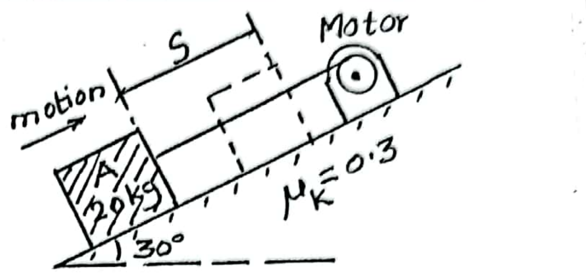
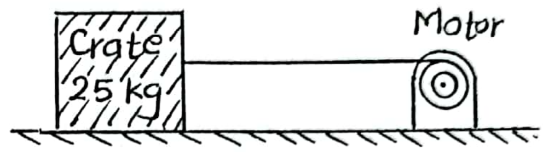
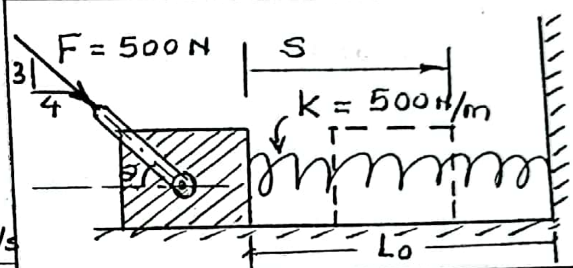
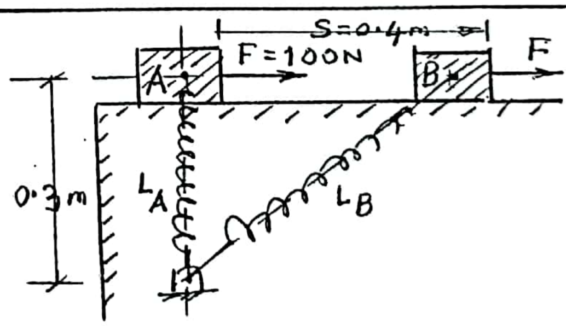
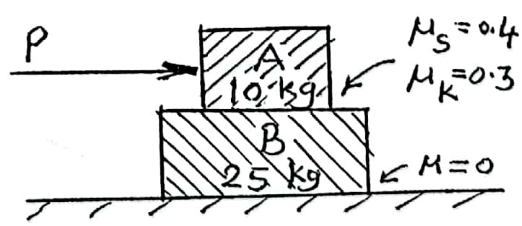
Rectilinear Kinetics(Newton's Second Law of Motion)

Curvilinear Kinetics (Newton’s Second Law)

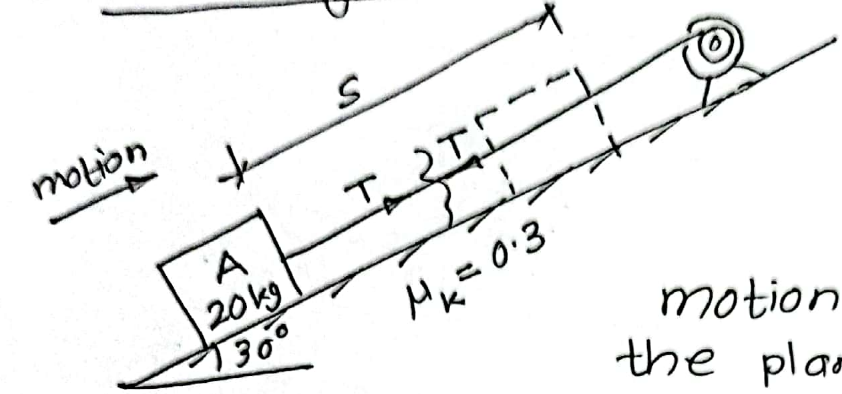
Work power energy and work energy principle

Lecture No: **Rectilinear Kinetics (Newton's Second Law of Motion)**

1	The motor winds in the cable with a constant acceleration, such that the 20-kg. Crate moves a distance s= 6m in 3 sec., starting from rest. Determine the tension developed in the cable. The coefficient of kinetic friction between the crate and the plane is $\mu_k = 0.3$ Ans. : T = 176 N	
2	If motor M exerts a force of $F = (10\ t^2 + 100)$ N on the cable, where t is in seconds, determine the velocity of the 25- kg. crate when t = 4 s. The coefficients of static and kinetic friction between the crate and the plane are $\mu_s = 0.3$ and $\mu_k = 0.25$ respectively. The crate is initially at rest. Ans. : $V_4 = 14.7$ m/s (→)	
3	A spring of stiffness k = 500 N/m is mounted against the 10 kg block. If the block is subjected to the force of F = 500 N, determine its velocity at s = 0.5m. When s=0, the block is at rest and the spring is uncompressed. The contact surface is smooth. Ans.: V = 5.24 m/s	
4	The 2 Mg. car is being towed by a winch. If the winch exerts a force of T=100 (s + 1) N on the cable where s is the displacement of the car in meters, determine the speed of the car when s= 10 m, starting from rest. Neglect rolling resistance of the car. Ans.: V = 2.45 m/s (→)	
5	The spring has a stiffness k = 200 N / m and is unstretched when the 25 kg block is at A. Determine the acceleration of the block when s = 0.4 m. The contact surface between the block and the plane is smooth. Ans. : a = 2.72 m/s² (→)	
6	Block B rests upon a smooth surface. If the coefficients of static and kinetic friction between A and B are $\mu_s = 0.4$ and $\mu_k = 0.3$, respectively, determine the acceleration of each block if P = 30N. Ans. : $a_A = a_B = 0.857$ m/s² (→)	

