UNIT NO 5

KINETICS

State and explain Newton's second law of motion.

ANS:- 'The rate of change of momentum is directly proportional to the impressed force.'

Let

Initial momentum = mu

Final momentum = mv

Rate of change of momentum w.r.t. time =

$$= \frac{mv - mu}{t} = \frac{m(v-u)}{t} = ma$$

$$F \propto ma \quad \text{Or} \quad F = kma$$

$$\text{If } k = 1 \text{ then } F = ma.$$

State and explain 'Dynamic Equilibrium'

ANS:- Let a body of mass m is moving with uniform acceleration 'a' under the action of external force 'F'.

According to the Newton's 2nd law

This equation can be written as

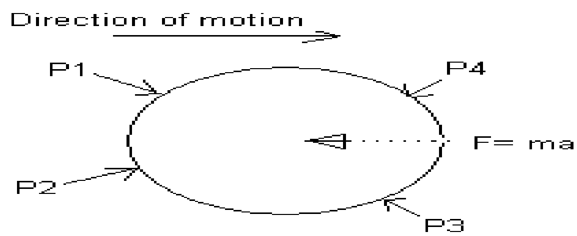
$$F\text{-}ma = 0 \quad \text{or} \quad \sum F = 0$$

From this equation, it can be said that, by applying force –ma on a body, the body will be in equilibrium, as the sum of all forces is zero.

Such equilibrium is known as dynamic equilibrium. The force *–ma* is known as inertia force.

State and explain 'D Alembert's principal'.

It states that 'The resultant of all forces acting on a moving body is in dynamic equilibrium with the inertia force ma'



$$P_1 + P_2 + P_3 + P_4 = F \text{ ---------- } (1)$$

By Newton's 2nd law

$$F = ma$$

$$P_1 + P_2 + P_3 + P_4 = ma$$

$$P_1 + P_2 + P_3 + P_4 - ma = 0$$

$$\text{Or } \sum F - ma = 0$$

$$\sum F - F_i = 0$$

$$\sum F_1 = 0$$

State and explain conditions of Dynamic Equilibrium OR State equations of kinetics.

