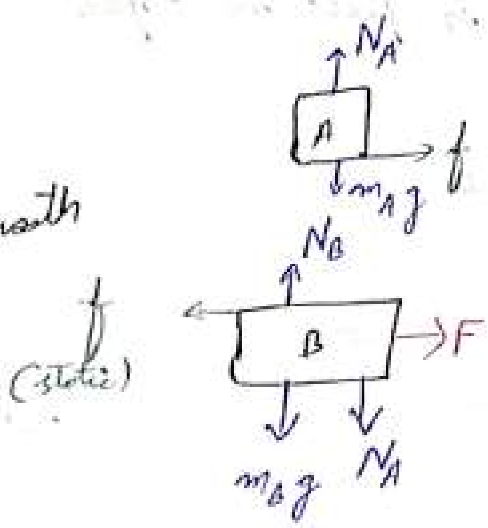
→ depends upon nature of surfaces in contact.

$\boxed{f_L = \mu N}$

μ = Coefficient of friction between 2 surfaces.

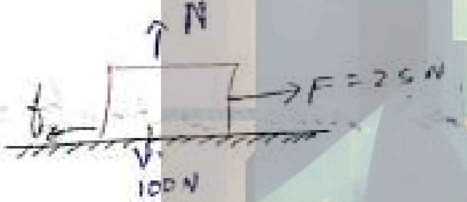
→ The Direction of Limiting Friction force is opposite to the direction in which the body is on the verge of starting its motion.





$$a_{A_{max}} = \frac{f_l}{m_A}$$

Q. Weight 100 N just begins to move at 25N horizontal force. find coefficient of friction.



$N = 100\,N$

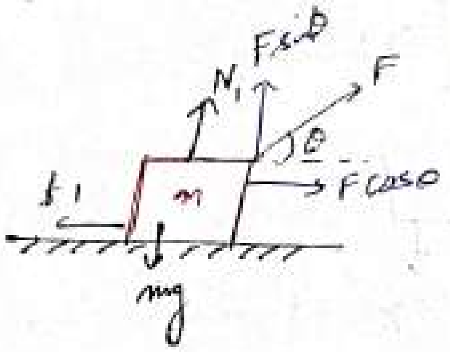
$f = 25\,N$

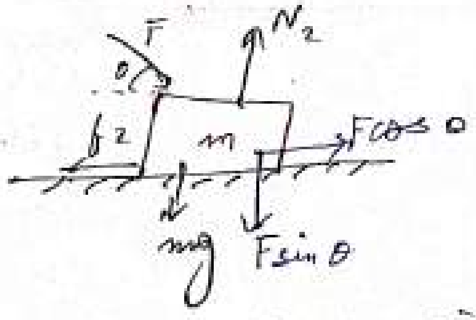
$25 = \mu(100)$

$\mu = \frac{25}{100}$

$\boxed{\mu = \frac{1}{4} = 0.25}$

is It easy to pull or push an object.





$N_1 = mg - F \sin\theta$

$N_2 = mg + F \cancel{\cos\theta} \sin\theta$

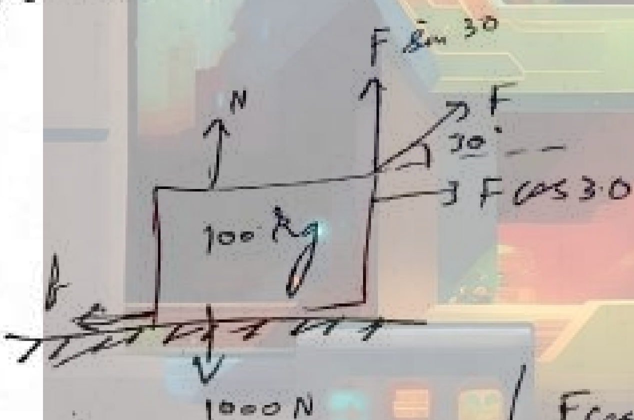
$N_2 > N_1$

$f_2 > f_1 \quad (f \propto N)$

Thus ~~f~~ it is easier to Pull an object.

~~(If object~~

Q $M = 100\,kg$ $\theta = 30$ $\mu = 0.3$ find F so block moves uniformly on surface.



$1000 = N + F \times \frac{1}{2}$

$1000 = \frac{2N + F}{2}$

$2000 = 2N + F$

$\frac{2000 - F}{2} = N$

$F\cos 30 = \mu \times N$

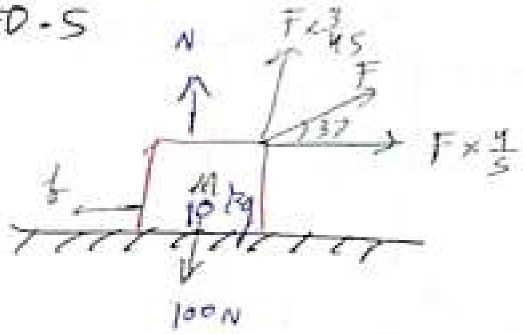
$\frac{F\sqrt{3}}{2} = 0.3 \times \frac{2000 - F}{2}$

$F\left(\frac{\sqrt{3} + 0.3}{0.3}\right) = \frac{600}{1}$

$F = \frac{600}{\sqrt{3} + 0.3}$

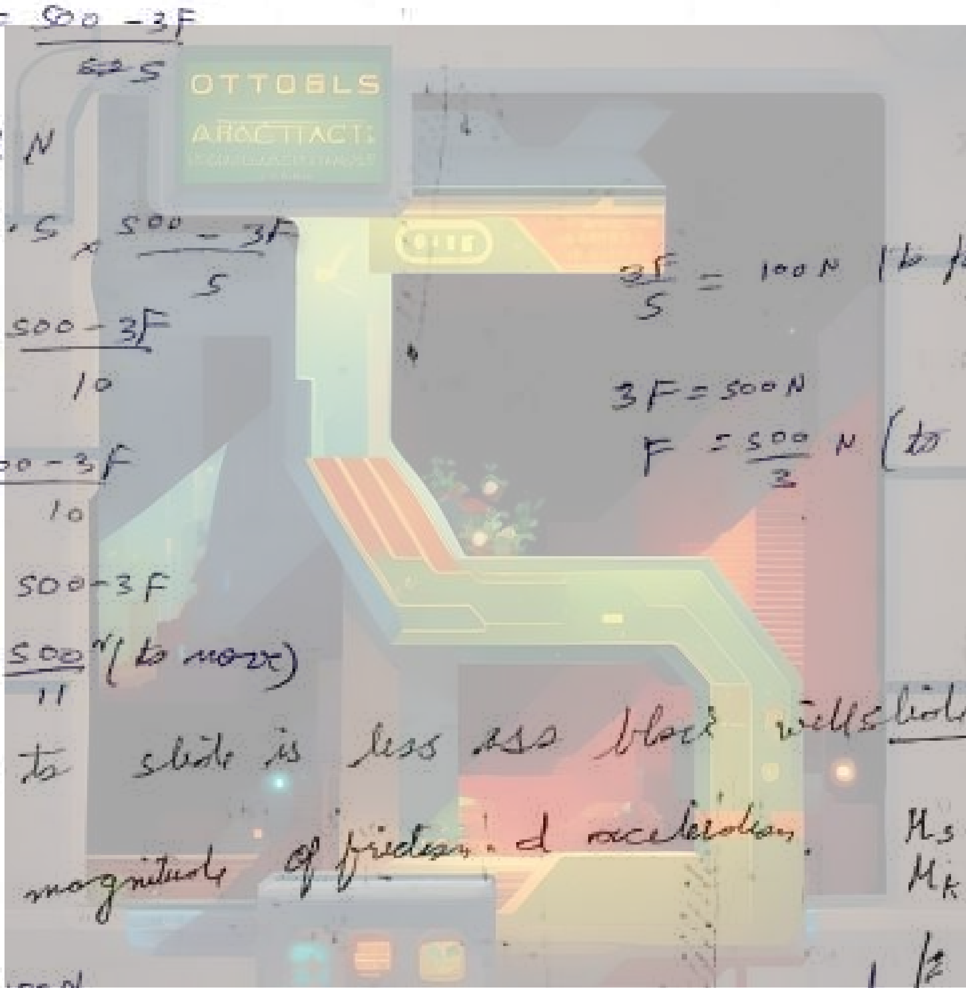
Q For Force is gradually increased from 0, will block first slide or lift.

$\mu = 0.5$



$$N = 100 - \frac{3F}{5}$$

$$N = \frac{500 - 3F}{5}$$



$$f = \mu N$$

$$= 0.5 \times \frac{500 - 3F}{5}$$

$$f = \frac{500 - 3F}{10}$$

$$\frac{4F}{5} = \frac{500 - 3F}{10}$$

$$8F = 500 - 3F$$

$$F = \frac{500}{11} N \text{ (to move)}$$

$$\frac{3F}{5} = 100 N \text{ (to lift)}$$

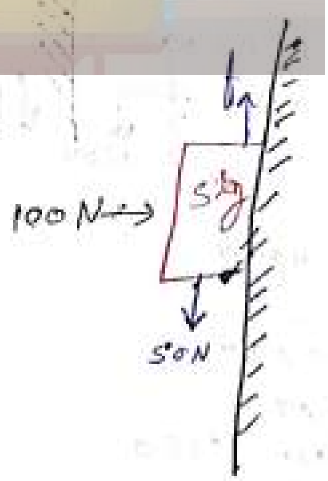
$$3F = 500 N$$

$$F = \frac{500}{3} N \text{ (to lift)}$$

force to slide is less so block will slide first.

Q Determine magnitude of friction and acceleration.

$\mu_s = 0.4$
$\mu_k = 0.3$



a) $N = 100 N$

$$f_{max} = f_e = \mu_s \times N$$
$$= 0.40 \times 100$$
$$\boxed{f_e = 40 N} < 50 N$$

So object will move

$$f_k = \mu_k \times N$$
$$= 0.3 \times 100$$
$$\boxed{f = 30 N}$$

$$50 - 30 = 5 \times a$$
$$\frac{20}{5} = a$$
$$\boxed{a = 4 m/s^2 \downarrow}$$

123

b) mass = 2 kg

$f_{s,max} = \mu_s \times 100$

$= 40 N > 20$

the object will not move

$\boxed{\begin{array}{l} f = 20 N \\ a = 0 \ m/s^2 \end{array}}$

c) $\mu_s = 0.4$

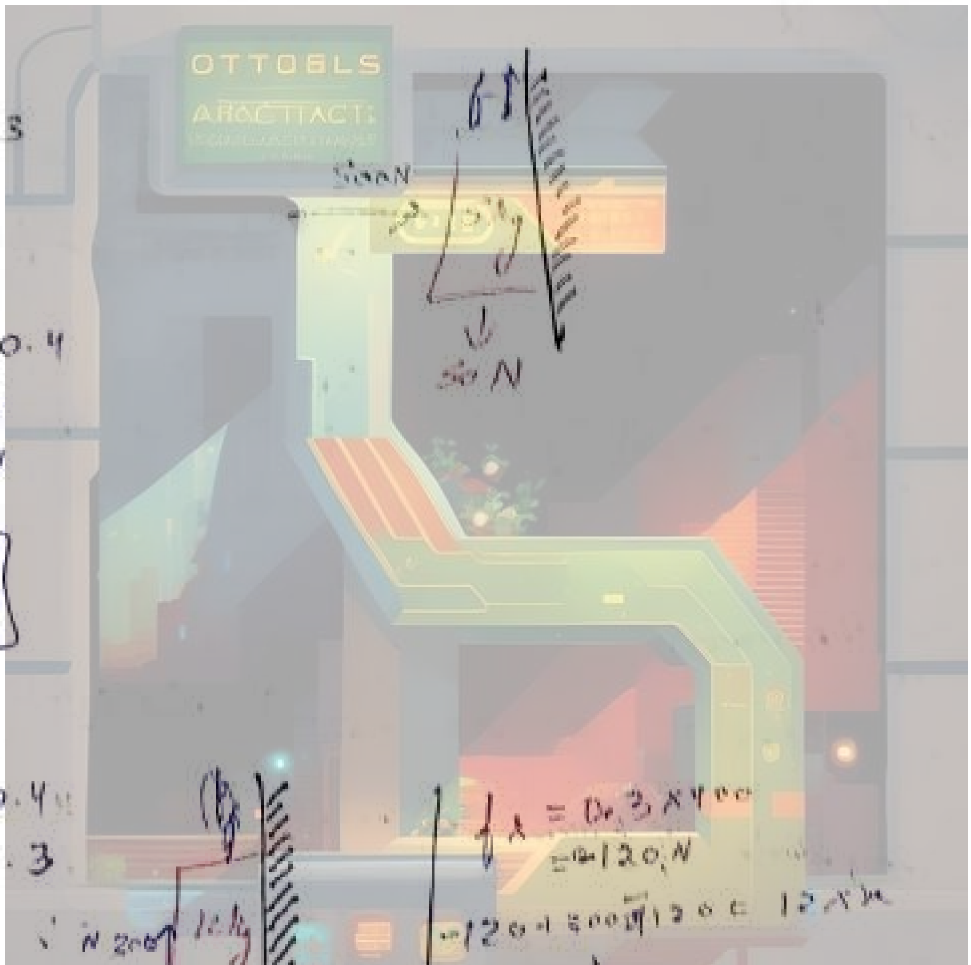
$\mu_k = 0.3$

$N = 500$

$f_s = 500 \times 0.4$

$= 40 \times 5$

$= 200 N$



$\boxed{\begin{array}{l} a = 0 \\ f = 50 N \end{array}}$

Q

$\mu_s = 0.4$

$\mu_k = 0.3$

$N = 400 N$

$f_s = 0.4 \times 400$

$= 40 \times 4$

$= 160 N < 180$

will move

$f_k = 0.3 \times 400$

$= 120 N$

$-120 + 300 - 120 = 12 a$

$\cancel{\frac{300}{12} = 25}$

$\cancel{\boxed{\begin{array}{l} a = 25 \ m/s^2 \uparrow \\ f = 120 N \end{array}}}$

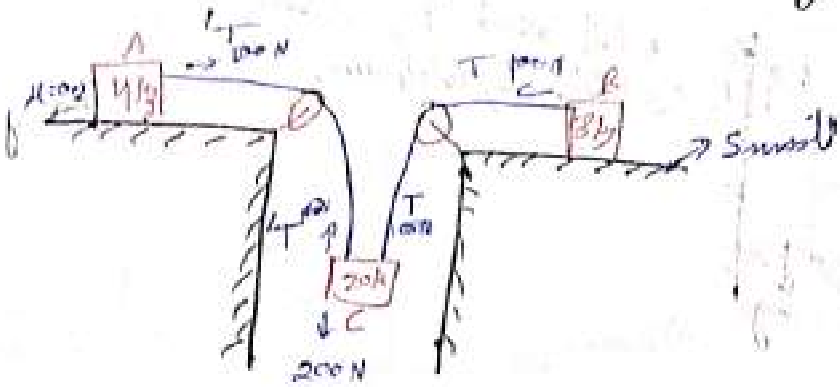
$300 - 240 = 12 a$

$a = \frac{60}{12}$

$\boxed{a = 5 \ m/s^2 \uparrow}$

$\boxed{f = 120 N \downarrow}$

Q find accelertion of blocks & tension in strings



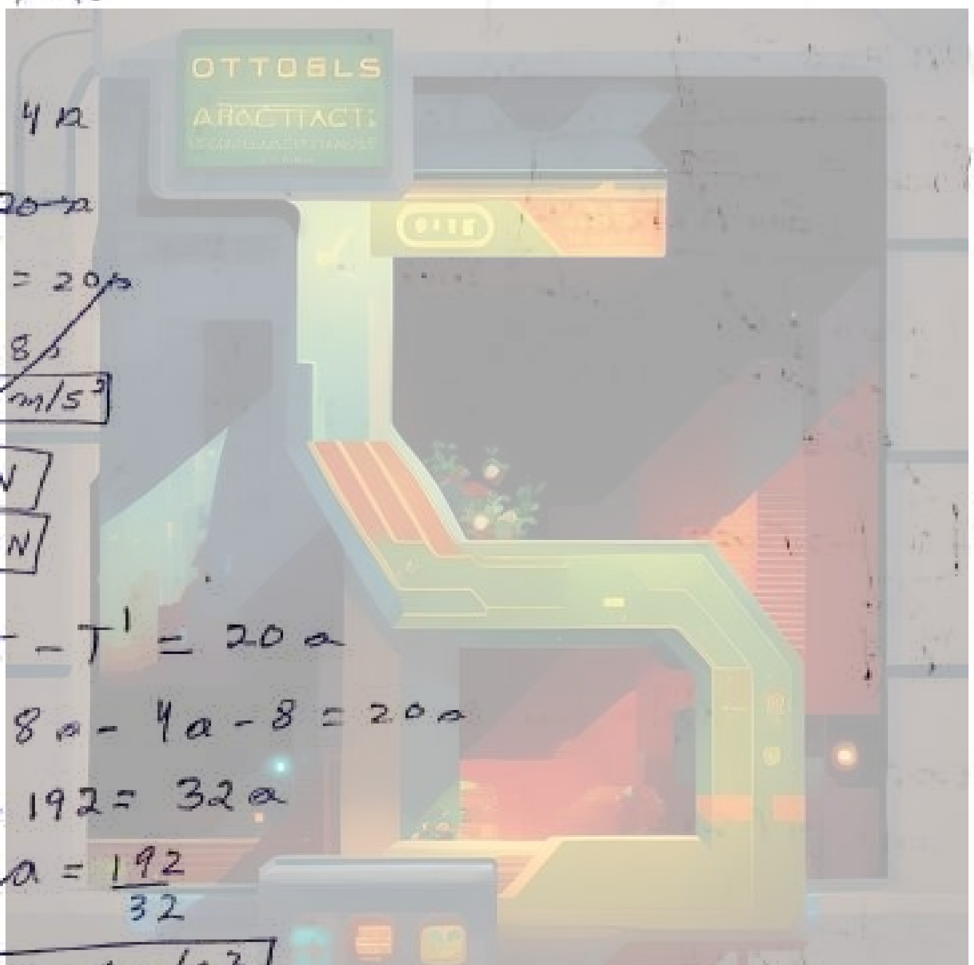
$\boxed{T = 8a}$

$f_1 = 0.2 \times 40$
$= 8N$

$T' - 8 = 4a$

~~$T + T' = 20a$~~

$\cancel{8a + 4a + 8 = 20a}$
$\cancel{8 = 8a}$
$\cancel{\boxed{a = 1 m/s^2}}$
$\cancel{\boxed{T = 8N}}$
$\cancel{\boxed{T' = 12N}}$

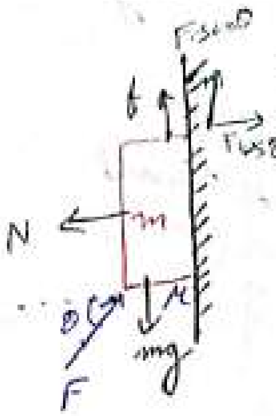


$200 - T - T' = 20a$
$200 - 8a - 4a - 8 = 20a$
$192 = 32a$
$a = \frac{192}{32}$
$\boxed{a = 6 m/s^2}$

$T = 8 \times 6$
$\boxed{T = 48N}$

$T' = 24 + 8$
$\boxed{T' = 32N}$

Q



what what range F block remains in static equilibrium.