Lecture No: (13) D'Alembert's Principle/Newton's 2nd law (Rectillinear motion)

(1) F 13·1/ pg. 742/RCH



$m = 20\,kg$

$u = 0$

a = constant

$s = 6\,m$ at $t = 3\,s$

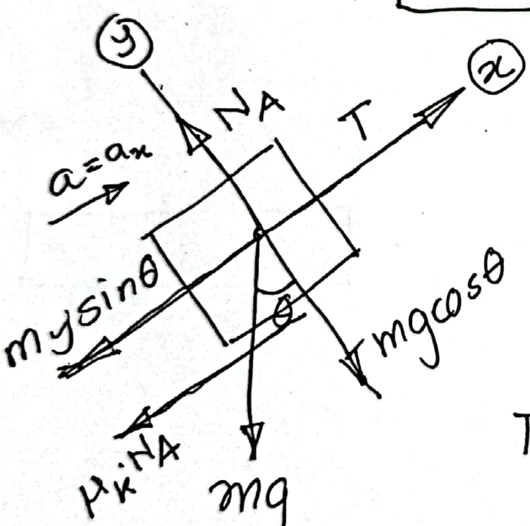
$\theta = 30°$

motion of the crate along the plane is uni. acc. motion

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

$$6 = 0 + \frac{1}{2} \times a \times (3)^2$$

$$\boxed{a = 1.333\ m/s^2}$$



Along 'y' axis, $\Sigma F_y = m \cdot a_y$

But, $a_y = 0 \quad \therefore \Sigma F_y = 0$

$\therefore N_A - (20 \times 9.81 \times \cos 30°) = 0$

$$\boxed{N_A = 169.914\ N}$$

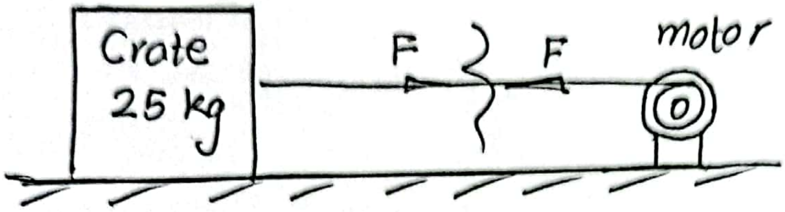
Along 'x' axis, $\Sigma F_x = m \cdot a_x$

$T - (20 \times 9.81 \times \sin 30°) - (0.3 \times 169.914)$

$= (20 \times 1.333)$

$$\therefore \boxed{T = 176\ N}$$

② F13.2/pg.742/RCH

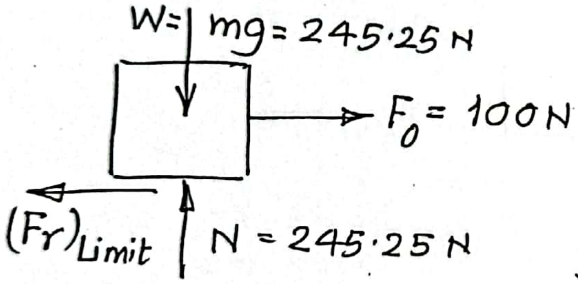


$$\mu_s = 0.30$$
$$\mu_k = 0.25$$
At $t=0$, $v=0$

$$F = (10 \cdot t^2 + 100)\ N$$

At $t=0$, $F_0 = 100\ N$

$$(Fr)_{max} = (Fr)_{Limit} = \mu_s \cdot N$$
$$= (0.3 \times 25 \times 9.81) = 73.575\ N$$



As, $F_0 > (Fr)_{Limit}$ at $t=0$, the crate will start moving immediately after 'F_0' is applied.

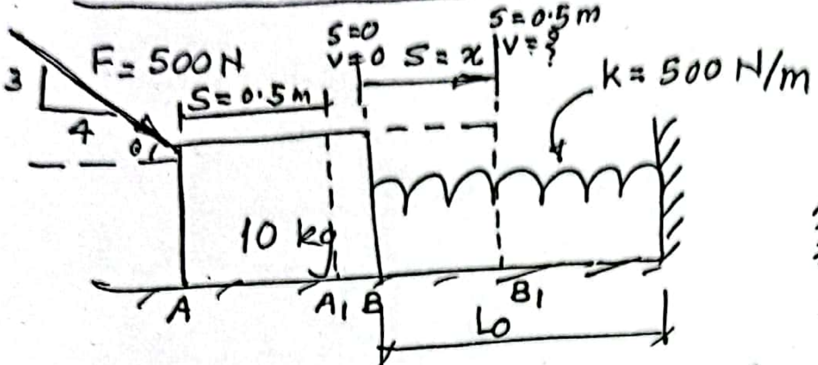
During motion of the crate,

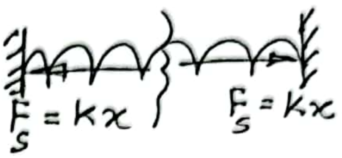
$$\Sigma F_y = m \cdot a_y = 0$$
$$N - 245.25 = 0 \quad \therefore \boxed{N = 245.25\ N}$$