Following are the conditions of Dynamic Equilibrium or equations of Kinetics

- $\sum H = 0$
- $\sum Y = 0$
- $\sum M = I\alpha$

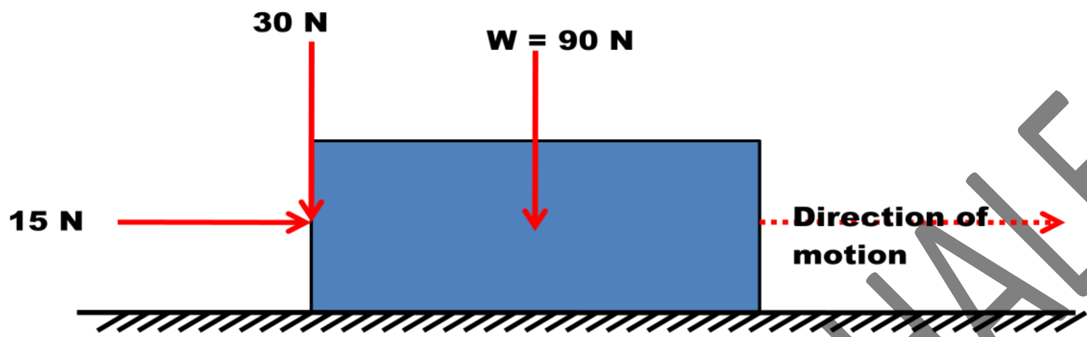
Where I = moment of inertia

$I = mk^2$

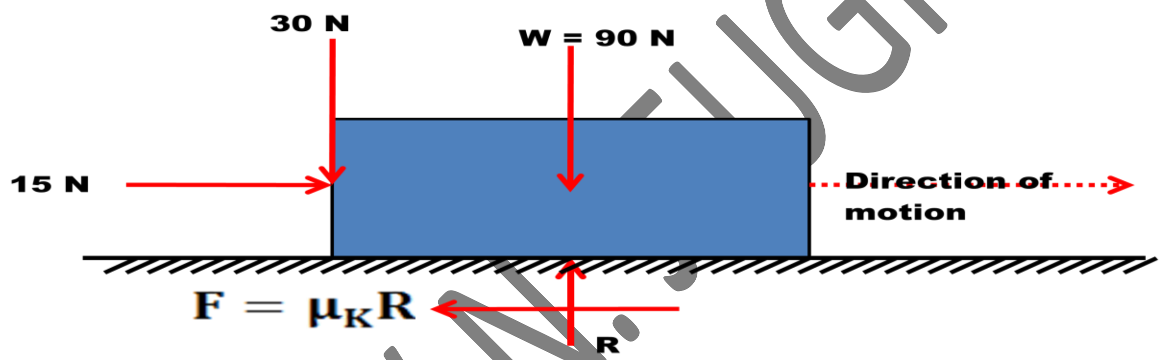
k = radius of gyration

α = angular acceleration

1. A box weighing 90N is being pushed over a flat horizontal floor. It was found that the box was slowing at a constant rate of 0.75 m/s each second. If the push force has a horizontal component of I5N and a vertical component of 30N downward, find the coefficient of kinetic friction between the box and the floor.



ANS:-



Let R - Normal reaction exerted by the floor on the box

kinetic friction = $\mu_k R$

RESOLVING THE FORCES ON THE BLOCK VERTICALLY,

$$\sum V=0$$

$$R-90-30=0$$

$$R=90+30$$

$$R=120$$

SO, KINETIC FRICTION = $\mu_k R$

$$=\mu_k(120)$$

NOW,

NET RETARDING FORCE = MASS X RETARDATION

$$MASS = \frac{WEIGHT}{g}$$

$$\mu_K(120) - 15 = \frac{90}{9.81} X\, 0.75$$

$$120\mu_K - 15 = 6.881$$

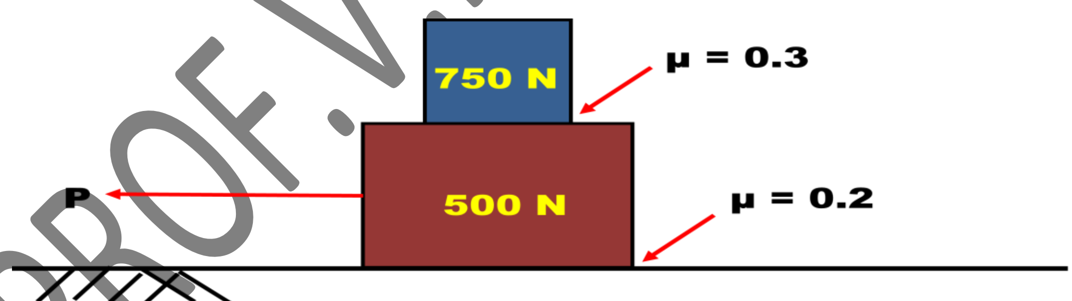
$$\mu_K = \frac{21.881}{120}$$

$$\mu_K = 0.182$$

2. A 750 n weight rest on a 500 n cart the coefficient of friction between weight and cart is 0.3 & between cart and road is 0.2. if the cart is to be pulled by force P such that the weight does not slip.