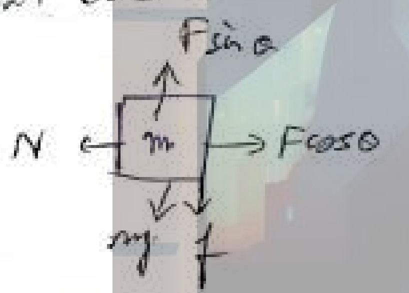
F will be minimum when friction will be max

$f = \mu N$
$= F\mu\cos\theta$

$F\sin\theta + F\mu\cos\theta = mg$

$$\boxed{F_{min} = \frac{mg}{\sin\theta + \mu\cos\theta}}$$

As $F\sin\theta$ increases from f_{μ}, block tends to move up & so friction acts down.



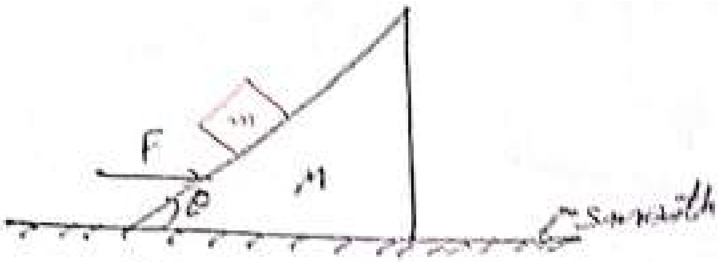
$f_L = \mu N$
$= \mu F\cos\theta$

$F\sin\theta = mg - \mu F\cos\theta$

$F = \frac{mg}{\sin\theta - \mu\cos\theta}$

$$\boxed{F_{max} = \frac{mg}{\sin\theta - \mu\cos\theta}}$$

Q find F for friction between block & wedge is 0.



For zero friction, acc of m ~~wrt~~ wrt wedge = 0.
or
Normal = 0.

$\cancel{N}^{0} + ma\sin\theta = mg\cos\theta$

$ma\sin\theta = mg\cos\theta$

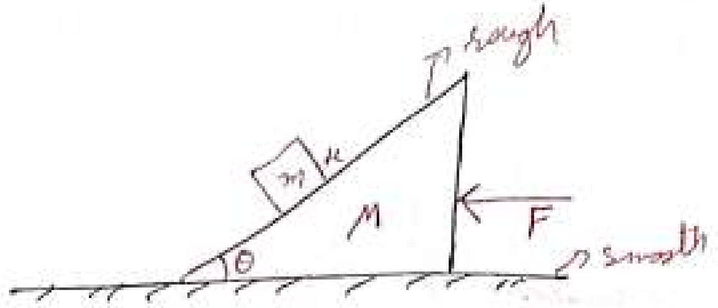
$a = g\cot\theta$

$F = Ma$ (contact breaks as $N=0$)

$\boxed{F = Mg\cot\theta}$

~~Q find min & Max F so block do not slip~~

Q find min & Max F so block do not slip.



for min F block has a tendency to move down

$a = \frac{F}{(m+M)}$

$fl = \mu N$

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

~~$F - N\sin\theta = Ma$~~

~~$a = \frac{F - N\sin\theta}{M}$~~

$ma\sin\theta\,\mu + mg\cos\theta\,\mu + ma\cos\theta = mg\sin\theta$

$a\sin\theta\,\mu + g\cos\theta\,\mu = a\cos\theta = g\sin\theta$

~~$\cos\theta(g\mu - a) + \sin\theta(a\mu - g) = 0$~~

$a(\sin\theta\,\mu - \cos\theta) + g(\cos\theta\,\mu - \sin\theta) = 0$

$a = \frac{g\sin\theta - g\cos\theta\,\mu}{\mu\sin\theta + \cos\theta}$

$$\boxed{F_{min} = \frac{(m+M)(g\sin\theta - \mu g\cos\theta)}{\mu\sin\theta + \cos\theta}}$$

for max F, block has tendency to move up.

$fl = \mu N$

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

$mg\sin\theta + ma\sin\theta\,\mu + mg\cos\theta\,\mu = ma\cos\theta$

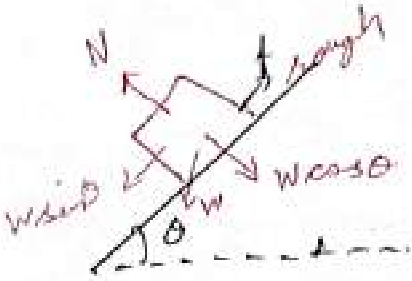
$a = \frac{g\sin\theta + g\cos\theta\,\mu}{\cos\theta - \mu\sin\theta}$

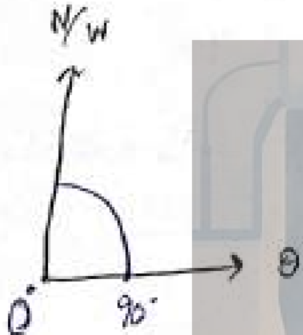
$$\boxed{F_{max} = \frac{(M+m)(g\sin\theta + \mu g\cos\theta)}{\cos\theta - \mu\sin\theta}}$$

Q. A block of weight W rests on a rough wooden plank. The angle of incline of ~~plan~~ plank is gradually increased from 0° to 90°.

Draw. i) ratio of N/W vs θ graph

ii) ratio of f/W vs θ graph





$N = W\cos\theta$

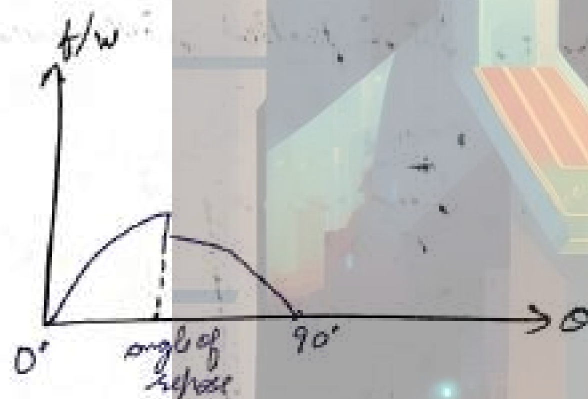
$\frac{N}{W} = \cos\theta$

Till the block is static

$f = W\sin\theta$

$\frac{f}{W} = \sin\theta$

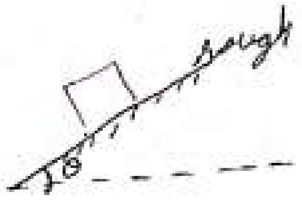
Block just begins to slide at θ = angle of repose

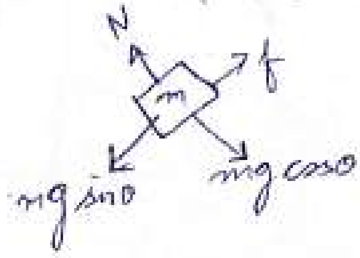


$f = \mu W\cos\theta$

$\frac{f}{W} = \mu\cos\theta \quad (\mu < 1)$

Q A block slides down an incline plane of angle θ with constant velocity. It is then projected up the same plane with u velocity. How far up the incline will it move before comming to rest?





$mg\sin\theta = f$

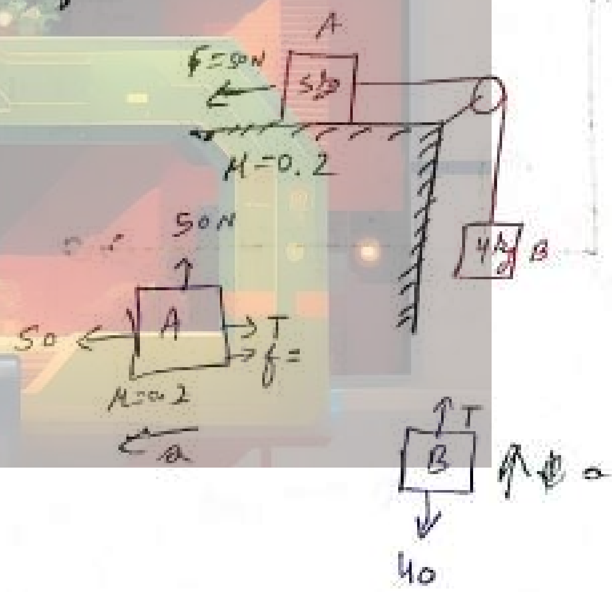
$f + mg\sin\theta = ma$

$\boxed{2g\sin\theta = a}$

$v = 0$
$u = u$
$a = -2g\sin\theta$
$v^2 = u^2 + 2as$

$$\boxed{S = \frac{+u^2}{4g\sin\theta}}$$

Q2. find acc & friction b/w A & surface. It is pulled with force 50N.



$f_L = 10N$

If system at rest,
$T = 40$ (Block-B)

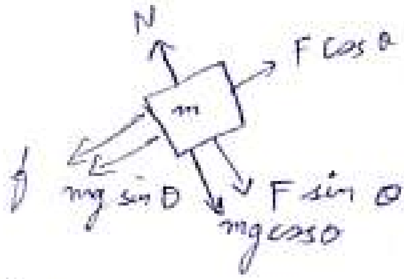
Block-A
$50 = 40 + f$
$f = 10$ (possible)
So, system is in rest

$\boxed{f = 10N}$

$\boxed{T = 40N}$

$\boxed{a = 0}$

Q Find max μ_s such that block do not go up the incline no matter how much F is.



$F\cos\theta = f + mg\sin\theta$

$N = F\sin\theta + mg\cos\theta$

$F\cos\theta = \mu F\sin\theta + \mu mg\cos\theta + mg\sin\theta$

$F(\cos\theta - \mu\sin\theta) = mg(\mu\cos\theta + \sin\theta)$

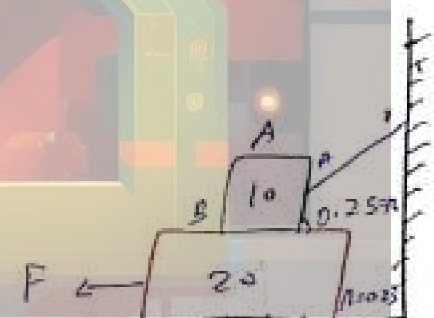
$$F = \frac{mg(\mu\cos\theta + \sin\theta)}{\cos\theta - \mu\sin\theta}$$

let F be infinite so,

$\cos\theta - \mu\sin\theta = 0$

$\boxed{\mu = \cot\theta}$

Q find F to pull ~~F~~ 20kg block, find tension in string.



$N + \frac{T}{\sqrt{2}} = 100$

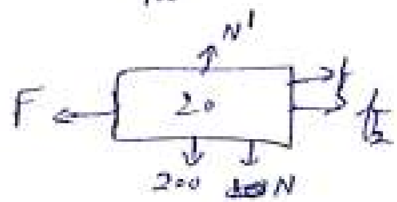
$N = 100 - \frac{T}{\sqrt{2}}$

$\frac{T}{\sqrt{2}} = 0.25 \times \frac{100\sqrt{2} - T}{\sqrt{2}}$ $\quad \frac{100\sqrt{2} - T}{\sqrt{2}}$

$T = 25\sqrt{2} - 0.25T$

$\frac{5}{4}T = 25\sqrt{2}$

$\boxed{T = 20\sqrt{2}}$ ✓



$N = ~~20~~\ 100 - 20$

$\boxed{N = 80N}$

$f = \frac{20\sqrt{2}}{\sqrt{2}}$

$f = 20$

$N' = 200 + 80$

$N' = 280$

$f = \cancel{0} \, 0.25 \times 280$

$f = 2.5 \times 28$

$f = 2\cancel{8}^{14} \times \frac{5}{\cancel{2}}$

$\boxed{f = 70\,N}$

$F = f + 20$

$\boxed{\cancel{F = 70\,N}}$

$\boxed{F = 90\,N}$

we use $f_k(max)$ because the blocks slide.

① There is sufficient friction between man & board. Find min force required to exert on string to slide the board.

$N = Mg - F$

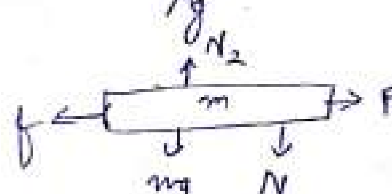
$mg + N = N_2$

$mg + Mg - F = N_2$

$f_k = \mu(mg + Mg - F)$

$F = \mu g(M+m) - \mu F$

$$\boxed{F \geq \frac{\mu g (M+m)}{1+\mu}}$$



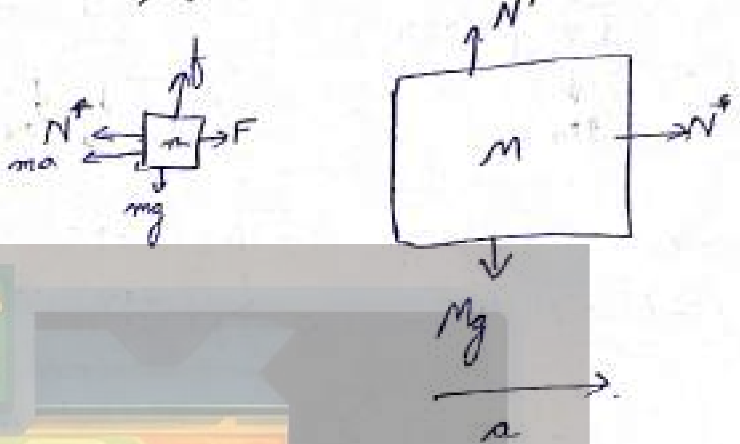
Q find min F so m do not slide

$f = mg = \mu N$

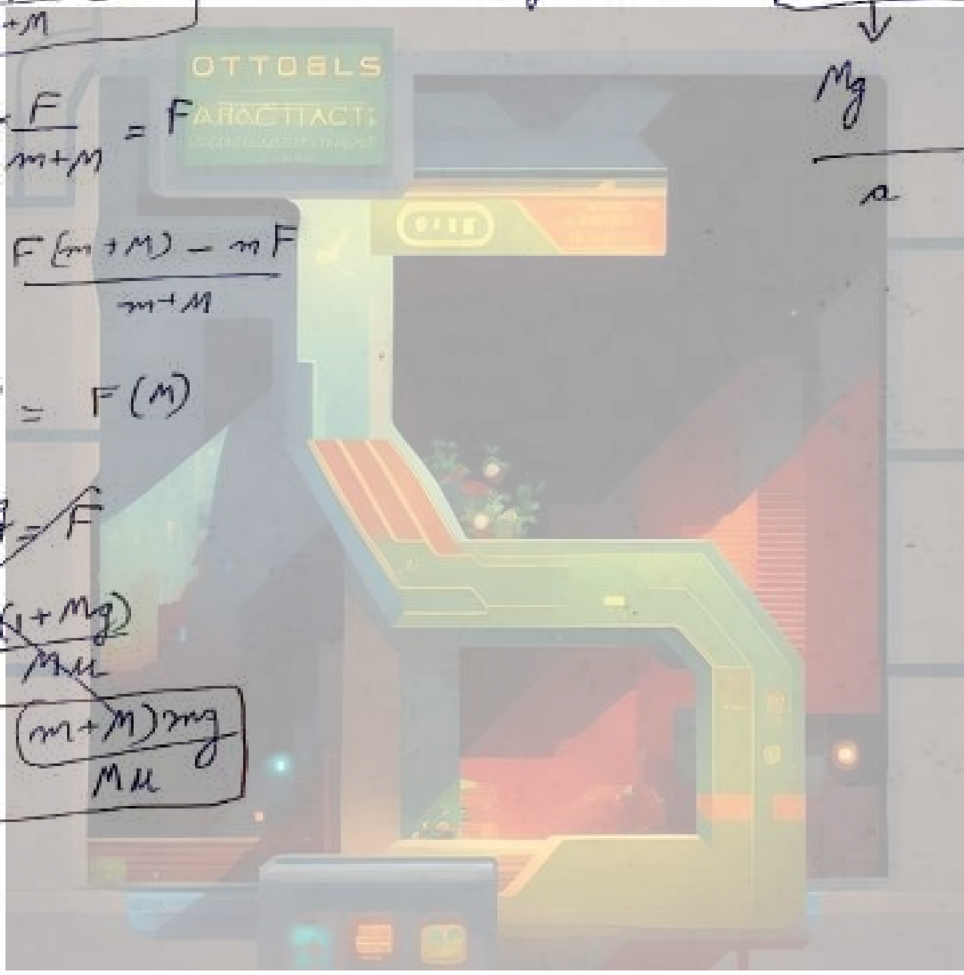
$N = \dfrac{mg}{\mu}$

$N + ma = F$

$\dfrac{mg}{\mu} + ma = F$



$\boxed{\dfrac{F}{m+M} = a}$



$\dfrac{mg}{\mu} + m \times \dfrac{F}{m+M} = F$

$\dfrac{mg}{\mu} = \dfrac{F(m+M) - mF}{m+M}$

$\dfrac{(m+M)(mg)}{\mu} = F(M)$

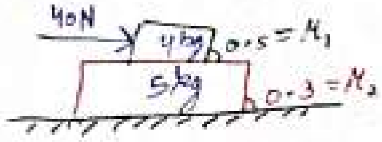
$\cancel{\dfrac{m + Mmg}{M\mu} = F}$

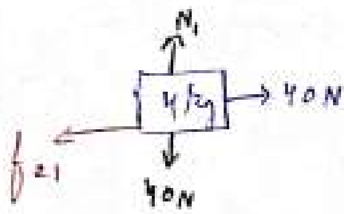
$\cancel{F = \dfrac{m(1+Mg)}{M\mu}}$

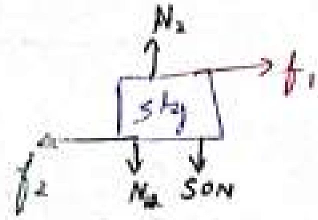
$\boxed{F = \dfrac{(m+M)mg}{M\mu}}$

Two Block System :-

eg.