$$\Sigma F_x = m \cdot a_x$$
$$F - (Fr)_{kinetic} = 25 \cdot a_x$$
$$(10 \cdot t^2 + 100) - (0.25 \times 245.25) = 25 \cdot a_x$$
$$\therefore\ a_x = a = [(0.4)t^2 + (1.5475)]\ m/s^2$$
$$dV = a \cdot dt$$
$$\int_0^V dV = \int_0^4 [(0.4)t^2 + (1.5475)]\,dt$$
$$\therefore\ \boxed{v_4 = 14.72\,m/s\ (\rightarrow)}$$

Scanned with CamScanner

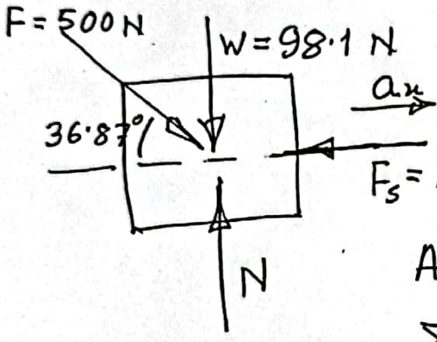
③ F 13·3/ pg·742/RCH :





x = deformation of the spring in 'm'

$\tan\theta = \frac{3}{4}$ $\therefore$ $\theta = 36.87^\circ$



Along 'x' axis,

$$\Sigma F_x = m \cdot a_x$$

$$(500)(\cos 36.87^\circ) - (500 \cdot x) = 10 \cdot a_x$$

$$\therefore \quad a_x = (40 - 50 \cdot x) \ m/s^2 = a \ (\text{say})$$

But, $\quad a \cdot dx = v \cdot dv$

$$\int_0^{0.5\,m} (40 - 50 \cdot x)\, dx = \int_0^v v \cdot dv$$

$$\left(40 \cdot x - 25 \cdot x^2\right)_0^{0.5} = \left[\frac{v^2}{2}\right]_0^v$$

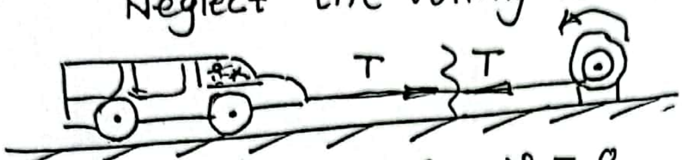
$$\therefore \quad \boxed{v = 5.24 \ m/s \ (\rightarrow)}$$

④ F 13.4 / pg. 742 / RCH :

$m = 2000$ kg

$T = (100)(s+1)$ N

Neglect the rolling resistance.



when $s = 0$, $v = 0$

$s = 10$ m, $V = ?$

$$\Sigma F_x = m \cdot a_x$$

$$\therefore T = m \cdot a_x$$

$$\therefore (100)(s+1) = (2000)\, a_x$$

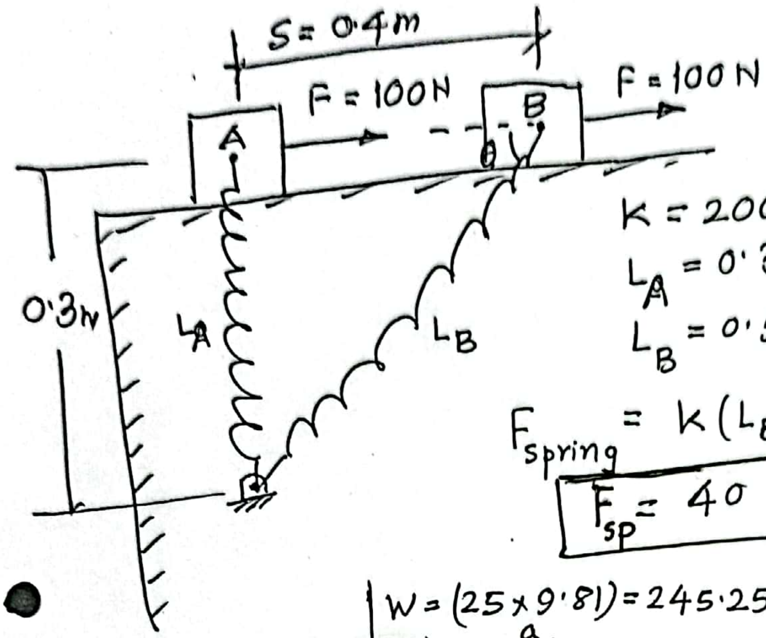
$$\therefore a_x = a = [(0.05)x + (0.05)] \ m/s^2$$