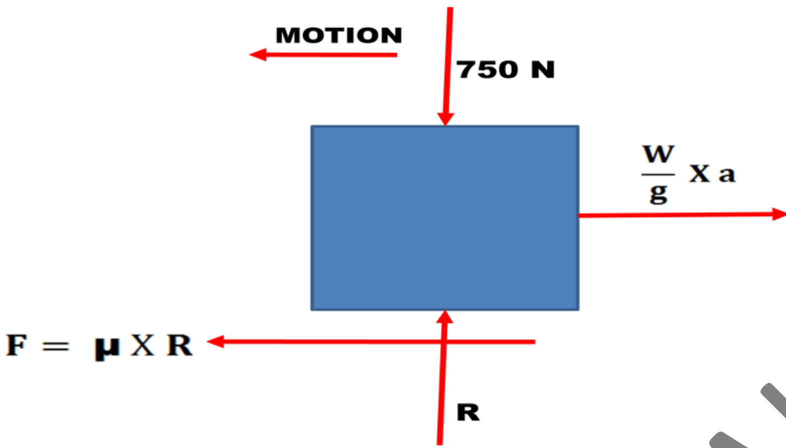
   Determine

1. The maximum allowable magnitude of P
2. The corresponding acceleration of cart



Ans:-

CONSIDERING FREE BODY DIAGRAM OF 750 N WEIGHT



$$\frac{W}{g}\ X\ a$$

$$F = \mu\ X\ R$$

$$R - 750 = 0$$

$$R = 750\ N$$

WE HAVE

$$F = \mu\ X\ R$$

$$F = 0.3\ X\ 750$$

$$F = 225\ N$$

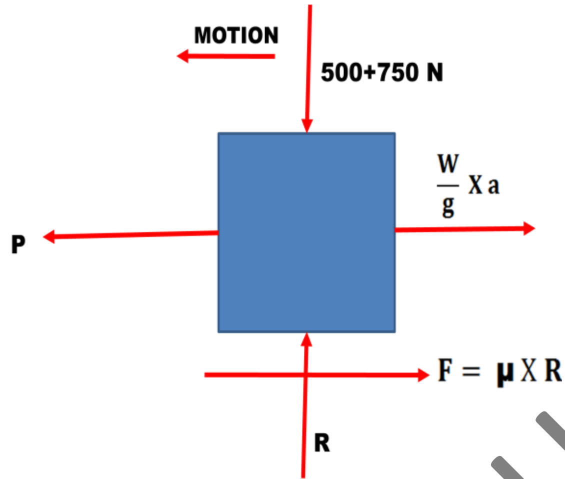
$$-F + (\frac{W}{g}\ X\ a) = 0$$

$$-225 + \frac{750}{9.81}\ X\ a = 0$$

$$a = 225 + \frac{9.81}{750}$$

$$a = 2.94\ m/S^2$$

NOW, FBD OF CART



NOW, $\Sigma_V^{\uparrow +} = 0$

$$R - 1250 = 0$$

$$R = 1250$$

$$\mathrm{F} = \mu \mathrm{~X~R}$$

$$\mathrm{F} = 0.2 \mathrm{~X~} 1250$$

$$\mathrm{F} = 250\ N$$

$\Sigma_{\mathrm{H}}^{\rightarrow +} = 0$

$$-\mathrm{P} + \mathrm{F} + (\frac{\mathrm{W}}{\mathrm{g}} \mathrm{~X~a}) = 0$$

$$-\mathrm{P} + 250 + (\frac{1250}{9.81} \mathrm{~X}2.94) = 0$$

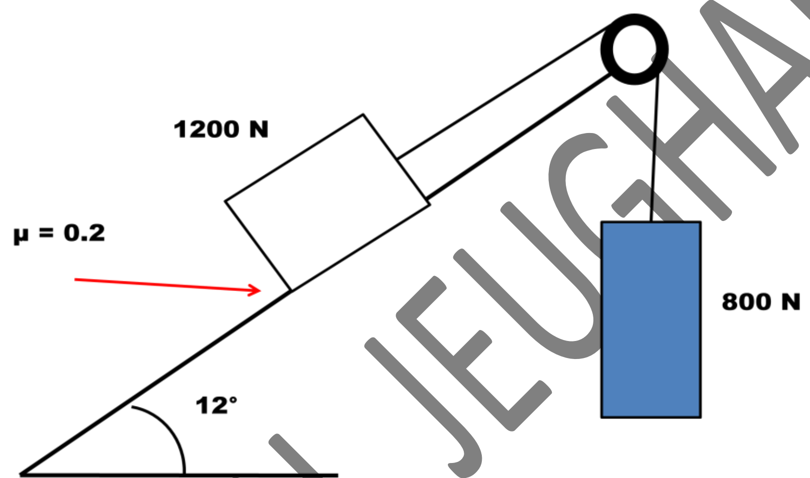
$$\mathrm{P} = 250 + (\frac{1250}{9.81} \mathrm{~X}2.94)$$

$$\mathrm{P} = 624.61 \mathrm{~N}$$

3) A body weighing 1200 n rest on a rough inclined plane inclined at 12° to horizontal. It is pull-up the plane by means of light flexible rope running parallel to the plates passing over frictionless pulley at the top of plane as shown. The portion of rope beyond the pulley hangs vertically down & carries a weight of 800 n at its end. If the coefficient of friction of the plane & body is 0.2