$N_1 = 40$

$f_1(max) = \mu_1 N_1$

$= 0.5 \times 40$

$= 20N$

$N_2 = 50 + N_1 = 50 + 40 = 90$

$f_2(max) = \mu_2 N_2$

$= 0.3 \times 90$

$= 27N$

$f_{21}(max) < f_2(max)$

$\boxed{a_{5kg} = 0\, m/s^2}$

$40 - f_1 = 4a$

$\frac{40-20}{4} = a$

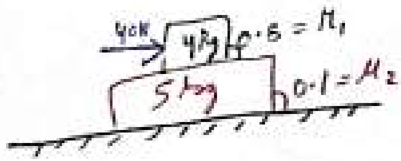
$a = \frac{20}{4}$

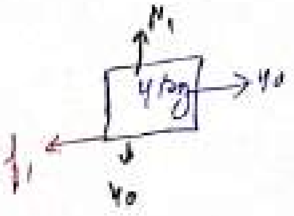
$\boxed{a_{4kg} = 5\, m/s^2}$

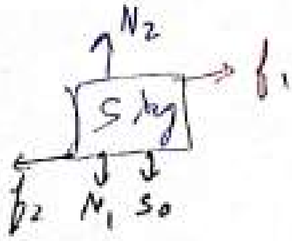
$f_1 = f_2$

$\boxed{f_2 = 20N}$.

eg 2.







$N_1 = 40\,N$

$f_1(max) = \mu_1 N_1$

$= 0.8 \times 40$

$= 32\,N$

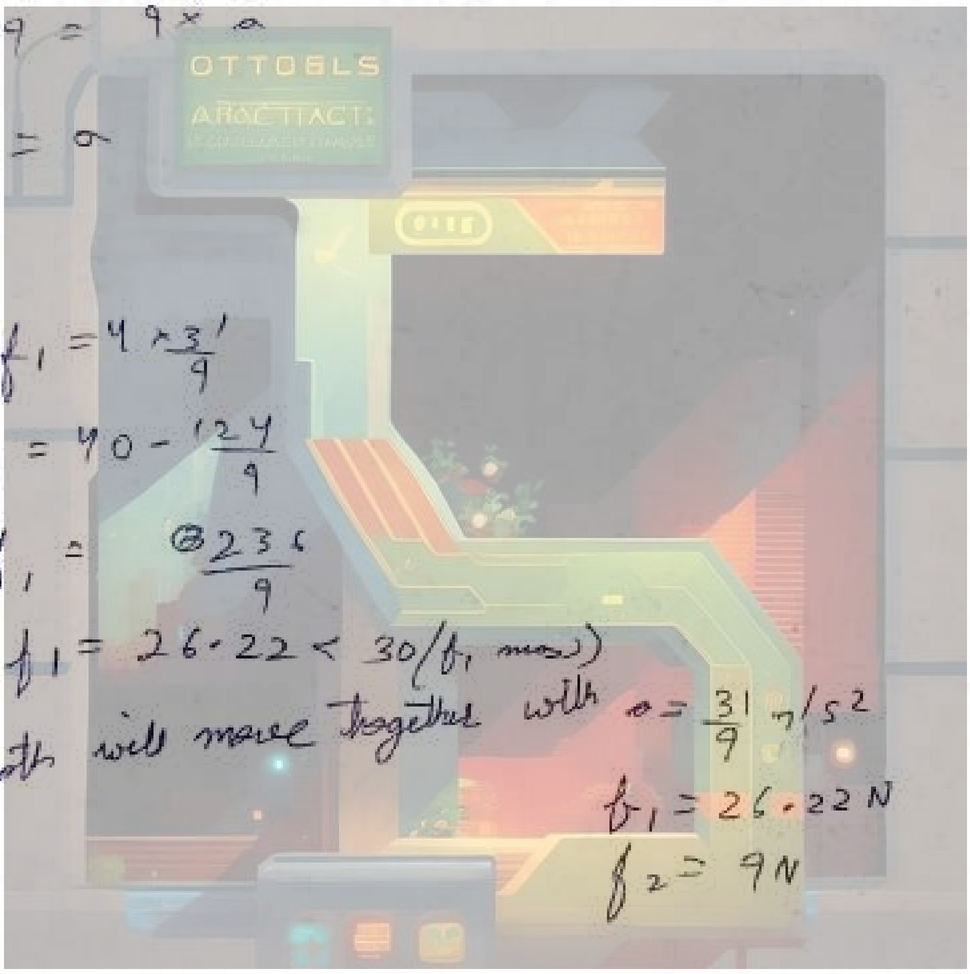
$N_2 = 50 + 40 = 90\,N$

$f_2(max) = \mu_2 N_2$

$= 0.1 \times 90\,N$

$= 9\,N$

If both move together,



$40 - 9 = 9 \times a$

$\frac{31}{9} = a$

Verify

$40 - f_1 = 4 \times \frac{31}{9}$

$f_1 = 40 - \frac{124}{9}$

$f_1 = \frac{236}{9}$

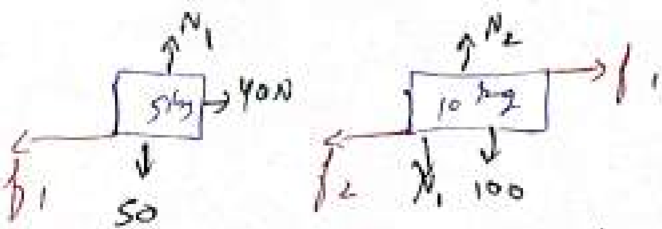
$f_1 = 26.22 < 30\,(f_1\ max)$

So, both will move together with $a = \frac{31}{9}\ m/s^2$

$f_1 = 26.22\,N$

$f_2 = 9\,N$

Q find acc. & friction forces.

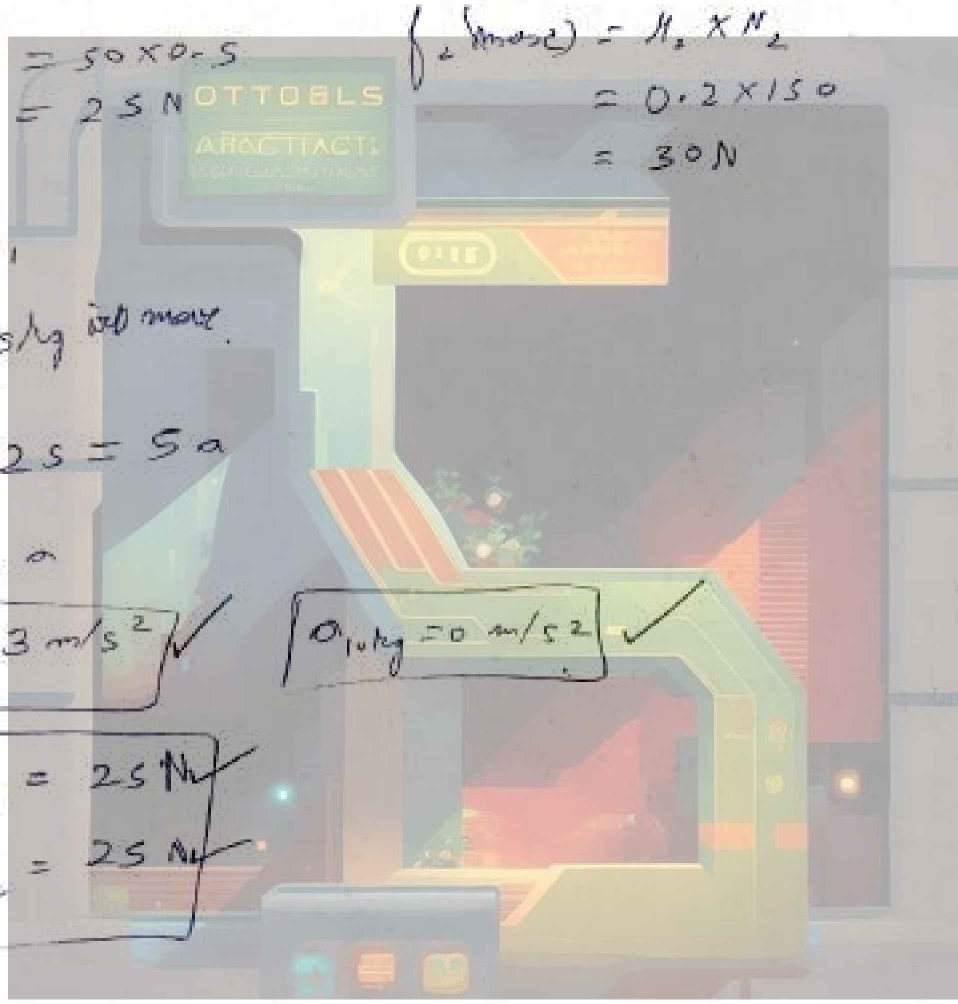


$N_2 = N_1 + 100 = 150$

$N_1 = 50$

$f_1(max) = 50 \times 0.5$
$= 25\,N$

$f_2(max) = \mu_2 \times N_2$
$= 0.2 \times 150$
$= 30\,N$



$f_2 > f_1$

Only 5kg will move.

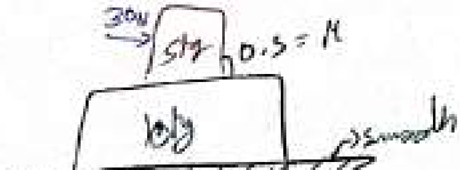
$40 - 25 = 5a$

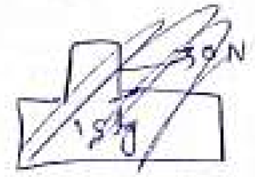
$\frac{15}{5} = a$

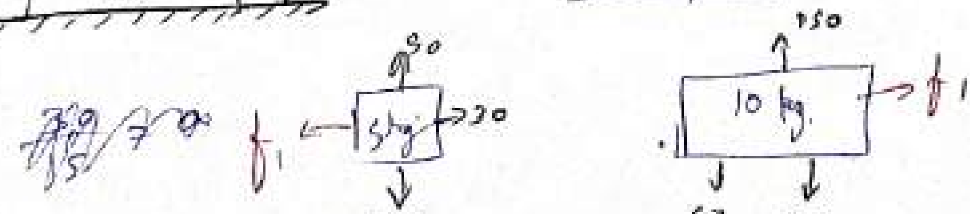
$\boxed{a_{5kg} = 3\,m/s^2}$ ✓ $\boxed{a_{10kg} = 0\,m/s^2}$ ✓

$\boxed{\begin{aligned} f_1 &= 25\,N \\ f_2 &= 25\,N \end{aligned}}$

Q







$f_1(max) = 25\,N$

If both move together

$$\frac{30}{15} = \boxed{a = 2\ m/s^2}\ \checkmark$$

verify

$$30 - f_1 = 5 \times 2$$

$$f_1 = 30 - 10$$

$$\boxed{f_1 = 20}\ \checkmark\ \text{(possible)}$$

F applied force = 50 N

If both move together

$$\frac{50}{15} = \frac{10}{3}$$

Verify $f_1 = 50 - \frac{100}{3} > f_1$ max

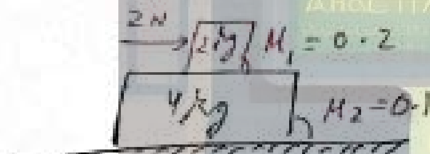
So will move separately

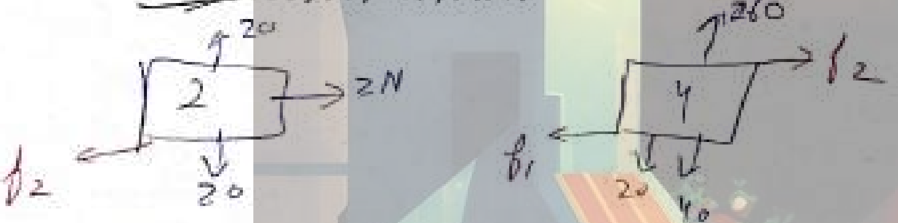
$$f_1 = 25$$

$$\frac{50 - 25}{5} = a_{5kg}$$

$$\boxed{\begin{aligned} a_{5kg} &= 5\ m/s^2 \checkmark \\ A_{10kg} &= \frac{25}{10} = 2.5\ m/s^2 \checkmark \end{aligned}}$$

Q find acc & friction





$$f_2\ max = 0.2 \times 20 = 4\ N$$

$$f_1\ max = 0.1 \times 60 = 6\ N$$

$$\boxed{a_{4kg} = 0\ m/s^2}$$

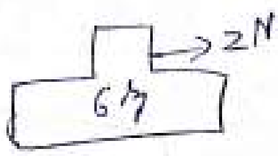
$$A_{2kg} = 2 - 2$$

$$\boxed{= 0\ m/s^2}$$

$$\boxed{\begin{aligned} f_2 &= 2N \\ f_1 &= 2N \end{aligned}}$$

If ground is smooth

If both move together



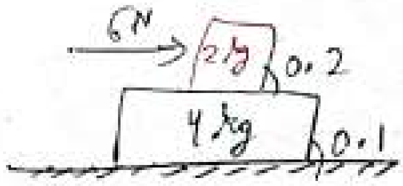
$$\frac{2}{6} = \boxed{a = \frac{1}{3}}\ \checkmark$$

verify

$$\frac{2}{3} = 2 - f_1$$

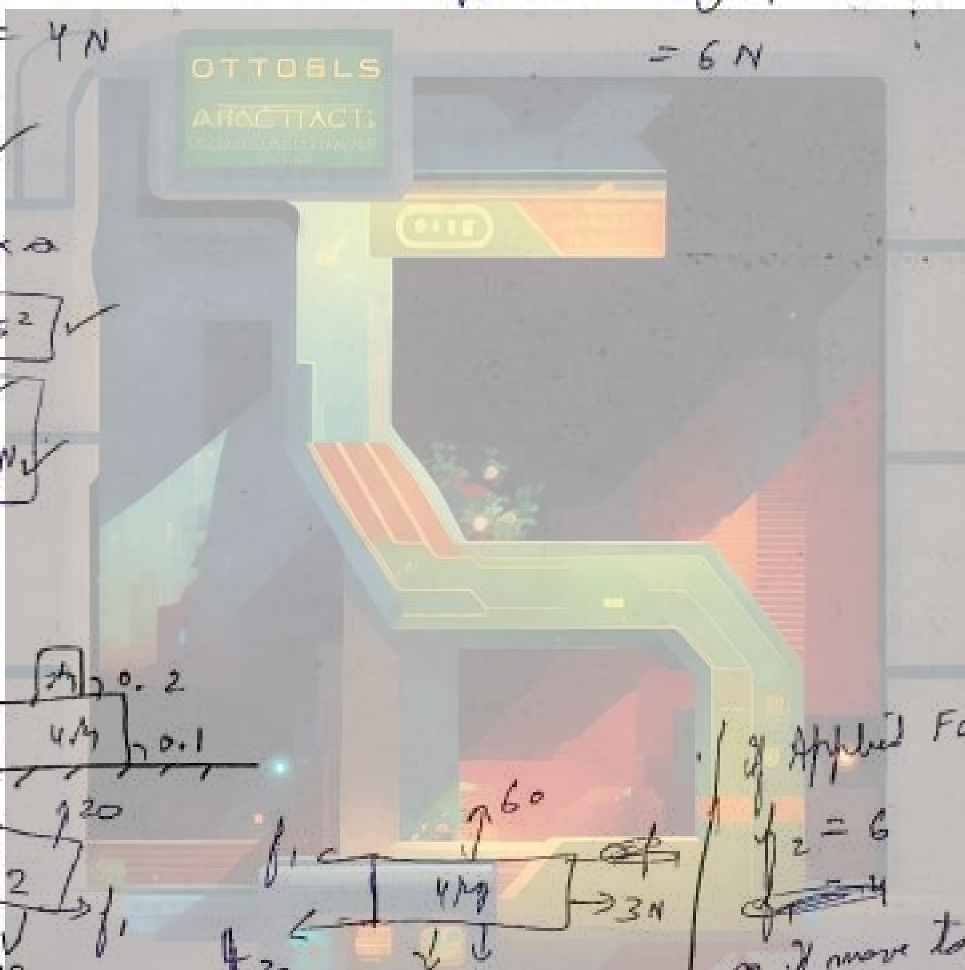
$$\boxed{f_1 = \frac{4}{3}}\ \checkmark\ \text{(possible)}$$

Q find acc of blocks & friction



$f_1(max) = 0.2 \times 20$
$= 4N$

$f_2(max) = 0.1 \times 60$
$= 6N$



$\boxed{a_{4kg} = 0}$ ✓

$6 - 4 = 2 \times a$

$\boxed{a = 1\ m/s^2}$ ✓

$f_1 = 4N$ ✓
$f_2 = 4N$ ✓

Q

If Applied Force = 12 N
$f_2 = 6$
$f_1 = 4$

If move together
$\frac{6}{6} = \boxed{a = 1\ m/s^2}$ ✓

Verify, $6 - f_1 = 4$
$\boxed{f_1 = 2}$ ✓ (possible)
$f_2\ 6N$ ✓

$f_1\ max = 4N$

$f_2\ max = 6N$

$3N < f_2\ max$

$a_{4kg} = 0$ ✓
$a_{2kg} = 0$ ✓
$f_2 = 3N$ ✓
$f_1 = 0N$ ✓

(138)

If Applied Force = 24.