Now, $a \cdot dx = v \cdot dv$

$$\int_0^{10} [(0.05)x + (0.05)]\, dx = \int_0^v v \cdot dv$$

$$\therefore \boxed{v = 2.45 \ m/s \ (\rightarrow)}$$

5) F 13.5/pg. 742/RCH :



$\tan\theta = \frac{0.3}{0.4}$

$\theta = 36.87°$

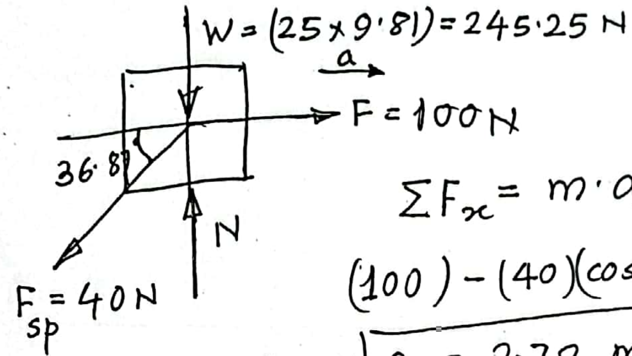
$K = 200 N/m$

$L_A = 0.3 m = L_0$

$L_B = 0.5 m, \ (L_B - L_0) = x_B$

$F_{spring} = k(L_B - L_0) = (200)(0.5 - 0.3)$

$\boxed{F_{sp} = 40 N}$



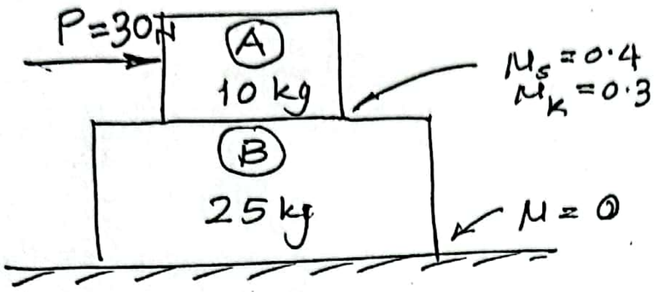
$\Sigma F_x = m \cdot a_x$

$(100) - (40)(\cos 36.87°) = 25 \cdot a_x$

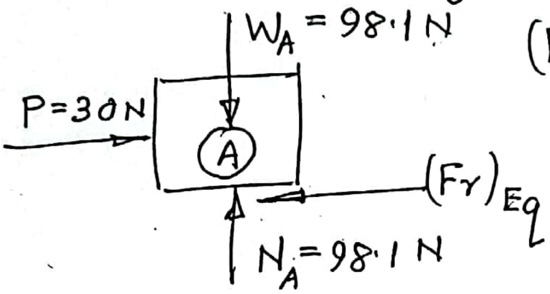
$\therefore a_x = \boxed{a = 2.72 \ m/s^2 \ (\rightarrow)}$

Scanned with CamScanner

⑥ F 13.6 / Pg. 742 / RCH :



I) Check, if slipping occurs betn A & B :



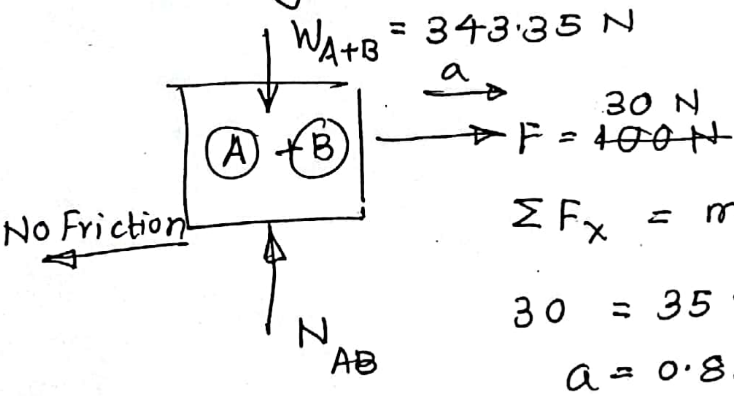
$(Fr)_{Eq} = 30$ N

$(Fr)_{Limit} = (0.4 \times 98.1) = 39.24$ N

As, $(Fr)_{Equi.} < (Fr)_{Limit}$

Block A is not sliding at the top of block B .

II) Consider blocks A and B together as one rigid body :