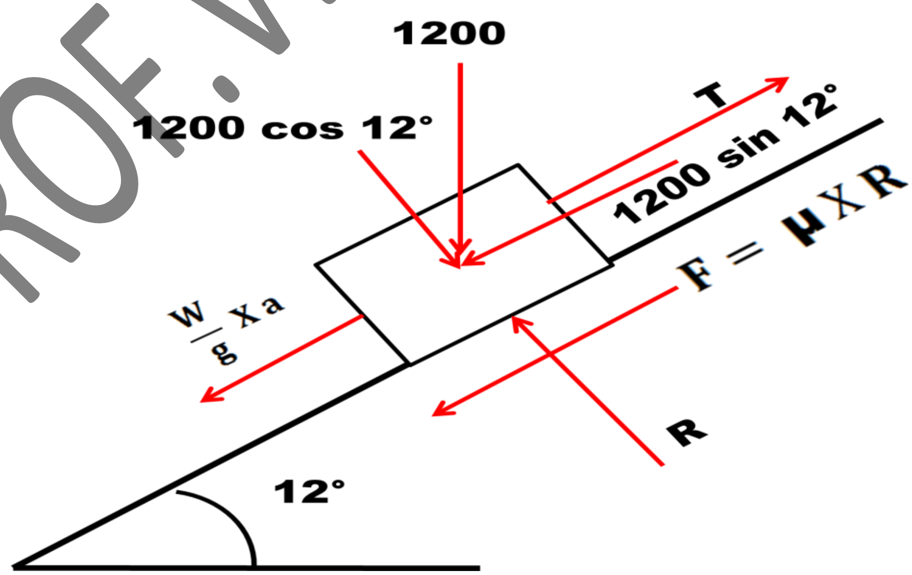
Find

1. Tension in the rope
2. Acceleration with which body moves up the plane
3. The distance move by the body in 3 sec after start from rest.



Ans:-

CONSIDERING FBD OF 1200 N WEIGHT



MAKING ALGEBRIC SUM OF ALL FORCES PERPENDICULAR TO THE PLANE

$\sum V\uparrow + = 0$

$$R - 1200\ Cos12° = 0$$

$$R = 1200\ Cos12°$$

$$R = 1173.77\ N$$

ALSO

$$F = \mu\ X\ R$$

$$F = 0.2\ X\ 1173.77$$

$$F = 234.76\ N$$

$\sum H\rightarrow + = 0$

$$-\left(\frac{W}{g}\ X\ a\right) + T - 1200\ Sin12° - F = 0$$

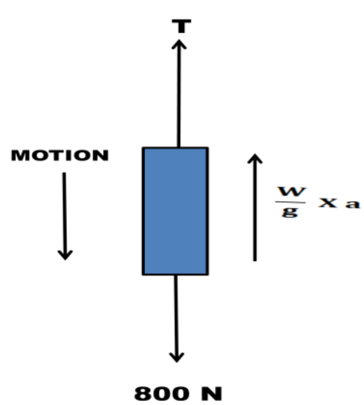
$$-\left(\frac{1200}{9.81}\ X\ a\right) + T - 249.49 - 234.76 = 0$$

$$-(122.32\ a) + T - 249.49 - 234.76 = 0$$

$$-(122.32\ a) + T = 484.25$$

$$T - (122.32\ a) = 484.25 \ldots\ldots\ldots\ldots.(1)$$

CONSIDERING FBD OF 800 N FORCE



HERE

$\sum V\uparrow + = 0$

$$T - 800 + \left(\frac{W}{g}\ X\ a\right) = 0$$

$$T - 800 + \left(\frac{800}{9.81}\ X\ a\right) = 0$$

$$T + 81.55a = 800\ \ldots\ldots\ldots\ldots.(2)$$

EQUATION (1) – (2)