If move Together

$$\frac{18}{6} = a$$

$a = 3$

Verify-

$f_1 = 6\,N$ (not possible)

So move separately ✓

$\boxed{f_1 = 4N}$ ✓

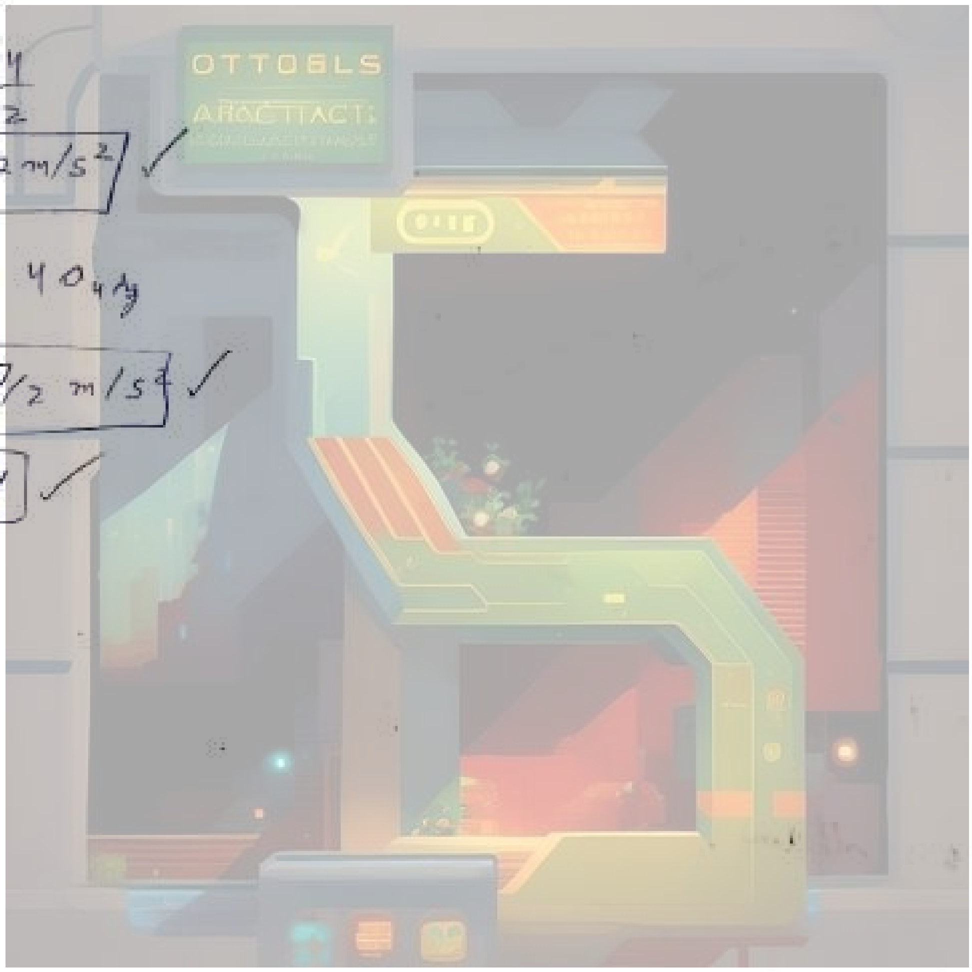
$a_{2kg} = \frac{4}{2}$

$\boxed{a_{2kg} = 2\,m/s^2}$ ✓

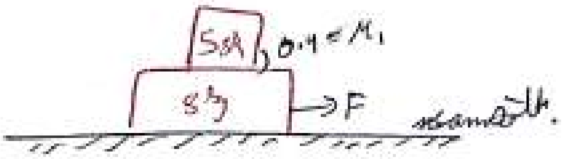
$24 - 10 = 4\,a_{4kg}$

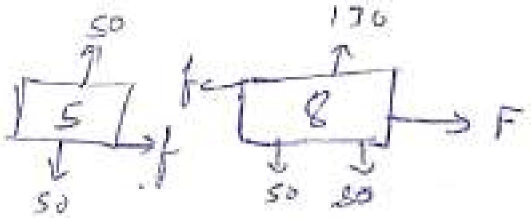
$\boxed{a_{4kg} = 7/2\,m/s^2}$ ✓

$\boxed{f_2 = 6N}$ ✓



Q find $F^{(max)}$ if they move Together.





$f_l = 0.4 \times 50$
$= 4 \times 5$
$= 20N$

to move together $f_l \leq 20$

$f = 5 \times a$

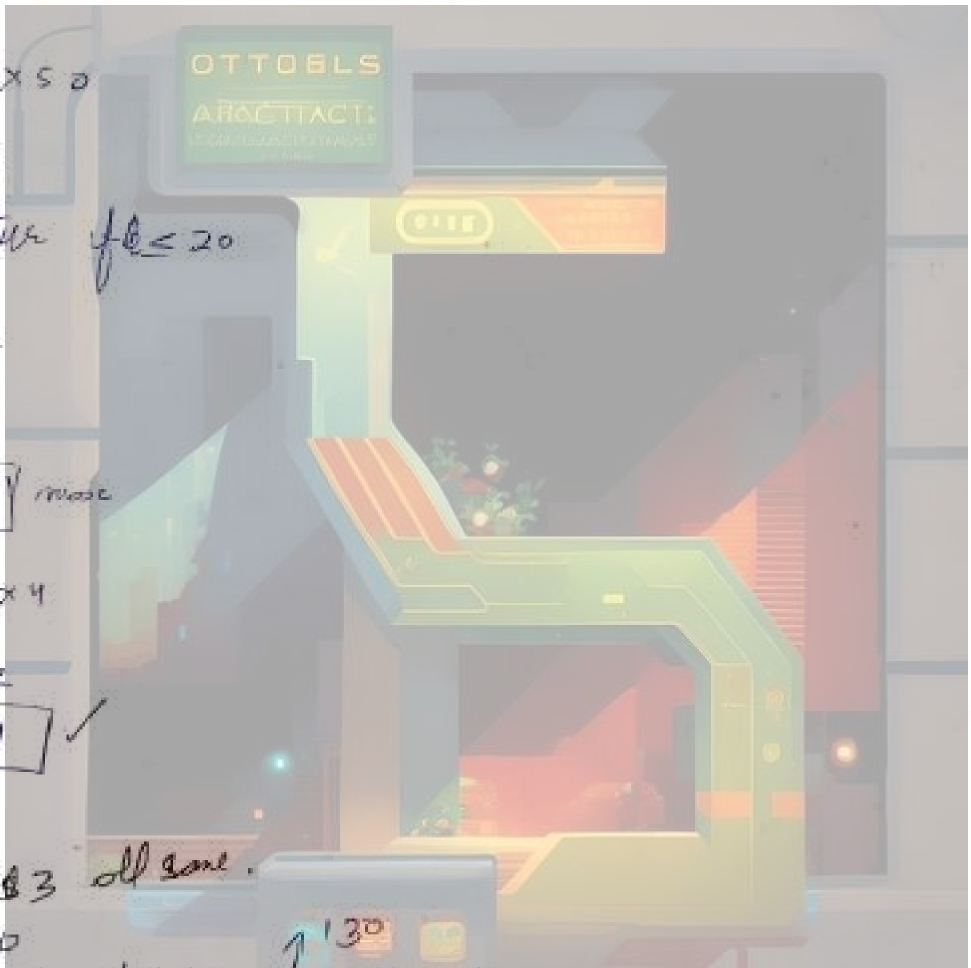
$20 = 5a$

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

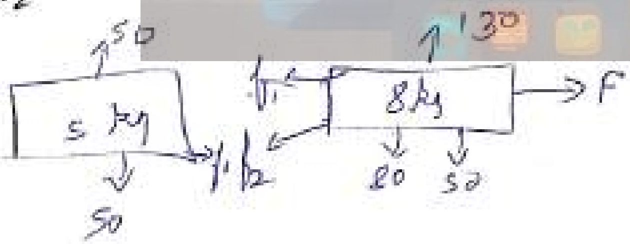
$F - 20 = 8 \times 4$

$F - 20 = 32$

$\boxed{F \leq 52 N}$ ✓



Q. $\mu_2 = 0.3$ all same.



$f_1 (max) = 20$

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

$f_2\ max = 0.3 \times 130$
$= 13 \times 3$
$= 39$

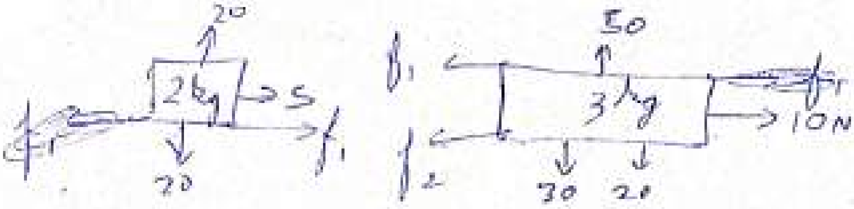
$F - 20 - 39 = 8 \times 4$

$F = 32 + 20 + 39$

$F = 52 + 39$

140 $\boxed{F = 91 N}$

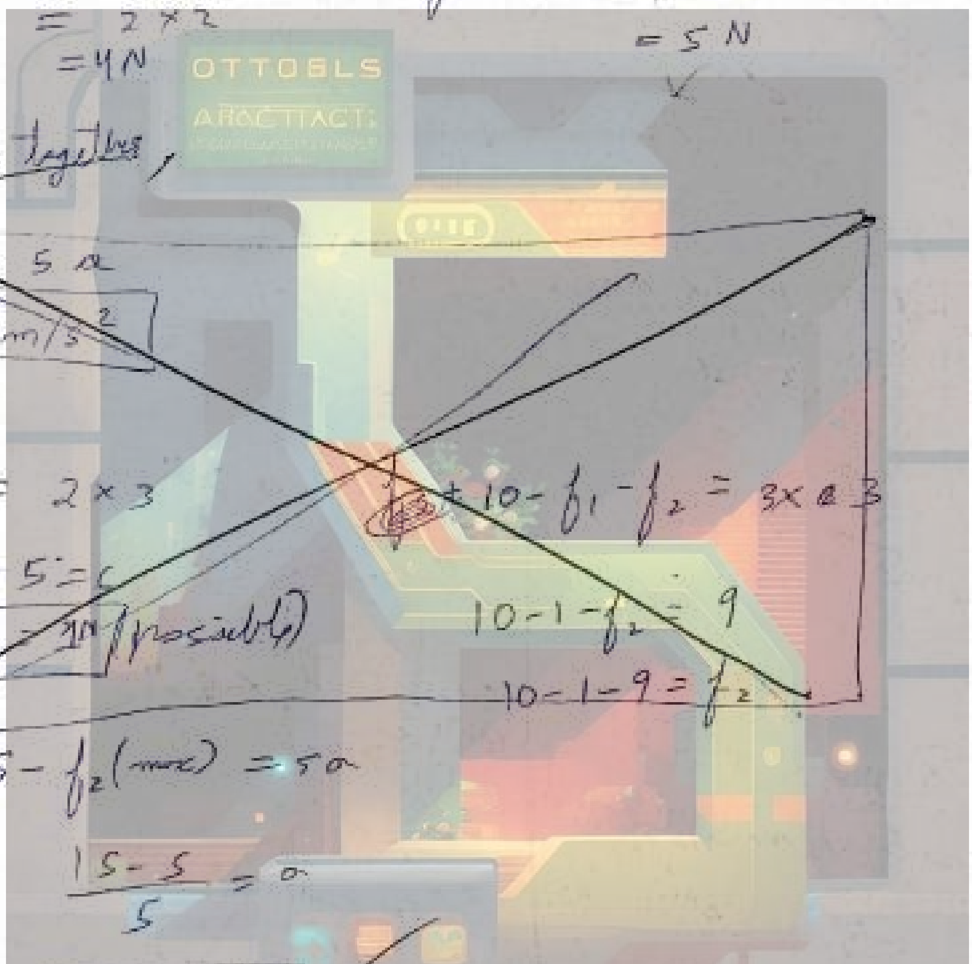
Q Find acc & Friction



$f_1(max) = 0.2 \times 20$ $\qquad$ $f_2(max) = 0.1 \times 50$

$= 2 \times 2$ $\qquad$ $= 5\,N$

$= 4N$



If move together,

$\cancel{15 = 5a}$

$\cancel{\boxed{a = 3\,m/s^2}}$

~~verify.~~

$\cancel{f_1 + 5 = 2 \times 3}$ $\qquad$ $\cancel{+10 - f_1 - f_2 = 3 \times 3}$

$\cancel{f_1 + 5 = 6}$ $\qquad$ $\cancel{10 - 1 - f_2 = 9}$

$\cancel{\boxed{f_1 = 1N}}$ ~~(possible)~~ $\qquad$ $\cancel{10 - 1 - 9 = f_2}$

$15 - f_2(max) = 5a$

$\frac{15 - 5}{5} = a$

$\boxed{a = 2\,m/s^2}$ ✓

Verify:-

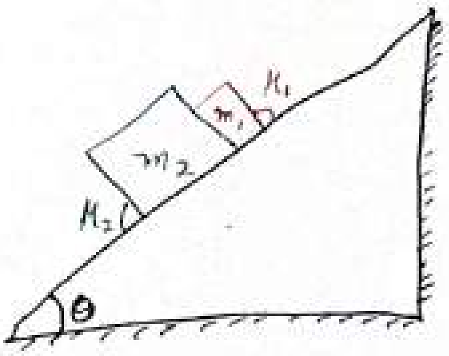
$f_1 + 5 = 2 \times 2$ $\qquad$ $10 + 1 - f_2 = 3 \times 2$

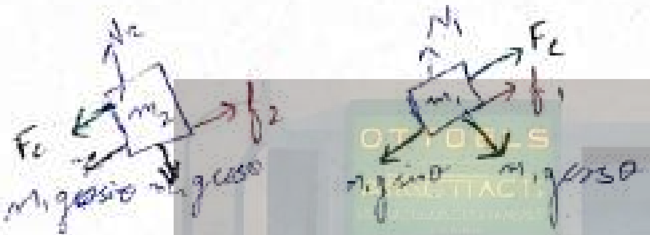
$f_1 = 4 - 5$ $\qquad$ $11 - f_2 = 6$

$\boxed{f_1 = -1N}$ ✓ $\qquad$ $f_2 = 11 - 6$

$\boxed{f_2 = 5}$ ✓ (possible)

Blocks In Contact on an inclined plane



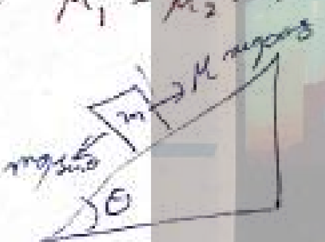


$N_1 = m_1 g \cos\theta$

$f_{1\,max} = \mu_1 N_1 = \mu_1 m_1 g \cos\theta$

$f_{2(max)} = m_2 g \cos\theta$

case 1:- $\mu_1 = \mu_2 = \mu$



$mg\sin\theta - \mu mg\cos\theta = ma$

$\boxed{a = g\sin\theta - \mu g\cos\theta}$

depend only on μ

$a_1 = a_2 = a$

$F_c = 0$

case 2:- $\mu_1 > \mu_2$

$a_2 > a_1$

$F_c = 0$

case 3:- $\mu_1 < \mu_2$

The blocks will move together

$a_1 = a_2 = a$

$F_c \neq 0$

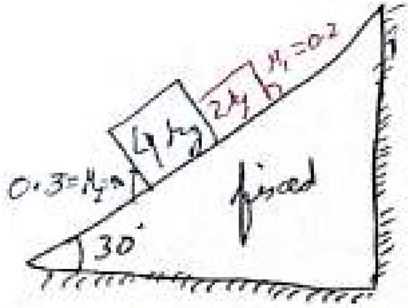
$m_2 g\sin\theta + F_c - \mu_2 g m_2 \cos\theta = m_2 a$

$m_1 g\sin\theta - F_c - \mu_1 g m_1 \cos\theta = m_1 a$

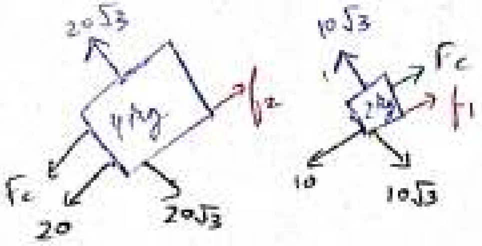
add

$\boxed{(m_1 + m_2) g\sin\theta - (\mu_2 m_2 + \mu_1 m_1) g\cos\theta = (m_1 + m_2) a}$

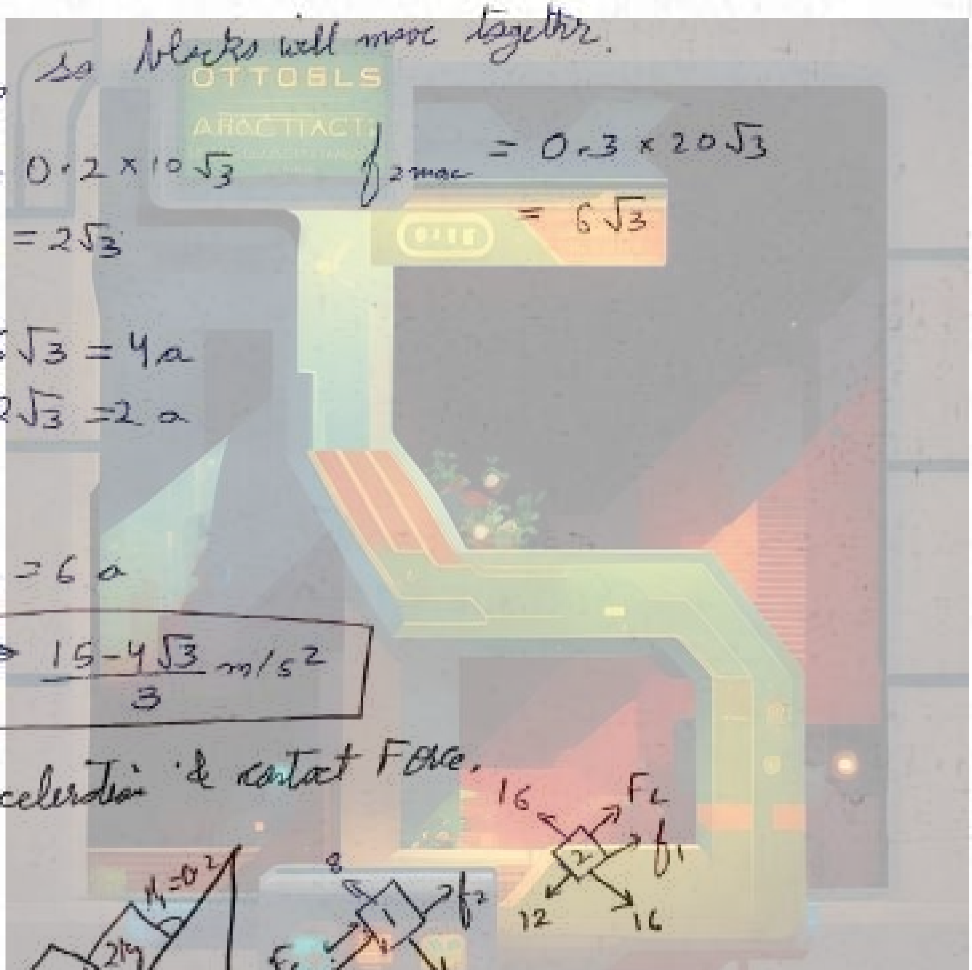
Q



Find the acceleration of blocks.



$\mu_2 > \mu_1$, so blocks will move together.



$f_{1\,max} = 0.2 \times 10\sqrt{3}$ $= 2\sqrt{3}$ $\quad f_{2\,max} = 0.3 \times 20\sqrt{3}$ $= 6\sqrt{3}$

$20 + F_c - 6\sqrt{3} = 4a$

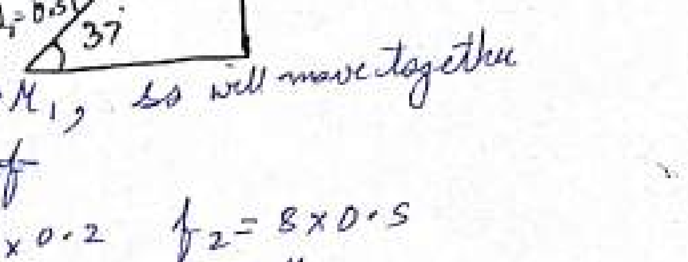
$10 - F_c - 2\sqrt{3} = 2a$

add

$30 - 8\sqrt{3} = 6a$

$$\boxed{a = \frac{15 - 4\sqrt{3}}{3}\ m/s^2}$$

Q2. Find acceleration & contact Force.