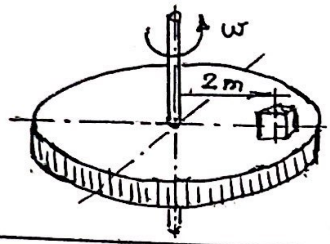
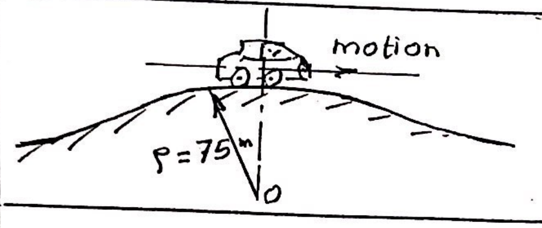
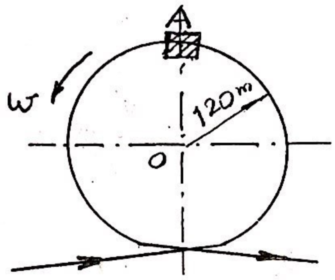
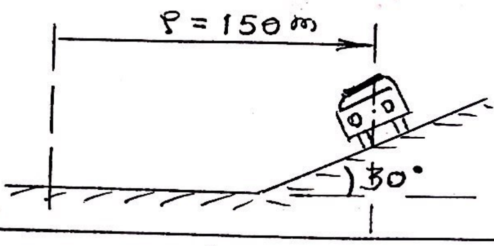
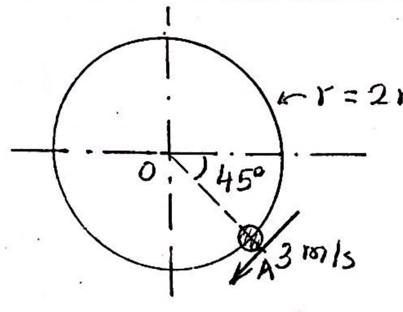
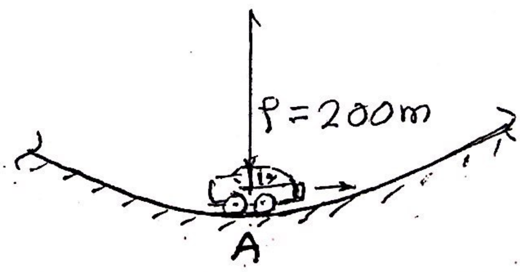
$\Sigma F_x = m \cdot a$

$30 = 35 \cdot a$

$a = 0.857 \ m/s^2$

$\therefore \boxed{a_A = a_B = 0.857 \ m/s^2 (\rightarrow)}$

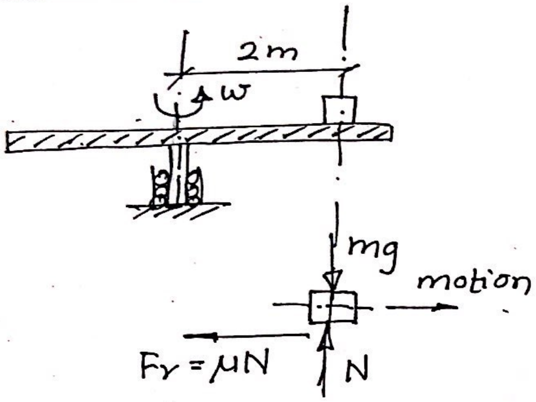
Lecture No: **Curvilinear Kinetics (Newton's Second Law of Motion)**

1	The block rests at a distance of 2m from the center of the platform. If the coefficient of static friction between the block and the platform is $\mu_s = 0.3$, determine the maximum speed which the block can attain before it begins to slip. Assume the angular motion of the disk is slowly increasing Ans.: $V_{max} = 2.426$ m/s	
2	Determine the maximum speed that the jeep can travel over the crest of the hill and not lose contact with the road. Ans, : $V_{max} = 27.125$ m/s	
3	A pilot weighs 70 kg and is travelling at a constant speed of 36 m / s. Determine the normal force he exerts on the seat of the plane when he is upside down at A. The loop has a radius of curvature of 120 m. Ans. ; $N_p = 69.3$ N (↓)	
4	The sports car is travelling along a 30^0 banked road having a radius of curvature of p = 150 m.. If the coefficient of static friction between the tires and the road is $\mu_s = 0.2$, determine the maximum safe speed so no slipping occurs. Neglect the size of the car. Ans.: $V = 35.96$ m/s	
5	If the 10 kg ball has a velocity of 3 m / s when it is at the position A, along the vertical path, determine the tension in the cord and the increase in the speed of the ball at this position. Ans.: T = 114 N, $a_t = 6.94$ m/s²	
6	The motorcycle has a mass of 0.5 Mg. and a negligible size. It passes point A travelling with a speed of 15 m/s, which is increasing at a constant rate of 1.5 m/s². Determine the resultant frictional force exerted by the road on the tires at this instant. Ans.: F = 938 N	