$$T - (122.32\ a) = 484.25$$

$$T + 81.55a = 800$$

$$-(122.32\ a) - (81.55a) = 484.25 - 800$$

$$-203.87a = -315.75$$

$$a = \frac{315.75}{203.87}$$

$$a = 1.54 m/s^2$$

From equation 1

$$T - (122.32\ a) = 484.25$$

$$T - (122.32\ x\ 1.54) = 484.25$$

$$T = 672.62\ N$$

USING EQUATION OF MOTION

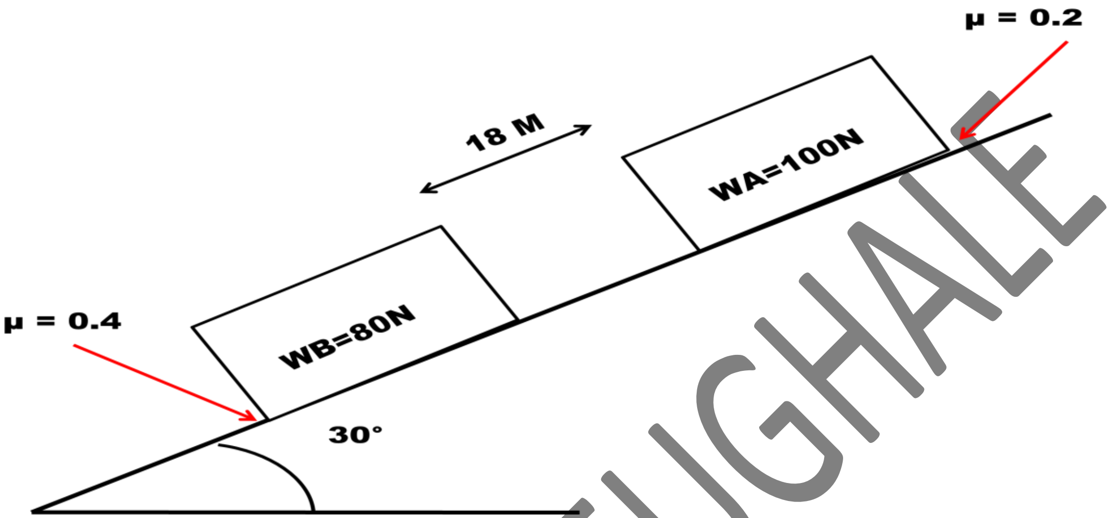
$$S = ut + \frac{1}{2}at^2$$

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

$$S = \frac{1}{2}X1.54X9$$

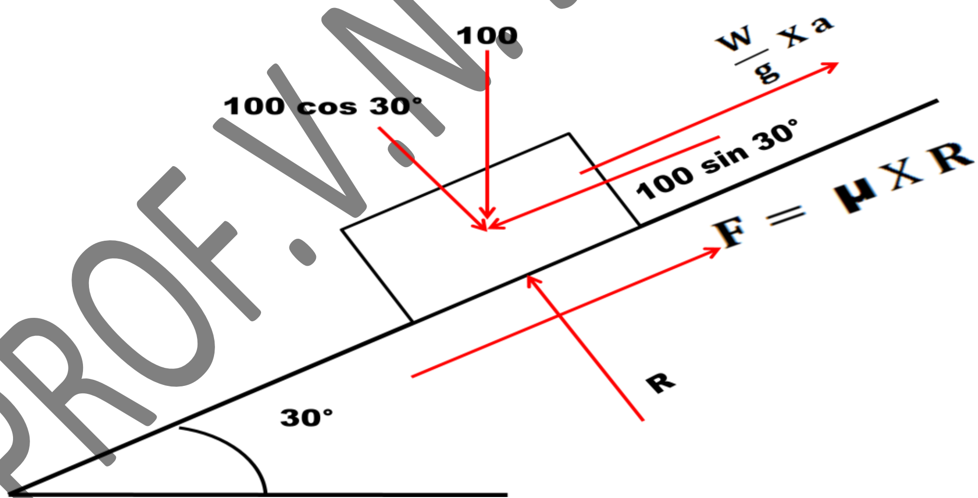
$$S = 6.93\ M$$

4) Two blocks A & B are released from rest on 30° inclined plane when they are18 m apart. The coefficient of friction under block A is 0.2 & under lower block B is 0.4. In what time block A reaches up to block B after the touch & move as a one unit. What will be the contact force between them? Weight of block A is 100N & block B is 80N.



ANS.:-

Consider FBD of block A, making algebraic sum of forces which are perpendicular to the plane .



i.e.

$\sum V\uparrow + = 0$

$$W_A Cos\ 30° + R_A = 0$$

$$R_A = W_A Cos\ 30°$$

Now making algebraic sum of all forces which are parallel with the plane i.e.

$\sum H \rightarrow + = 0$

$$W_A Sin\ 30° - \left(\frac{W_A}{g}\ X\ a_A\right) - F = 0$$

$$W_A Sin\ 30° - \left(\frac{W_A}{9.81}\ X\ a_A\right) - (0.2 X W_A Cos\ 30°) = 0$$