$\mu_2 > \mu_1$, so will move together

$\cancel{6 + F_c = f}$

$f_1 = 16 \times 0.2$ $= 3.2$ $\quad f_2 = 8 \times 0.5$ $= 4$

$6 + F_c - 4 = a$

$12 - F_c - 3.2 = 2a$

Add

$18 - 7.2 = 3a$

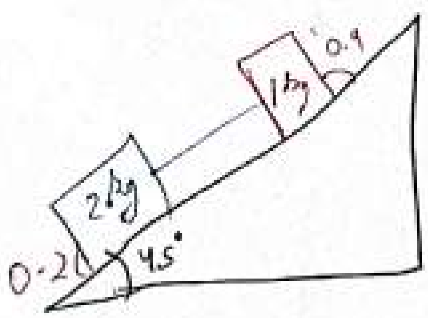
$a = \frac{10.8}{3}$ $= \frac{108}{30}$ $= \frac{36}{10}$ $\boxed{= 3.6\ m/s^2}$

$6 + F_c - 4 = 3.6$

$F_c = 3.6 - 2$

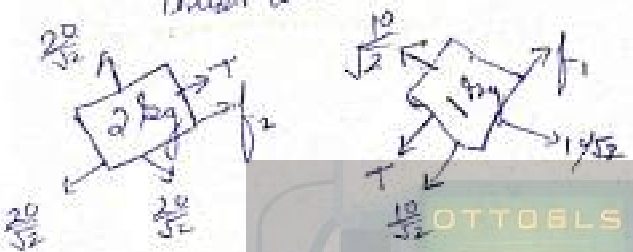
$\boxed{F_c = 1.6\ N}$

Q.



$\mu_1 > \mu_2$

Tention will act



$f_{1\,max} = 0.4 \times \frac{10}{\sqrt{2}}$

$= \frac{4}{\sqrt{2}}$

$\boxed{= 2\sqrt{2}}$ ✓

$f_{2\,max} = \frac{10}{\sqrt{2}} \times 2 \times 0.2$

$= \boxed{2\sqrt{2}}$ ✓

$10\sqrt{2} - T - 2\sqrt{2} = 2a$

$8\sqrt{2} - T = 2a$

$5\sqrt{2} + T - 2\sqrt{2} = a$

$3\sqrt{2} + T = a$

$11\sqrt{2} = 3a$

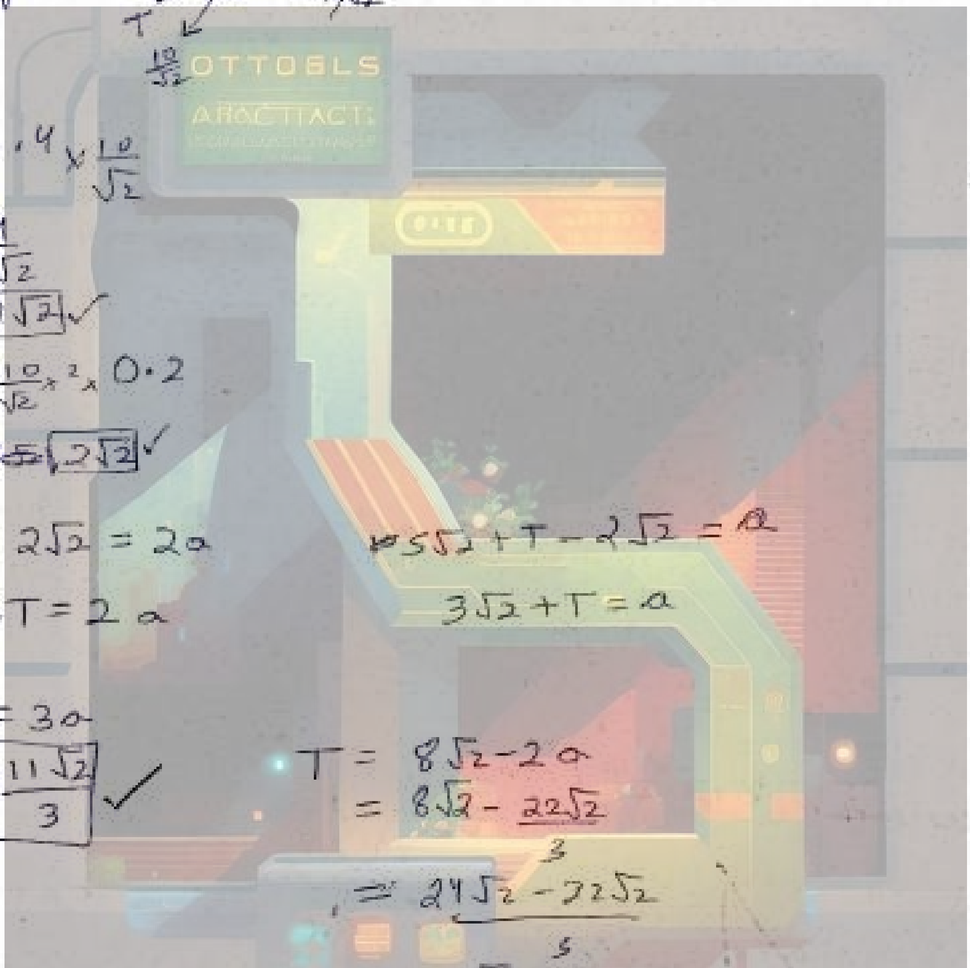
$\boxed{a = \frac{11\sqrt{2}}{3}}$ ✓

$T = 8\sqrt{2} - 2a$

$= 8\sqrt{2} - \frac{22\sqrt{2}}{3}$

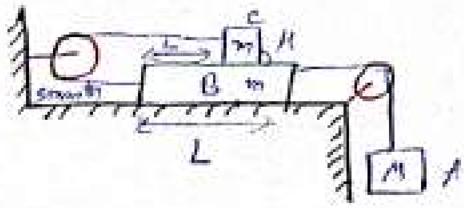
$= \frac{24\sqrt{2} - 22\sqrt{2}}{3}$

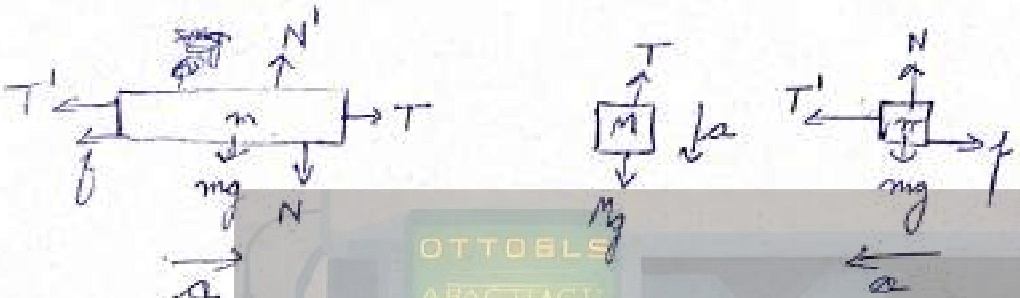
$= \frac{2\sqrt{2}}{3}$

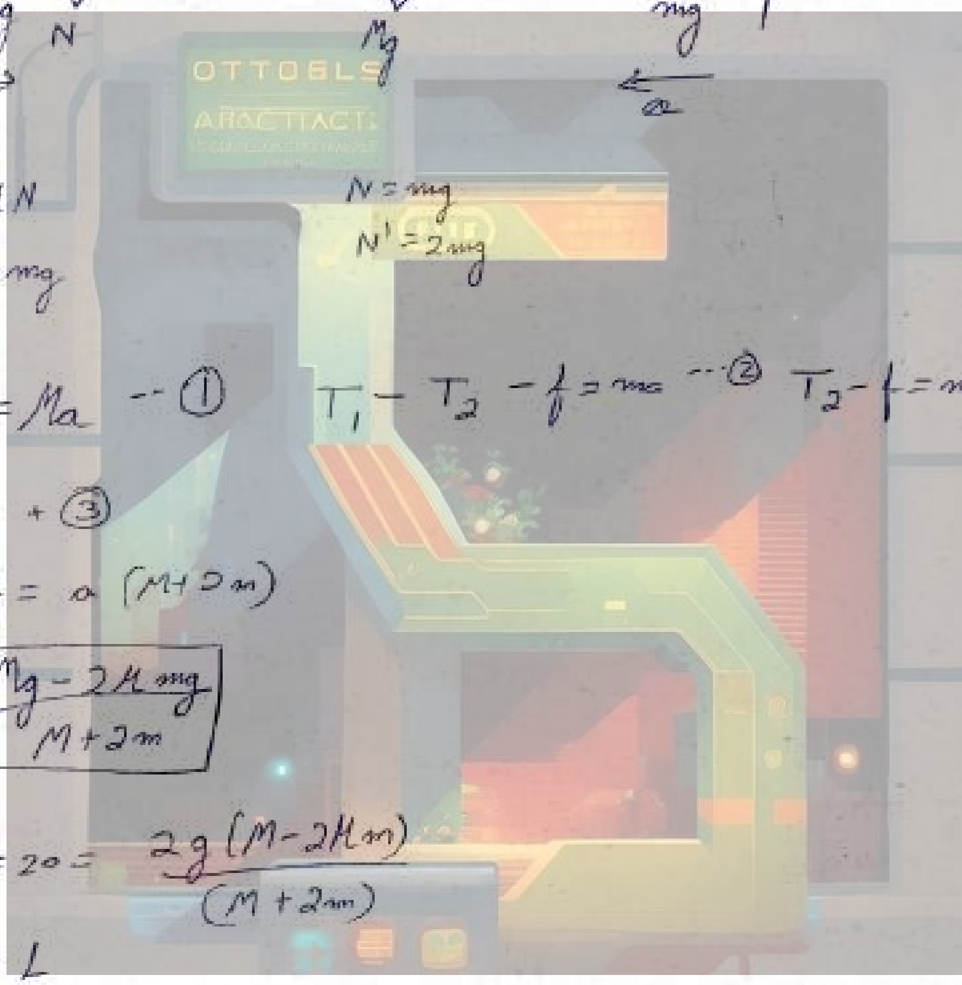


Q i) find acceleration of A

ii) Speed of block C as it reaches left end of B.







$f_l = \mu N$

$= \mu mg$

$N = mg$

$N' = 2mg$

$Mg - T = Ma$ --- ① $T_1 - T_2 - f = ma$ --- ② $T_2 - f = ma$ --- ③

① + ② + ③

$Mg - 2f = a(M+2m)$

$$\boxed{a = \frac{Mg - 2\mu mg}{M+2m}}$$

ii) $a_{rel} = 2a = \dfrac{2g(M-2\mu m)}{(M+2m)}$

$S_{rel} = L$

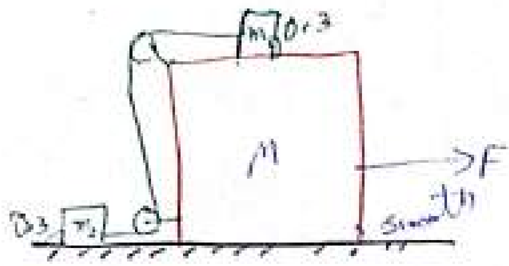
$u_{rel} = 0$

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

$v^2 = \dfrac{2g(M-2\mu m)}{M+2m} L$

$v = \left[\dfrac{2g(M-2\mu m)}{M+2m} \times L\right]^{1/2}$

Q find F for $f_1 = 2f_2$. Also find tension in string & acceleration.

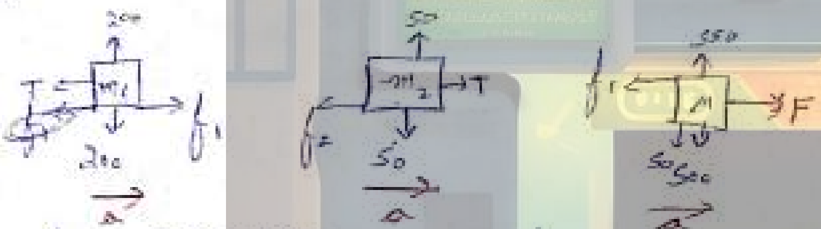


$m_1 = 20\,kg$

$m_2 = 5\,kg$

$M = 50\,kg$

for what F, $f_1 = 2f_2$



$f_{1\,max} = 0.3 \times 200 = 60$ $\quad f_{2\,max} = 0.3 \times 50 = 15$

$f_1 = 2f_2$

$f_2 = 15$

$f_1 = 30 < f_{max}$ so no sliding btw m1 & M so will move together

$f_1 - T = 20a$ --- ① $\quad T - f_2 = 5a$ --- ② $\quad F - f_1 = 50a$ --- ③

$30 - T = 20a$ $\quad T - 15 = 5a$ $\quad F - 30 = 50a$

① + ②

$15 = 25a$

$\boxed{a = \frac{3}{5}}\ m/s^2$

in ③

$F - 30 = 50 \times \frac{3}{5}$

$F = 30 + 30$

$\boxed{F = 60N}$

$30 - T = 20 \times \frac{3}{5}$

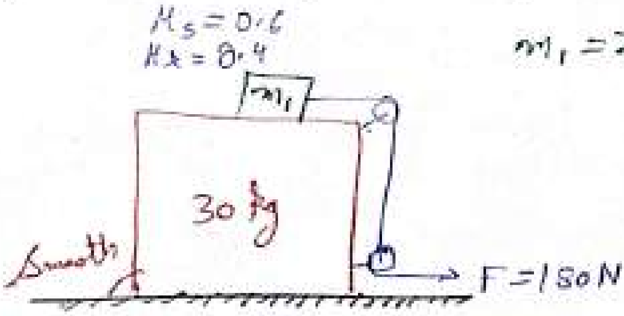
$30 - T = 12$

$T = 30 - 12$

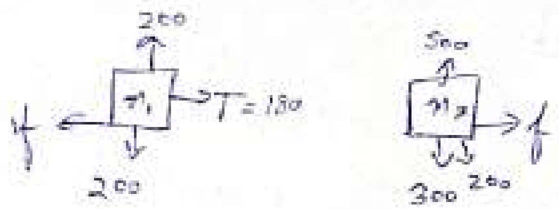
$\boxed{T = 18N}$

Q find a.

$m_1 = 20\,kg$



(2) $F = 400\,N$



$T - f = 20a$

$180 - 120 = 20a$

$\frac{60}{20} = a$

$a = 3$

but it will move so static friction will no longer act on it

$f_{max} = 0.6 \times 200$
$= 120\,N$

$f_{k\,max} = 0.4 \times 200$
$= 80\,N$

$180 - 80 = 20a$

$\frac{100}{20} = a$

$\boxed{a = 5\,m/s}$

$f_{s\,max} = 0.6 \times 200$
$= 120\,N$

$f_{k\,max} = 0.4 \times 200$
$= 80\,N$

If move together,

$50a = 180$

$\boxed{a = \frac{18}{5}}$

verify

$\frac{18}{5} \times 20 = 180 - f$

$f = 108\,N < f_{s\,max}$

(2) $F = 400$

If move together

$50a = 400$

$a = 8$

verify $= 8 \times 20 = \cancel{180}\ 400 - f$

$= \cancel{f = 20\,N}$

$= 240 = f$ (not possible)

sliding occurs.

$f = 80\,N$.

$400 - 80 = 20a$

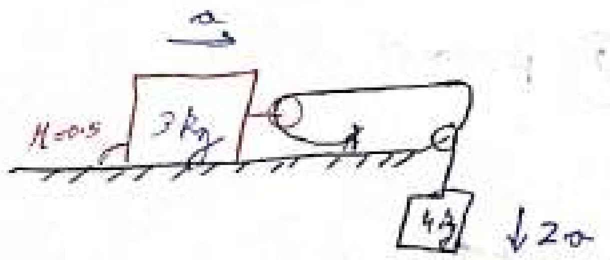
$\frac{320}{20} = a$

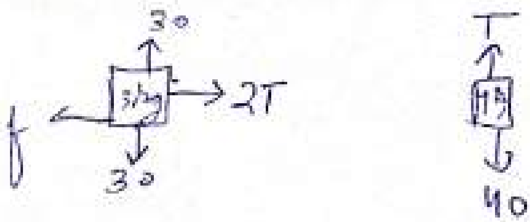
$\boxed{a = 16\,m/s^2}$

$a_{m_2} = \frac{80}{30}$

$\boxed{= \frac{8}{3}\,m/s^2}$

Q find acc of both & friction between ground & 3kg





$f_{max} = 0.5 \times 30$
$= 15N$

$2T - 15 = 3a$ — ①
$40 - T = \cancel{8a}\ 8a$
$80 - 2T = 16a$ — ②

① + ②
$80 - 15 = 19a$
$a = \frac{65}{19} m/s^2$

$\boxed{a_{3kg} = \frac{65}{19}}$ ✓

$\boxed{a_{4kg} = \frac{130}{19}}$ ✓

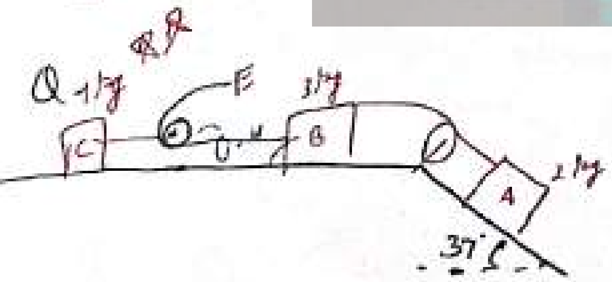
$\boxed{F = 15N}$ ✓

~~$40 - T = 8 \times \frac{65}{19}$~~

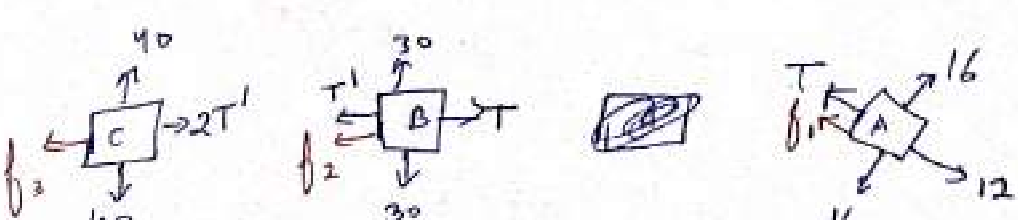
~~$40 - \frac{8 \times 65}{19} = T$~~

~~$T =$~~

Q find all friction.