Lecture No. 14 Newton's 2nd Law of Motion

Curvilinear Motion

1 F 13.7 / pg. 759 / RCH (14th Ed.) :

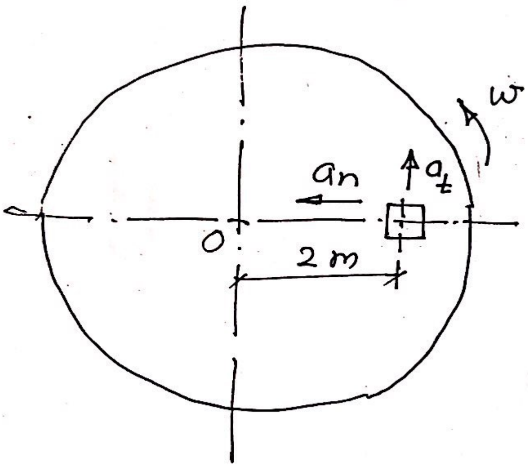


$$\Sigma F_N = m \cdot a_n$$

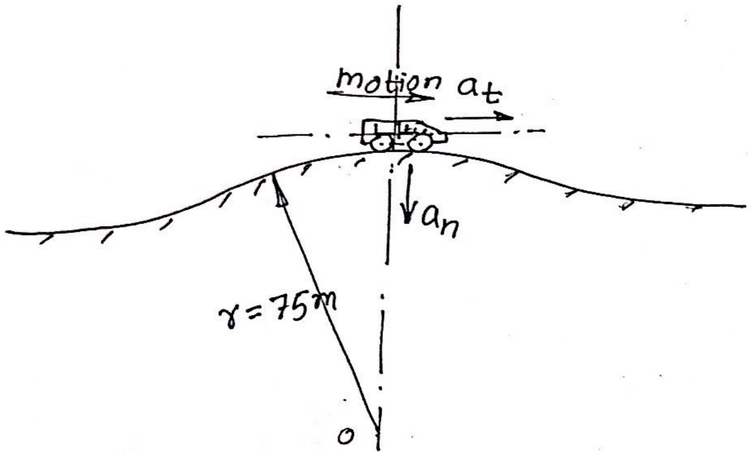
$$(0.3)\, m \times (9.81) = m \cdot \frac{V^2}{r}$$

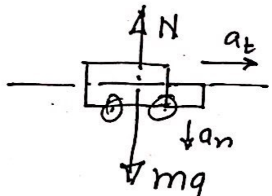
put, $r = 2\ m$

$$\therefore \boxed{V = 2.426\ m/s}$$



② F 13·8/pg. 759/RCH (14th Ed.) :





$$\Sigma F_N = m \cdot a_n$$

$$mg - N = \frac{mv^2}{r}$$

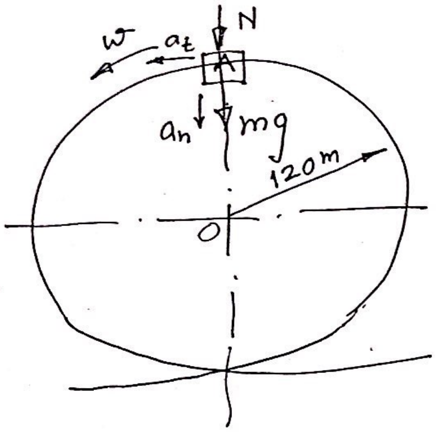
Consider $N = 0$

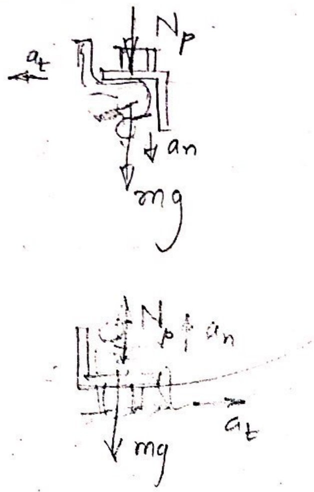
$$\therefore \quad mg = \frac{mv_{max}^2}{r}$$

$$V_{max}^2 = (75 \times 9.81)$$

$$\boxed{V_{max} = 27.125\ m/s}$$

③ F13.9/pg. 759/RCH (14th Ed.)