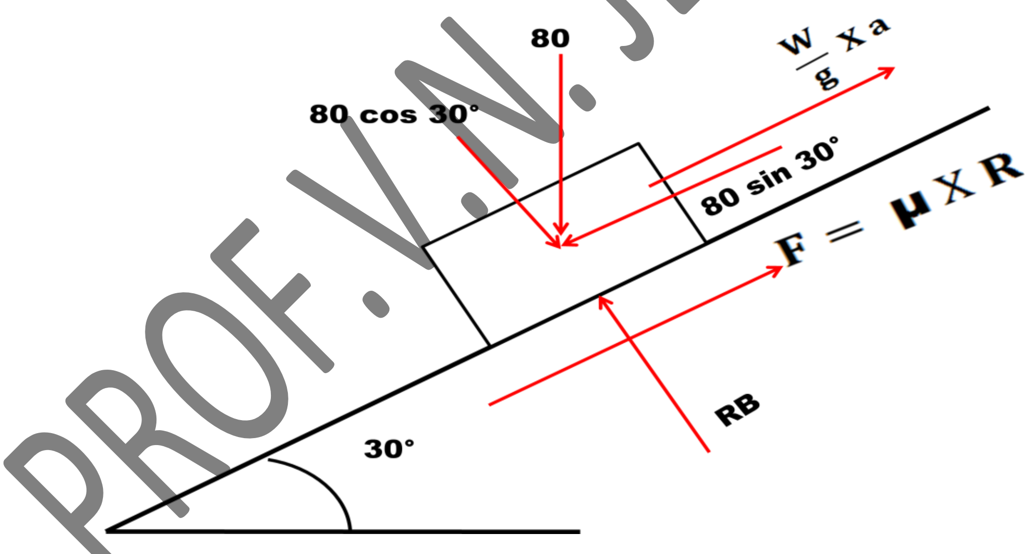
$$W_A Sin\ 30° - \left(\frac{W_A}{9.81}\ X\ a_A\right) - (0.2 X W_A Cos\ 30°) = 0$$

$$Sin\ 30° - \left(\frac{a_A}{9.81}\right) - (0.2 X Cos\ 30°) = 0$$

$$a_A = 9.81(Sin\ 30° - 0.2 X Cos\ 30°)$$

$$a_A = 3.205 m/s^2$$

Now consider FBD of block B



$\sum V \uparrow + = 0$

$$W_B Cos\ 30° - R_B = 0$$

$$R_B = W_B Cos\ 30°$$

$\sum H \rightarrow + = 0$

$$W_B Sin\ 30° - \left(\frac{W_B}{g}\ X\ a_B\right) - F = 0$$

$$W_B Sin\ 30° - \left(\frac{W_B}{9.81}\ X\ a_B\right) - (0.4XW_B Cos\ 30°) = 0$$

$$a_B = 1.506 m/s^2$$

BY USING KINETIC RELATION

$$S_A = S_B + 18$$

$$\frac{1}{2} X\ 3.205\ X\ t^2 = \frac{1}{2} X\ 1.50\ X\ t^2 + 18$$

$$0.8525\ t^2 = 18$$

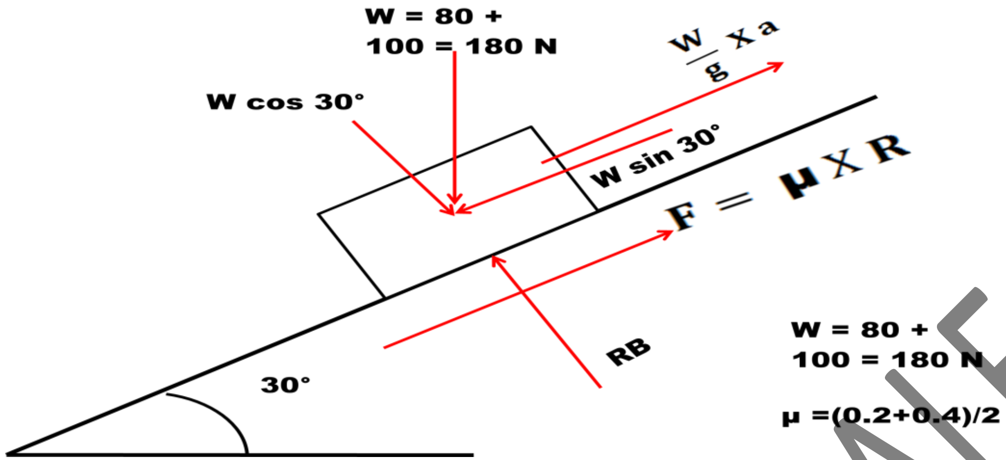
$$0.8525\ t^2 = 18$$

$$t^2 = \frac{18}{0.8525}$$

$$t = \sqrt{\frac{18}{0.8525}}$$

$$t = 4.60 sec$$

For the common acceleration of blocks when they move as a one unit considering FBD of them,



Making algebraic sum of forces which are perpendicular to plane i.e.