$\mu_C = 0.6$
$\mu_B = 0.4$
$\mu_A = 0.6$



$f_{1\,max} = 0.6 \times 16 = \frac{96}{10}$ $\quad$ $f_{2\,max} = 0.4 \times 30 = 12$ $\quad$ $f_{3\,max} = 0.6 \times 40 = 24$

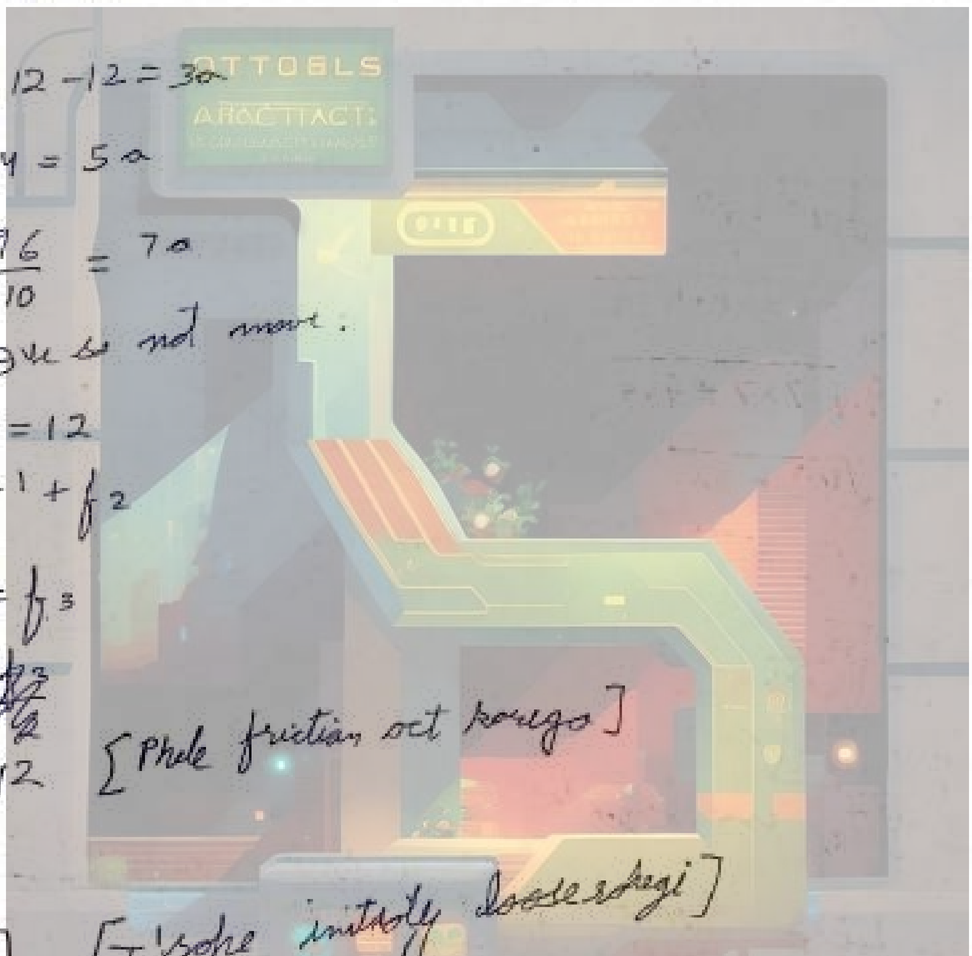
If system move

$$12 - T - \frac{96}{10} = 2a$$

$$T - T' - 12 = 3a$$

$$2T' - 24 = 4a$$

$$T' = 2a + 12$$



$$T - 2a - 12 - 12 = 3a$$

$$T - 24 = 5a$$

$$12 - 24 - \frac{96}{10} = 7a$$

$a = \ominus ve$ so not move.

$$T + f_1 = 12$$

$$T = T' + f_2$$

$$2T' = f_3$$

$\boxed{f_1 = 9.6}$

$T + 9.6 = 12$ [Phele friction act karego]

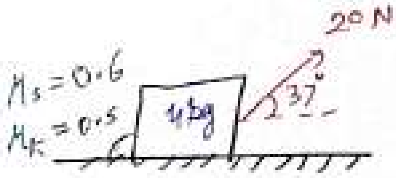
$T = 2.4$

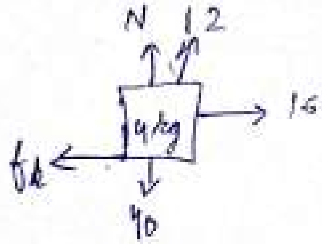
$\boxed{2.4 = f_2}$ [T' rope initially loose rahegi]

$T' = 0$

$\boxed{f_3 = 0}$

Q find value & direction of ~~contact force~~ between block & surface. resultant of N & f





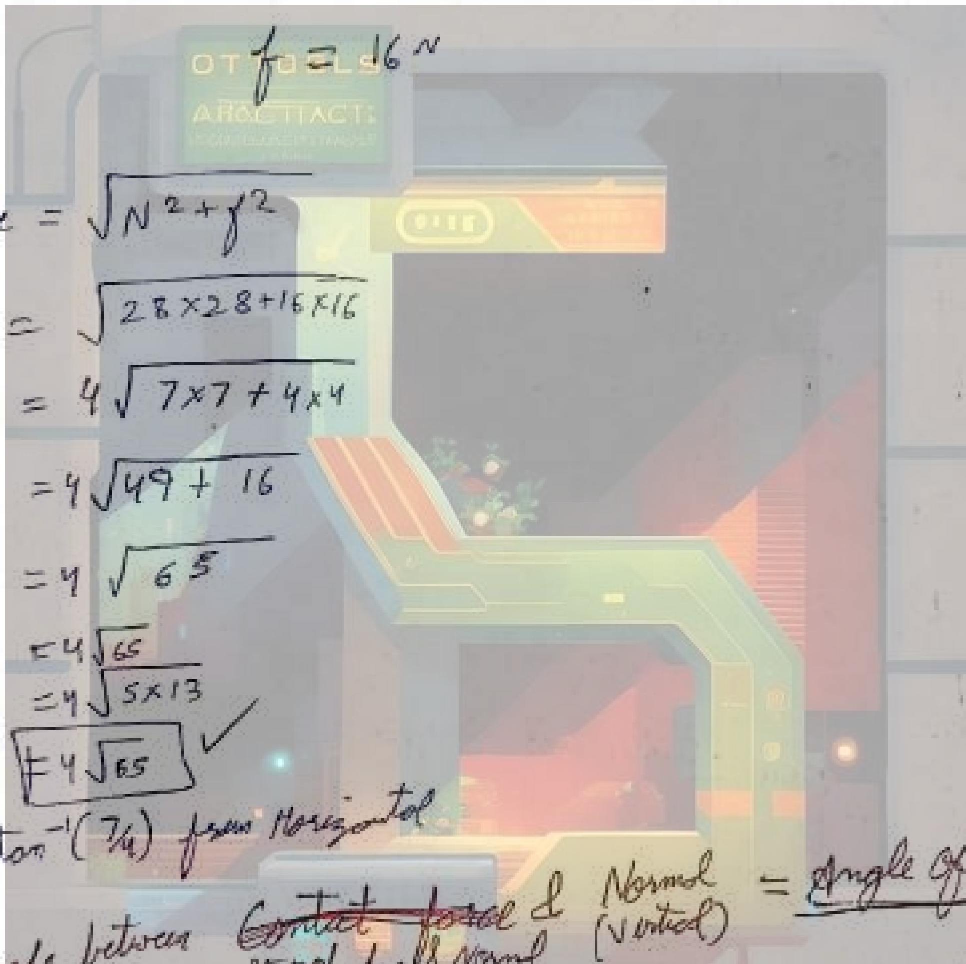
$N + 12 = 40$

$N = 28N$

$f_L = 0.6 \times 28$

$= 16.8$

$f = 16N$



contact force $= \sqrt{N^2 + f^2}$

$= \sqrt{28 \times 28 + 16 \times 16}$

$= 4\sqrt{7 \times 7 + 4 \times 4}$

$= 4\sqrt{49 + 16}$

$= 4\sqrt{65}$

$= 4\sqrt{65}$

$= 4\sqrt{5 \times 13}$

$\boxed{= 4\sqrt{65}}$

at angle $\tan^{-1}(7/4)$ from Horizontal

Note:- Angle between ~~Contact force~~ resultant of f_L & Normal & Normal (vertical) = Angle of Friction.

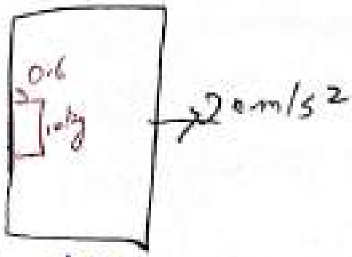
Angle of Friction:- The Angle of Friction between any two surfaces in Contact is defined as the angle which the resultant of The force of limiting friction & normal reaction makes with normal reaction

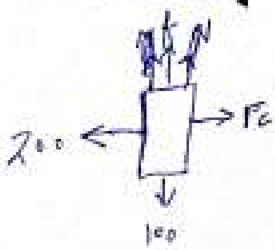
$\tan\theta = \frac{f_L}{N} = \frac{\mu N}{N} = \mu$

$\theta = \tan^{-1}(\mu)$

Q

find acc of Block, value of friction & contact force.





$F_c = 200$

$f_L = 0.6 \times 200$
$= 120\,N$

$\boxed{f = 100\,N}$

$a = 0$ (wrt block)

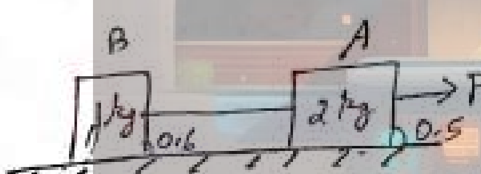
$\boxed{a = 20}$ (wrt ground)

contact force $= \sqrt{200 \times 200 + 100 \times 100}$

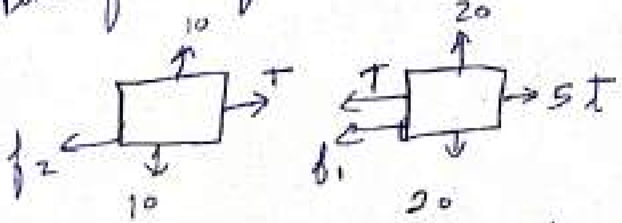
$\boxed{= 100\sqrt{5}}$ at $\tan^{-1}\left(\frac{200}{100}\right)$ from the horizontal

$\tan\theta = \frac{200}{100}$

Q



Find friction force between blocks & surface & tension
a) $t = 1\,s$
b) $t = 2\,s$
c) $t = 3\,s$
d) $t = 4\,s$



$f_1\,max = 0.5 \times 20$
$= 10\,N$

$f_2\,max = 10 \times 0.6$
$= 6\,N$

a) $F=5$

$\boxed{f_1=5}$, $T=0$

$\boxed{f_2=0}$

b) $F=10$

$\boxed{f_1=10}$, $T=0$

$\boxed{f_2=0}$

c) $F=15$

$\boxed{f_1=10}$, $T=5$

$\boxed{f_2=5}$

~~d)~~ $\cancel{F=20}$

$\cancel{\boxed{f_1=10}}$, $\cancel{T=10}$

$\cancel{f_2=6 \text{ (max)}}$

d) $F=\cancel{10}\ 20$

$f_1=10$, $f_2=6$ (max)

$a=\frac{4}{3}$

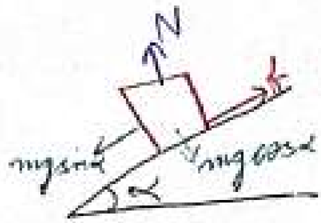
$T-6=\frac{4}{3}$

$T=\frac{4}{3}+6$

$\boxed{T=\frac{22}{3}}$

Angle of Repose (α)

→ It is the minimum angle of inclination of a plane with the horizontal such that a body placed on the plane just begins to slide down.



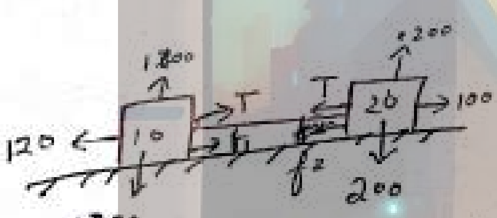
$N = mg\cos\alpha$

$f = \mu N = mg\sin\alpha$ [just begin to slide)

$\boxed{\mu = \tan\alpha}$

→ Angle of Repose does not depend on the mass of the object.

Q Find tension in the string.



$f_{1\,max} = 1200 \times 0.9$
$= 90\,N$

$f_{2\,max} = 200 \times 0.3$
$= 60\,N$

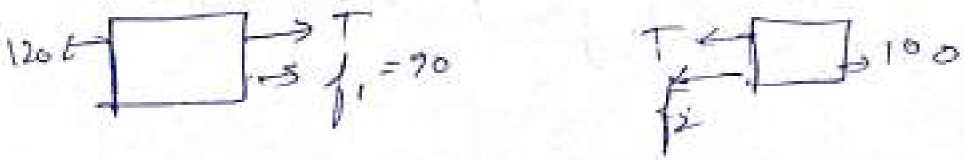
$F_{driving} = 120 - 100 = 20\,N$

$F_{resisting} = 90 + 60$
$= 150$

Blocks will not move

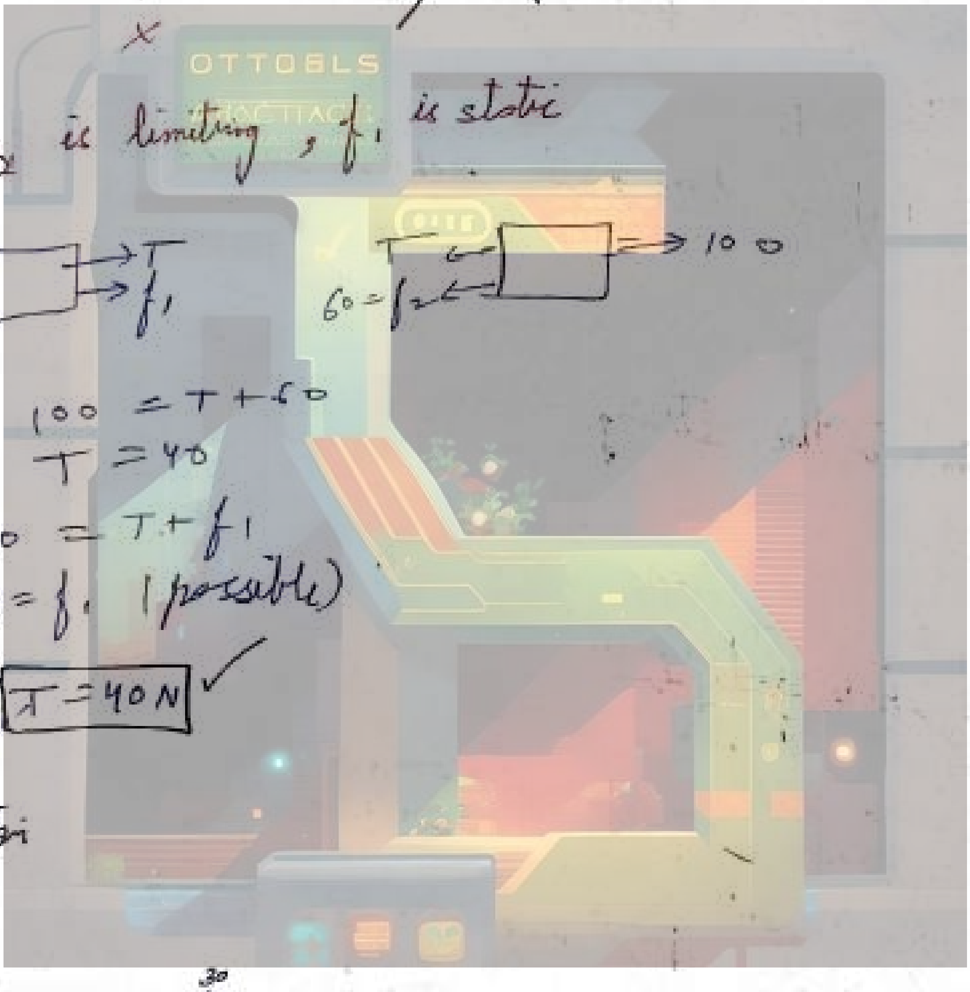
$80 = f_1$

Case I f_1 is limiting, f_2 is static



$T = 30$

$T + f_2 = 100$
$f_2 = 100 - 30$
$= 70 > f_{2max}$
not possible



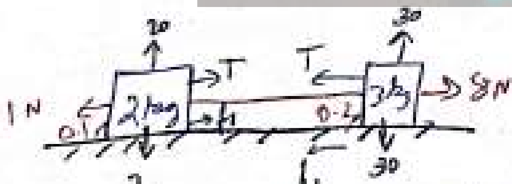
Case II f_2 is limiting, f_1 is static

$100 = T + 60$
$T = 40$

$120 = T + f_1$
$80 = f_1$ (possible)

Thus, $\boxed{T = 40N}$

Q2. Find Tension



$f_{1max} = 20 \times 0.1$
$= 2N$

$f_{2max} = 30 \times 0.2$
$= 6N$

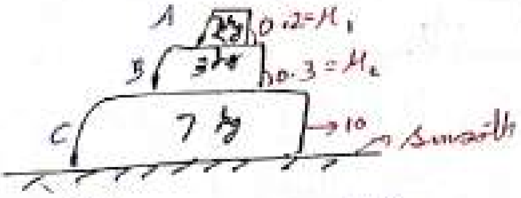
Net Driving F = 8 - 1 = 7N
Net resisting F = 6 + 2 = 8
at rest.

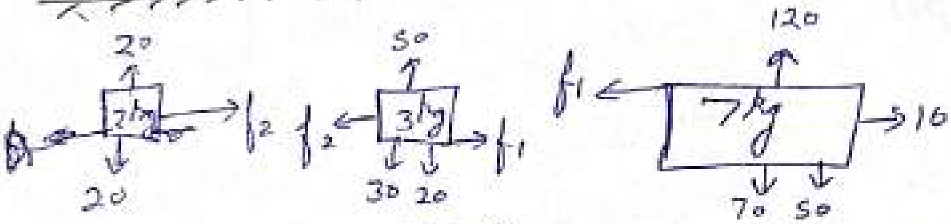
let f_2 = max
$8 - 6 = T$
$\boxed{T = 2}$
~~1 = T + f1~~
~~1 = 2 + f1~~
$T = f_1 + 1$
$2 = f_1 + 1$
$f_1 = 1$ (possible)

(154)

Three Block System

Q find acc & friction





Case 1:- If all move together.