$$\Sigma F_N = m \cdot a_n$$

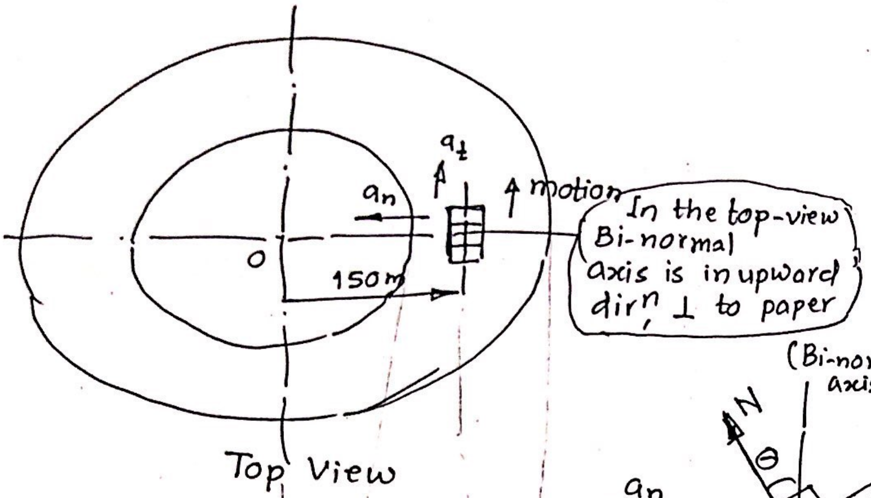
$$mg + N_p = m \cdot \frac{v^2}{r}$$

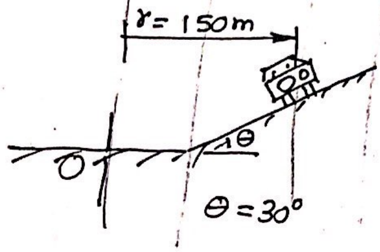
$$N_p = \frac{mv^2}{r} - mg$$

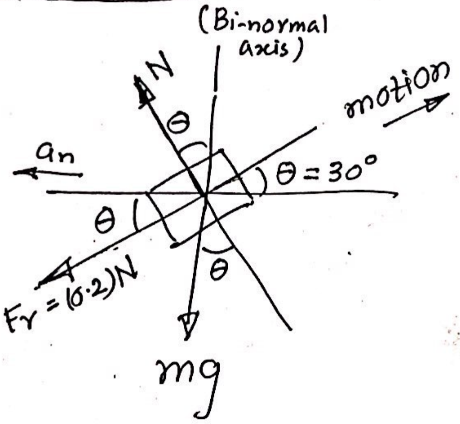
$$N_p = (70)\left[\frac{36^2}{120} - 9.81\right]$$

$$\boxed{N_p = 69.3 \text{ N}}$$

④ F13.10/pg. 759/ RCH(14th Ed.)







$$\Sigma F_N = m \cdot a_n$$

$$N \sin\theta + (0.2)N \cdot \cos\theta = \frac{mv^2}{r} \longrightarrow ①$$

$$\Sigma F_b = 0$$

$$N\cos\theta - (0.2)N \cdot \sin\theta - mg = 0 \longrightarrow ②$$

put, $\theta = 30°$, $(0.766)N - (9.81)m = 0$

$$\boxed{N = (12.807)\,m}$$

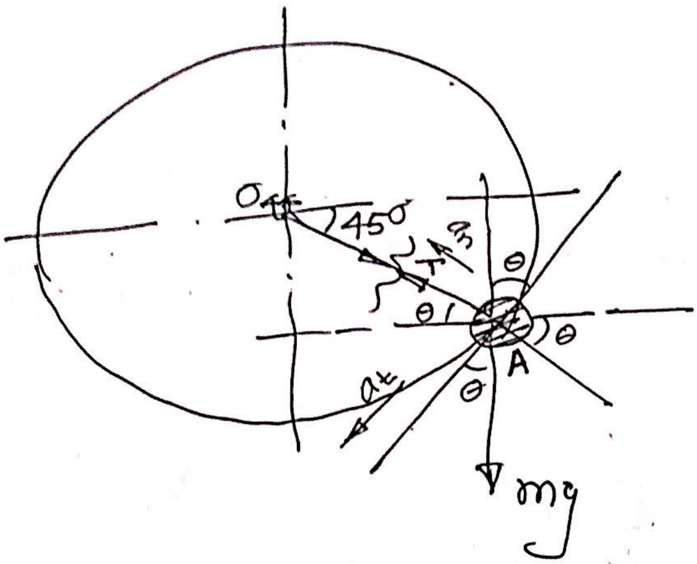
∴ eq^n ① becomes,

$$(12.807)\cancel{m} \times (0.5) + (0.2)(12.807)\cancel{m} \times (0.866) = \frac{\cancel{m}V^2}{150}$$

$$(6.403) + (2.218) = \frac{V^2}{150}$$

$$\boxed{V = 35.96 \text{ m/s}}$$

(5) F13·11/ pg. 759/ RCH (14th Ed) :