∑V↑+ = 0

$$-180 Cos\ 30° + R = 0$$

$$R = 180 Cos\ 30°$$

$$R = 155.88\ N$$

∑H→+ = 0

$$-\left(\frac{W}{g}\ X\ a\right) + W\ Sin30° - F = 0$$

$$F = \mu\ X\ R$$

$$F = \frac{0.2 + 0.4}{2}\ X\ 155.88$$

$$F = 46.764\ N$$

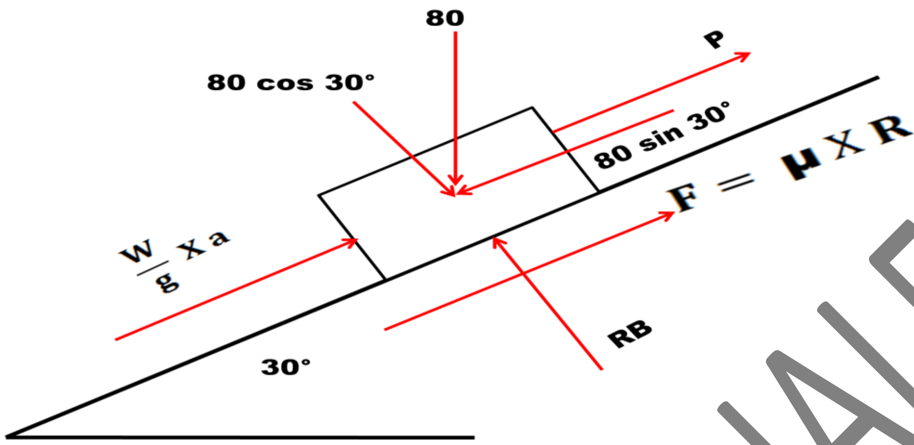
$$-\left(\frac{180}{9.81}\ X\ a\right) + 180\ Sin30° - 46.764 = 0$$

$$a = (180\ Sin30° - 46.7640)\left(\frac{9.81}{180}\right)$$

$$a = 2.356\ m/s^2$$

TO FIND OUT CONTACT FORCE BETWEEN TWO BLOCKS LET IT BE P.

Now consider FBD of block B



HERE

$\sum V\uparrow + = 0$

$$-80Cos\,30° + R = 0$$

$$R = 80Cos\,30°$$

NOW,

$\sum H\uparrow + = 0$

$$-\left(\frac{80}{g} \text{X a}\right) + 80 \text{ Sin}30° - \text{F} + \text{P} = 0$$

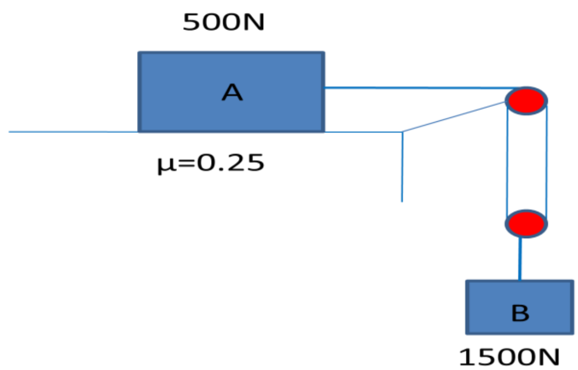
$$\text{F} = \mu \text{ X R}$$

$$\text{F} = 0.4 \text{ X } 80Cos\,30°$$

$$-\left(\frac{80}{9.81} \text{ X } 1.506\right) + 80 \text{ Sin}30° - 0.4 \text{ X } 80Cos\,30° + \text{P} = 0$$

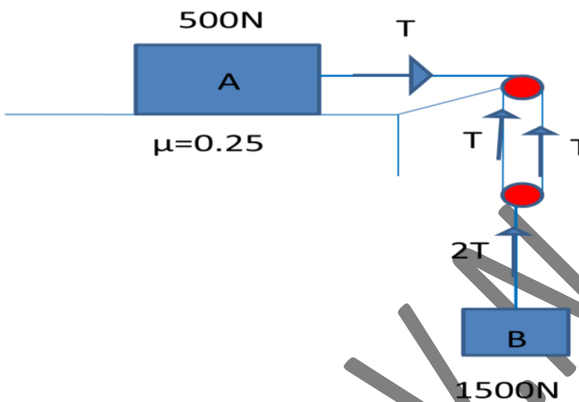
$$\text{P} = -0.05\,N$$

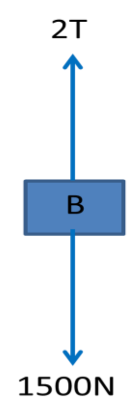
5) Two blocks as shown start from rest. The coefficient of friction between horizontal plane and block is 0.25, assuming that the pulleys are friction less & weightless. Determine the acceleration of each block & tension in cord.