$f_{2\,max} = 20 \times 0.2$
$= 4N$

$f_{1\,max} = 0.3 \times 50$
$= 15N$

$10 = 12a$

$\boxed{a = \frac{5}{6}\ m/s^2}$ ✓

Verify :-

i) $f_2 = 2 \times \frac{5}{6}$ ✓

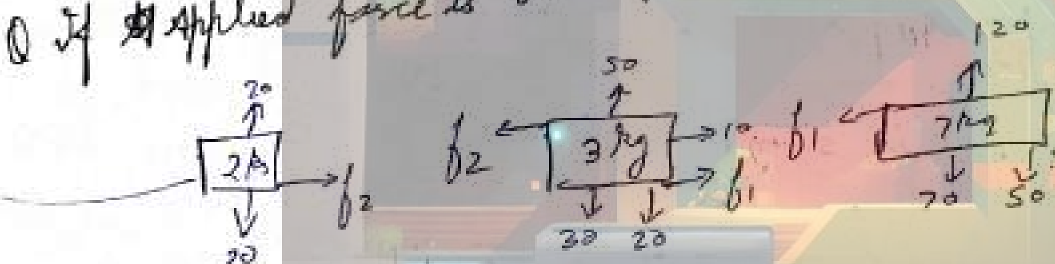
$\boxed{f_2 = \frac{5}{3}\ (\text{Possible})}$

ii) $f_1 - f_2 = 3 \times \frac{5}{6}$

$f_1 = \frac{5}{2} + \frac{5}{3}$

$\boxed{f_1 = \frac{25}{6}}$ (Possible) ✓

Q If applied force is on 3kg block.



Case:- 1 All move together ✓

$10 = 12a$

$\boxed{a = \frac{5}{6}}$ ✓

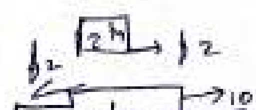
Verify :-

~~$10 + f_1 - f_2$~~

~~$f_1 = 10\,kg \times 10$~~ ~~(Possible)~~

$f_1 = 7 \times \frac{5}{6}$

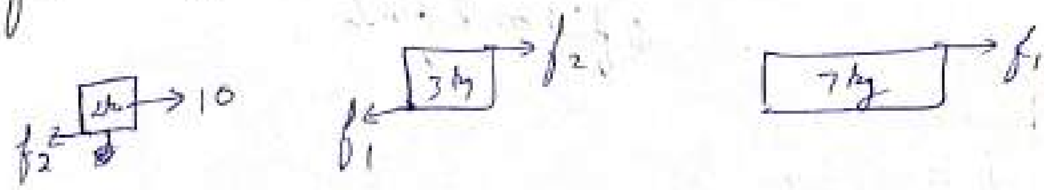
$\boxed{= \frac{35}{6}\ (\text{possible})}$ ✓



$f_2 = 2 \times \frac{5}{6}$

$\boxed{= \frac{5}{3}}$ (Possible)

Q If force Applied on 2 kg block.



Case 1:- If All move Together.

$a = \frac{5}{6}$

$f_2 = 10 \times \frac{5}{6}$

$= \frac{25}{3}$

$= 8.\text{sm}$ ~~(Possible)~~

(not-Possible)

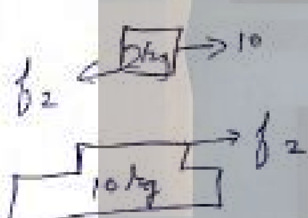
$f_1 = 7 \times \frac{5}{6}$

$=$ (Possible)

$f_1 = \frac{35}{6}$

So, There will be sliding between 2 kg & 3 kg block.

$f_2 = 4N$ (sliding friction)



$a_{2kg} = \frac{10-4}{2}$

A $\boxed{= 3\,m/s^2}$ ✓

$a_{3kg, 7kg} = \frac{4}{10}$

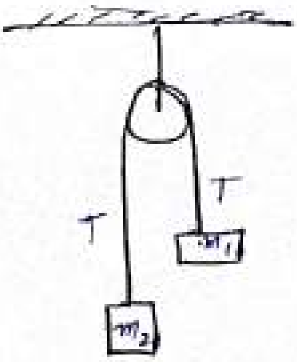
B, C $\boxed{= \frac{2}{5}\,m/s^2}$ ✓

$\boxed{f_1 = \frac{35}{6} N}$ ✓ $\boxed{f_2 = 4N}$ ✓

Shortcut to find Tension in string.

$$\boxed{T = \frac{\sum \left[(\text{Coefficients of tension connected with Block}) \times (g_{eff})\right]}{\sum_{i=1}^{n} \frac{(\text{Coeff. of } T)^2}{m_i}}}$$

1g.

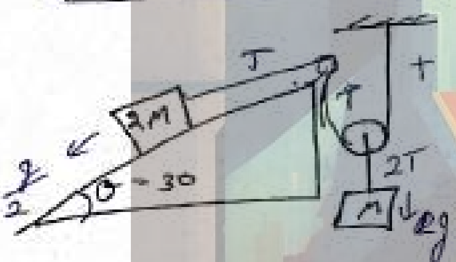


g_{eff} → component of g in direction of motion.
Coeff of T → a Number multiplied by T

$$T = \frac{1g + 1g}{\frac{(1)^2}{m_1} + \frac{(1)^2}{m_2}}$$

$$\boxed{= \frac{2g\, m_1 m_2}{m_1 + m_2}}$$

2.



$$T = \frac{\frac{g}{2} + 2g}{\frac{1}{2M} + \frac{4}{M}}$$

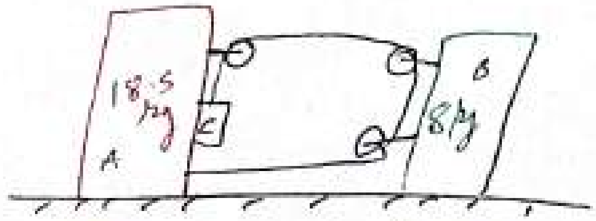
$$= \frac{5g}{2\left[\frac{9}{2M}\right]}$$

$$= \frac{5g \times 2M}{18}$$

$$\boxed{= \frac{5}{9} gM}$$

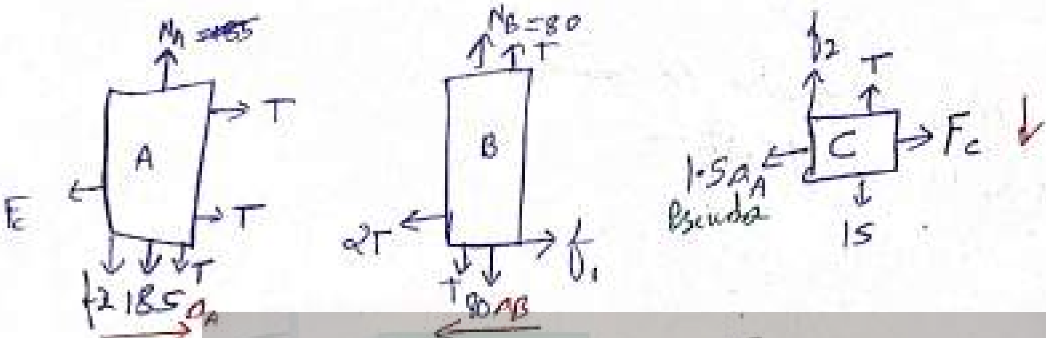
① find acc.

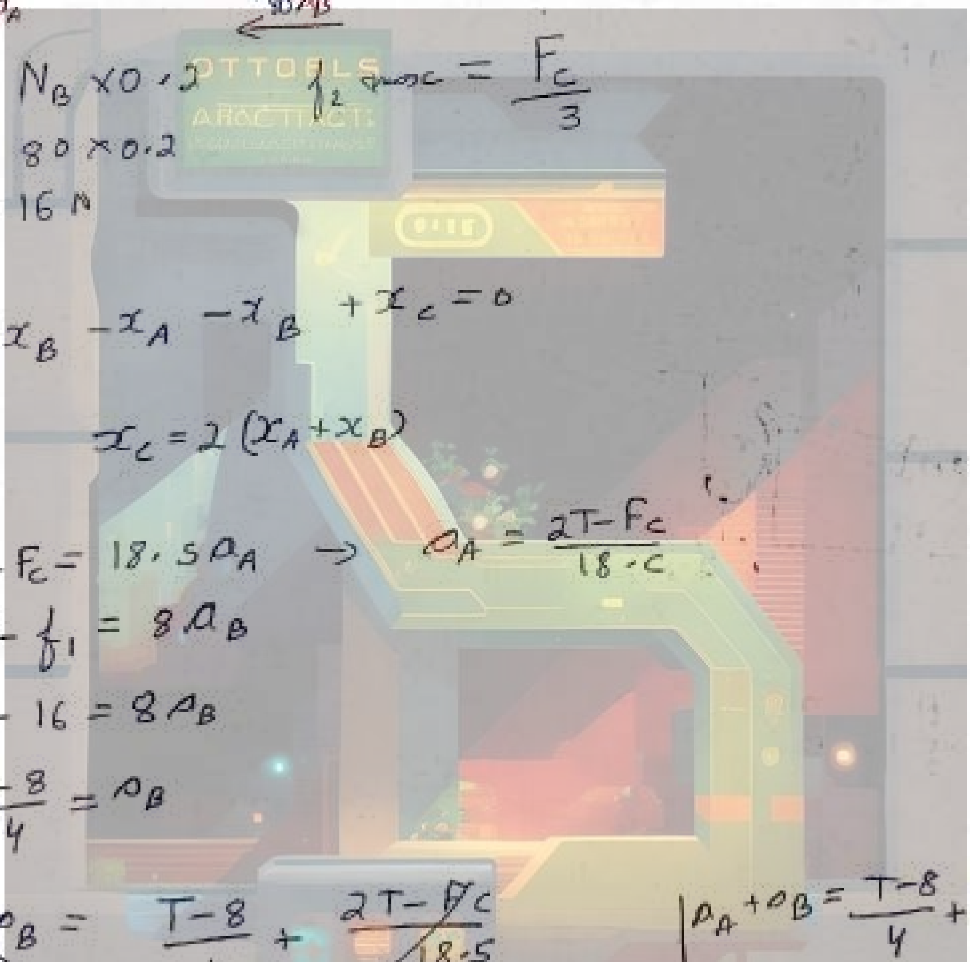
$M_c = 1.5\,kg$



$\mu_{AC} = \frac{1}{3}$

$\mu_B = 0.2$





$$f_{1\,max} = N_B \times 0.2 = 80 \times 0.2 = 16\,N \qquad f_{2\,max} = \frac{F_c}{3}$$

$$-x_A - x_B - x_A - x_B + x_c = 0$$

$$x_c = 2(x_A + x_B)$$

$$2T - F_c = 18.5\,a_A \rightarrow a_A = \frac{2T - F_c}{18.5}$$

$$2T - f_1 = 8a_B$$

$$2T - 16 = 8a_B$$

$$\frac{T-8}{4} = a_B$$

$$\cancel{a_A + a_B = \frac{T-8}{4} + \frac{2T-F_c}{18.5} = \frac{T-8}{4} + \frac{4T-2F_c}{37} = \frac{37T - 37 \cdot 8 + 16T - 8F_c}{148}}$$

$$\cancel{2(a_A + a_B) = \frac{21T - 8F_c - 296}{148} \times 2 \quad 74}$$

$$\cancel{a_c = \frac{15 - T - \frac{F_c}{3}}{1.5}}$$

$$a_A + a_B = \frac{T-8}{4} + \frac{T}{10} = \frac{10T - 80 + 4T}{40} = \frac{14T - 80}{40} = \frac{7T - 40}{20}$$

$$2(a_A + a_B) = \frac{7T - 40}{10}$$

(15)

$F_c = 1.5\, a_A$

$f_2 = \dfrac{a_A}{2}$

$\cancel{15 - f_2 - T = a_c 1.5}$

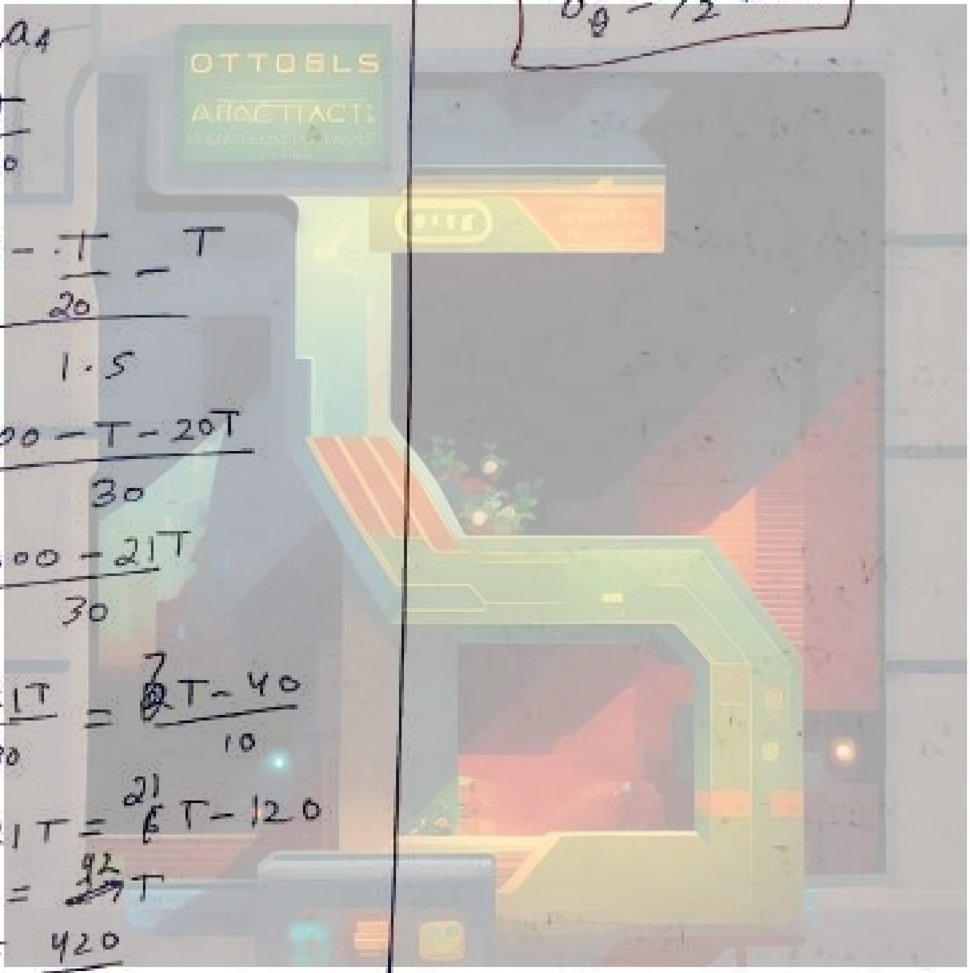
$\cancel{15 - T - 2T - F_c}$

$2T - F_c = 18.5\, a_A$

$2T - 1.5 a_A = 18.5 a_A$

$2T = 20 a_A$

$T = 10 a_A$



$a_A = \dfrac{T}{10}$

$a_c = \dfrac{15 - \frac{T}{20} - T}{1.5}$

$= \dfrac{300 - T - 20T}{30}$

$= \dfrac{300 - 21T}{30}$

$\dfrac{300 - 21T}{30} = \dfrac{7T - 40}{10}$

$300 - 21T = 21T - 120$

$420 = 42T$

$T = \dfrac{420}{42}$

$T = 10$

$a_A = \dfrac{10}{10}$

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

$a_c = \dfrac{300 - 21 \times 10}{30}$

$= 10 - 7$

$\boxed{a_c = 3 m/s^2}$

$2 + 2a_B = \dfrac{70 - 40}{10}$

$2 + 2a_B = 3$

$2a_B = 1$

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

MII

$2(a_A + a_B) = a_C$

for A,

$N_A = 18.5 + f_1 + T$

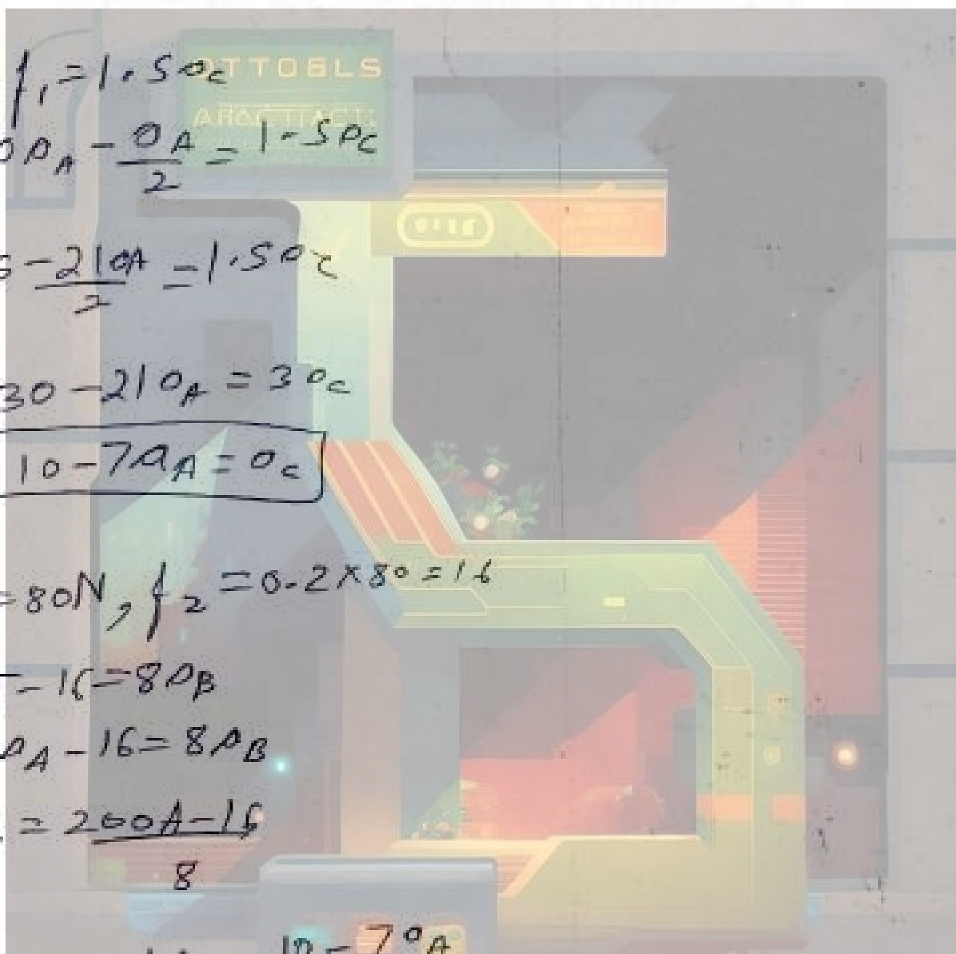
for $f_1 = \frac{1}{3}(1.5 a_A) = \frac{a_A}{2}$