To decide the correct direction of motion,

Considering both the blocks are at rest & considering FBD of block B.





$$\Sigma_V^{\uparrow +} = 0$$

$$2T = 1500$$

$$T = 750N$$

Considering FBD of block B.

$$\Sigma_H^{\rightarrow +} = 0$$

$$T = 0$$

$$750 > 0$$

As the value of tension in block B is graters then tension of block A, So block B will move in downward direction& as block B move in down ward direction block A moves toward right side.

Kinetic relation between Block A & block B

Work done by block A = Work down by block B

Force x Distance = Force x Distance

$$TxS_A = 2TxS_B$$

$$S_A = 2xS_B$$

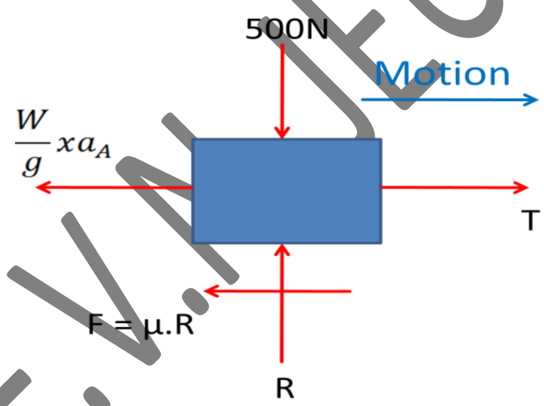
$$S_A = 2S_B$$

$$a_A = 2a_B$$

$$V_A = 2V_B$$

To determine acceleration & tension in cord,

Considering FBD of block A



$$\Sigma_V^{\uparrow +} = 0$$

$$RA - 500 = 0$$

$$RA = 500N$$

$$\Sigma_H^{\rightarrow +} = 0$$

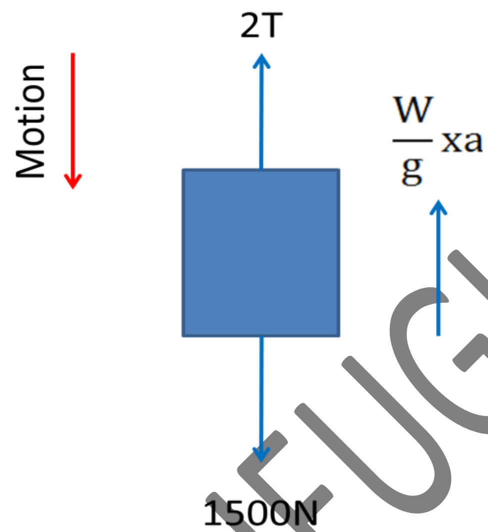
$$-\frac{W}{g}xa + T - F = 0$$

$$-\frac{500}{9.81}xa + T - 0.25x500 = 0$$

$$T = \frac{500}{9.81} xa + 0.25x500$$

$$T = 50.96xa + 125 \rightarrow 1)$$

Considering FBD of block B



$$\Sigma_{V}^{\uparrow +} = 0$$

$$2T - 1500 + \frac{w}{g} xa = 0$$

$$2T = 1500 - \frac{1500}{9.81} xa$$

$$2T = 1500 - 152.90xa$$

$$T = -76.45xa + 750 \rightarrow 2)$$

From equation 1&2

$$50.96xa + 125 = -76.45xa + 750$$

$$50.96x2a + 125 = -76.45xa + 750$$

$$101.92xa + 76.45xa = 750 - 125$$

$$178.37a = 625$$

$$a = \frac{625}{178.37}$$

$$a = 3.50\ \mathrm{m/s^2}$$

Put this value in eq.2

$$T = -76.45xa + 750 \rightarrow 2)$$

$$T = -76.45x3.50 + 750 \rightarrow 2)$$

$$T = 482.42N$$

Acceleration of each block 3.50m/s^2

Tension in cord is 482.42N