~~$2T - A -$~~

$2T - F_C = 18.5 a_A$

$\boxed{T = 10 a_A}$

for C,



$15 - T - f_1 = 1.5 a_C$

$15 - 10 a_A - \frac{a_A}{2} = 1.5 a_C$

$15 - \frac{21 a_A}{2} = 1.5 a_C$

$30 - 21 a_A = 3 a_C$

$\boxed{10 - 7 a_A = a_C}$

for B,

$N_B = 80N, f_2 = 0.2 \times 80 = 16$

$2T - 16 = 8 a_B$

$20 a_A - 16 = 8 a_B$

$a_B = \frac{20 a_A - 16}{8}$

$2 a_A + \frac{20 a_A - 16}{4} = 10 - 7 a_A$

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

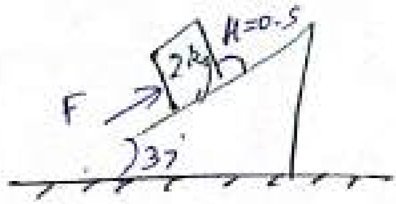
$a_C = 10 - 7$

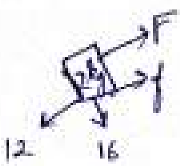
$\boxed{a_C = 3 \text{ m/s}^2}$

$\boxed{a_B = 0.5 \text{ m/s}^2}$

(160)

Q find F so block is at rest





$f_{max} = 0.5 \times 16$
$= 8$

$F + f = 12$

$F = 12 - f$

$F = 12 - 0$
$= 12$

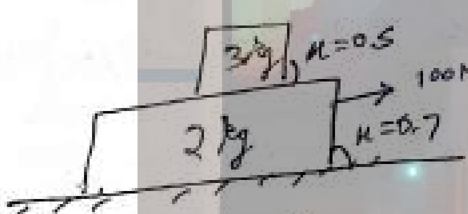
$F = 12 - 8$
$F = 4$

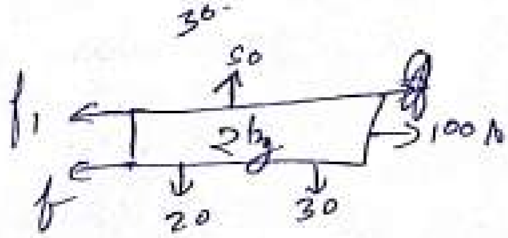
friction in opp dir

$F = 12 + f$
$= 12, 20$

$F \in [4, 20]$

Q2. find acc





$f_{max} = 50 \times 0.7$
$= 35$

$f_1 max = 30 \times 0.5$
$= 15$

If together,

$100 - 35 = 5a$

$a = 13$

slip,

$15 = 3a$

$\boxed{a = 5}$ m/s²

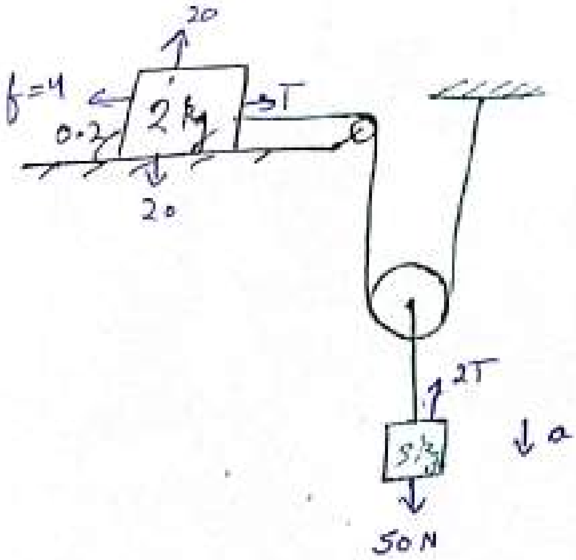
$100 - 15 - f = 2a$

$85 - 35 = 2a$

$a = \frac{50}{2}$

$\boxed{a = 25 \text{ m/s}^2}$

Q find acc of blocks.



$2T - 8 = 8a$

$50 - 2T = 5a$

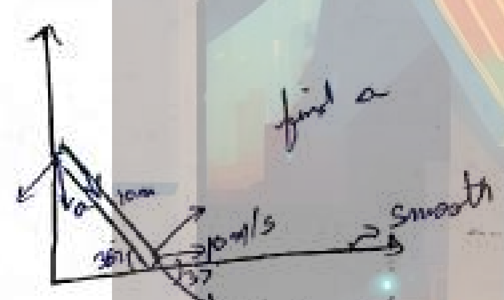
$42 = 13a$

$a = \frac{42}{13}$

$\boxed{a_{5kg} = \frac{42}{13}}$ $\boxed{a_{2kg} = \frac{84}{13}}$

Q

find a



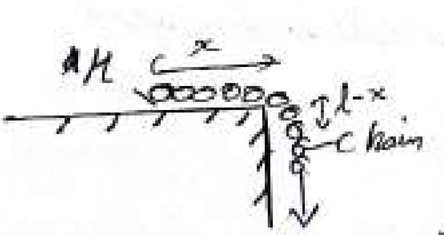
$10 \times \frac{4}{5} = 8$

$a \sin 37 = 8$

$a \times \frac{3}{5} = 8$

$\boxed{a = \frac{40}{3} m/s}$

Q



Mass - M

length - l

minimum length to keep in equilibrium

$\frac{M}{l} \times (l-x)\, g$

$f_{max} = \frac{M}{l} \times x \times g \times \mu$

$\frac{M}{l} x g \mu = \frac{M}{l} (l - x) g$

$x\mu = l - x$

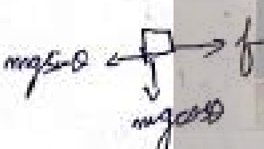
$x(1+\mu) = l$

$\boxed{x = \frac{l}{1+\mu}}$

Q

$y = 2x^2$

find max height the base can move without slipping.



$f = mg\sin\theta$

$0.5 \times mg\cos\theta = mg\sin\theta$

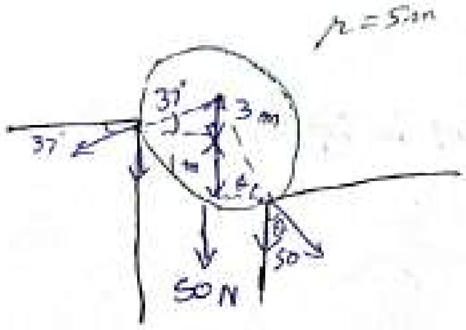
$0.5 = \tan\theta$

$\tan\theta = 4x = 0.5$

$x = \frac{1}{8}$

$\boxed{y = \frac{1}{32}}$

Q



find normal so ball remain intact

mass - 5 kg

$\sin\theta = \frac{4}{5}$

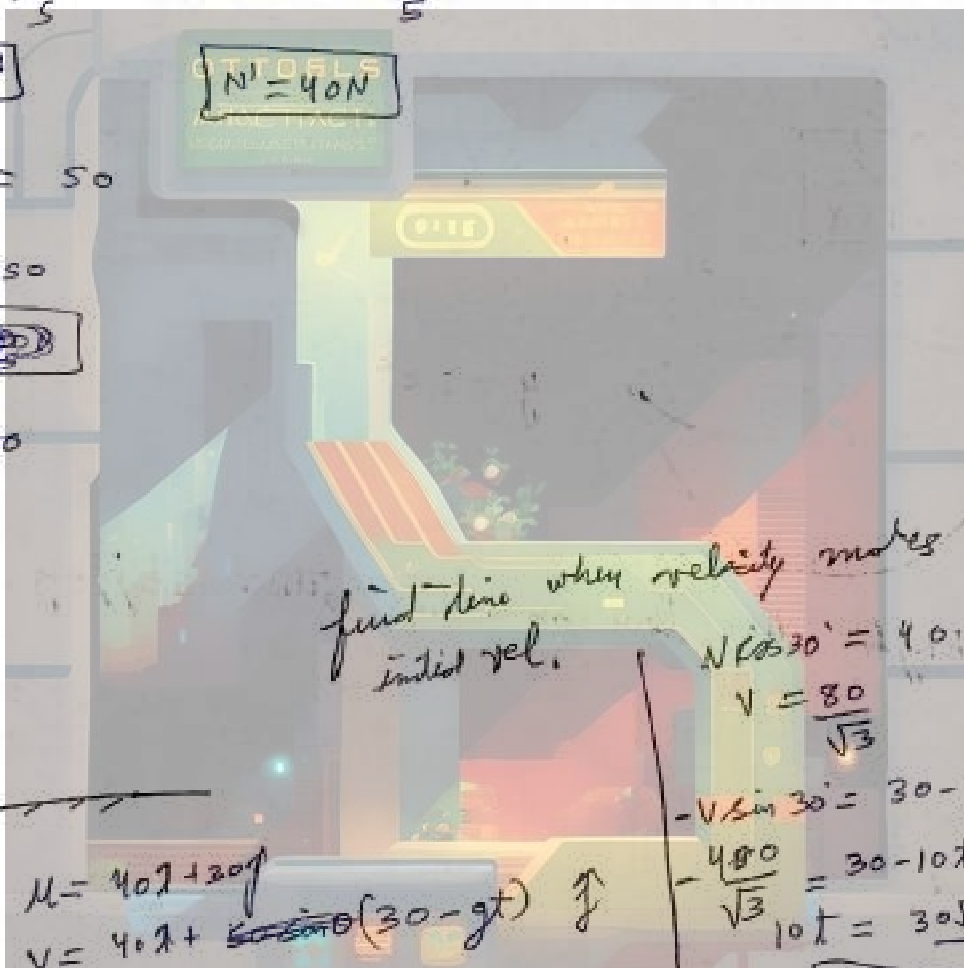
$\theta = 53^\circ$

$$\cancel{N = 50\cos 53^\circ = 50 \times \frac{3}{5}}$$

$$\cancel{\boxed{N = 30\,N}}$$

$$N' = 50 \times \frac{4}{5}$$

$$\boxed{N' = 40\,N}$$



$\sin 53^\circ \times N = 50$

$N \times \frac{5^2}{5} = 50$

$N = 30$

Q find time when velocity makes 67° with initial vel.

$N\cos 30^\circ = 40$

$V = \frac{80}{\sqrt{3}}$

$-V\sin 30^\circ = 30 - gt$

$-\frac{40}{\sqrt{3}} = 30 - 10t$

$10t = \frac{30\sqrt{3} - 40}{\sqrt{3}}$

$$\boxed{t = \frac{3\sqrt{3} + 4}{\sqrt{3}}}$$

$u = 40\hat{i} + 30\hat{j}$

$v = 40\hat{i} + (30 - gt)\hat{j}$

$$\cancel{\sin 30 \sin 37 - \cos 3\cos 37 = \frac{1600 + 900 - 300t}{50 \times \sqrt{1600 + 900 + 100t^2 - 600t}}}$$

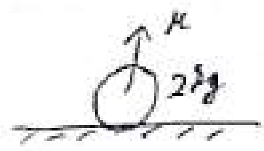
$$\cancel{\frac{3}{10} - \frac{4\sqrt{3}}{10} = \frac{2500 - 300t}{50 \times 10\sqrt{t^2 - 6t + 25}}}$$

$$\cancel{3 - 4\sqrt{3} = \frac{250 - 30t}{\sqrt{t^2 - 6t + 25}}}$$

$$\cancel{t^2 - 6t + 25 = \frac{(250 - 30t)^2}{3 - 4\sqrt{3}}}$$

(167)

Q



$F = -Kv$

$ma = -Kv$

$2\frac{dv}{dt} = -Kv$

$2\times\frac{dv}{dx} = -K$

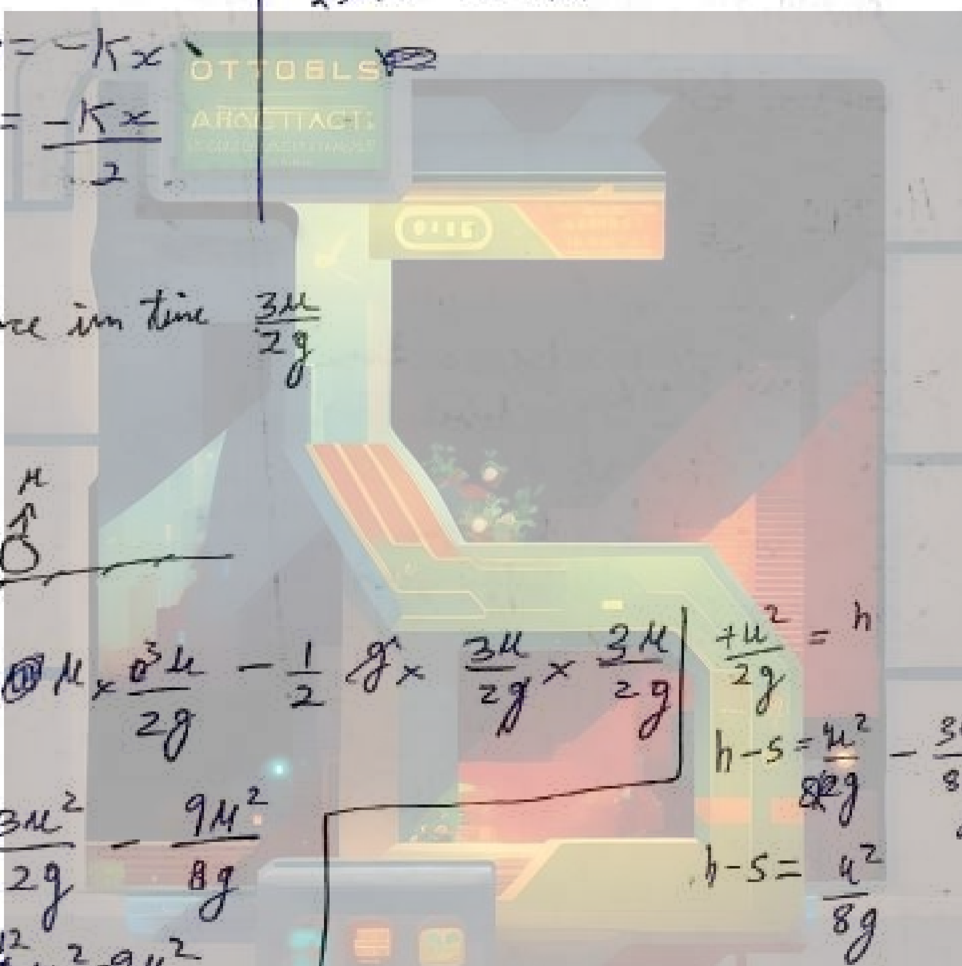
$2v = -Kx$

$v = \frac{-Kx}{2}$

$2\times\frac{dv}{dt} = -Kv$

$\frac{2}{v}dv = -K\,dt$

$2\ln v = -Kt$



Q find distance in time $\frac{3u}{2g}$

$s = u\times\frac{3u}{2g} - \frac{1}{2}g\times\frac{3u}{2g}\times\frac{3u}{2g}$

$= \frac{3u^2}{2g} - \frac{9u^2}{8g}$

$= \frac{12u^2 - 9u^2}{8g}$

$\boxed{s = \frac{3u^2}{8g}}$

$\frac{u^2}{2g} = h$

$h - s = \frac{u^2}{2g} - \frac{3u^2}{8g}$

$h - s = \frac{u^2}{8g}$

Distance $= \boxed{\frac{5u^2}{8g}}$

Important Result

① $a = \frac{(m_1 - m_2)\, g}{(m_1 + m_2)}$

② $T = \frac{2 m_1 m_2\, g}{m_1 + m_2}$

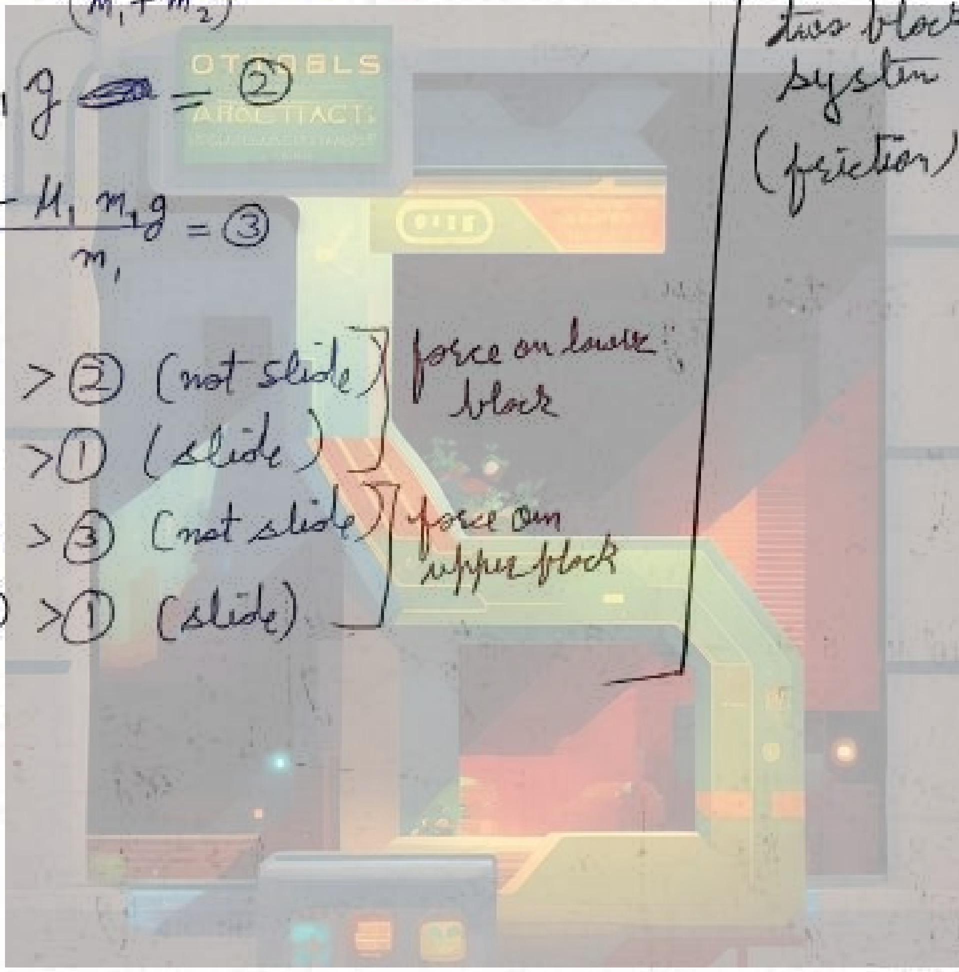
atwood machine ($m_1 > m_2$)

$\frac{F - \mu_2 (m_1 + m_2) g}{(m_1 + m_2)} = ①$

$\mu_1 g = ②$

$\frac{F - \mu_1 m_1 g}{m_1} = ③$

two block system (friction)



① > ② (not slide)
② > ① (slide)
force on lower block

① > ③ (not slide)
③ > ① (slide)
force on upper block


OTTOBLS
ARGCTTACT: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