$\theta = 45°$
$r = 2\ m$
$V = 3\ m/s$
$m = 10\ kg$

$\Sigma F_t = m \cdot a_t$

$mg\cos\theta = m \cdot a_t$

$\cancel{10} \times 9.81 \times \cos 45° = \cancel{10} \cdot a_t$

$\boxed{a_t = 6.94\ m/s^2}$

$\Sigma F_n = m \cdot a_n$

$T - mg\sin\theta = \frac{mv^2}{r}$

$T = \left(mg\sin\theta + \frac{mv^2}{r}\right)$

$T = (10)\left[(9.81 \times \sin 45°) + \frac{3^2}{2}\right] = 114\ N$

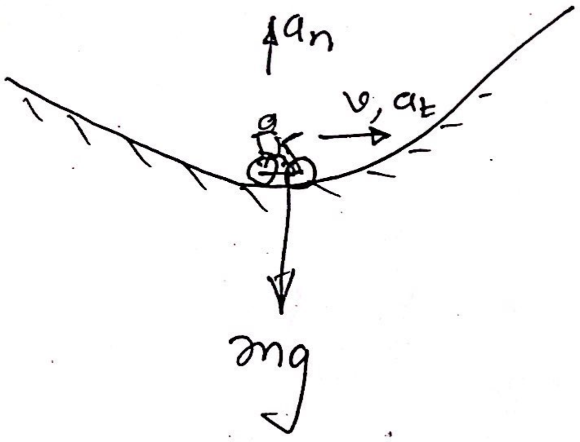
$\boxed{T = 114\ N}$

(6) F13.12/ pg. 759/ RCH (14th Ed),

$m = 500\,kg \quad r = 200\,m$

$V = 15\ m/s$

$a_t = 1.5\ m/s^2$



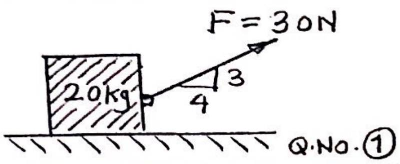
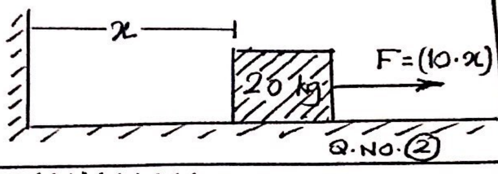
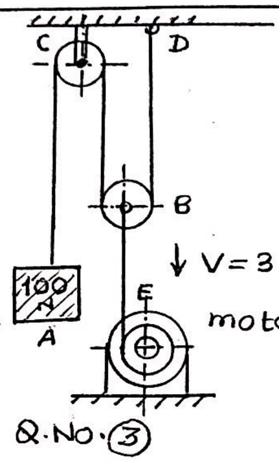
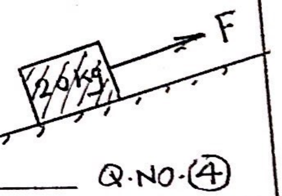
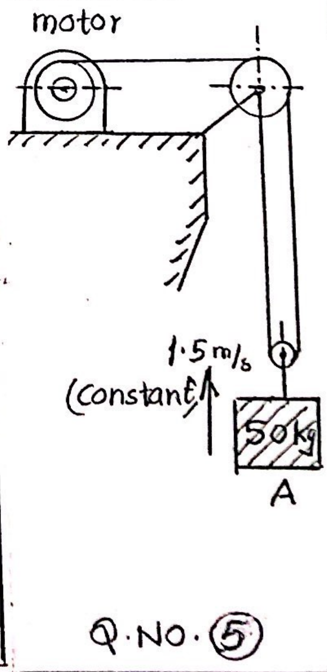
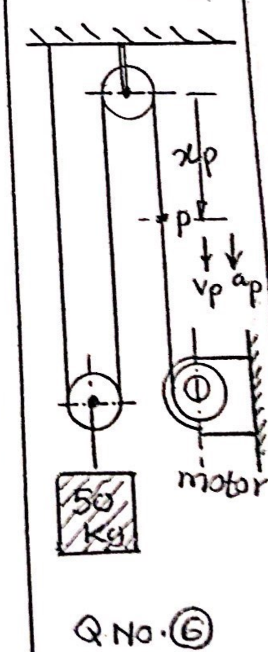
$$\Sigma F_n = m \cdot a_n = \frac{mV^2}{r} = \frac{500 \times 15^2}{200} = 562.5\ N$$

$$\Sigma F_t = m \cdot a_t = 500 \times 1.5 = 750\ N$$

$$F = \sqrt{F_t^2 + F_n^2} = \sqrt{750^2 + 562.5^2}$$

$$\boxed{F = 938\ N}$$

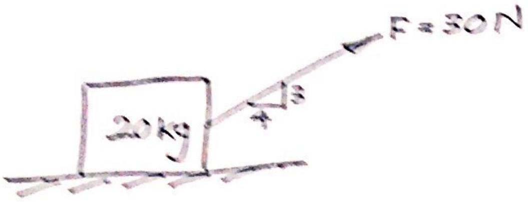
Lecture No: **Work , Power, Energy**

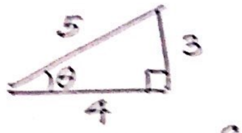
1	If the contact surface between the 20-kg block and the ground is smooth, determine the power of force F when t = 4 s. Initially, the block is at rest.	
2	If F = (10s) N, where s is in meters, and the contact surface between the block and the ground is smooth, determine the power of force F when s = 5 m. When s = 0, the 20 kg block is moving at v = 1 m/s.	
3	If the motor winds in the cable with a constant speed of v = 3 m/s, determine the power supplied to the motor. The load weighs 100 N and the efficiency of the motor is η = 0.8. Neglect the mass of the pulleys.	
4	The coefficient of kinetic friction between the 20-kg block and the inclined plane is μ_k = 0.2. If the block is travelling up the inclined plane with a constant velocity v =5m/s, determine the power of force F.	
5	If the 50 kg-kg load A is hoisted by motor M so that the load has a constant velocity of 1.5 m/s. determine the power input to the motor, which operates at an efficiency η = 0.8	
6	At the instant shown, point P on the cable has a velocity V_p = 12 m/s, which is increasing at a rate of a_p = 6 m/s^2. Determine the power input to motor M at this instant if it operates with an efficiency η = 0.8. The mass of block A is 50 Kg.	

Scanned with CamScanner

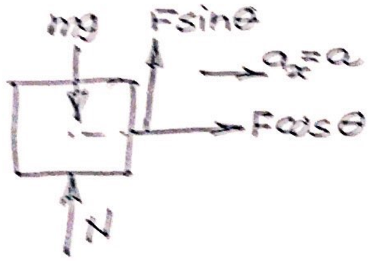
Lecture No (11) Work, Power, Energy

(1) F 14·7/ Pg. 822/ RCH (14th Ed.)





$\theta = 36.87°$



$\sum F_x = m \cdot a_x$

$30 \times \cos 36.87° = 20 \times a_x$

$a_x = a = 1.2\ m/s^2$

At $t = 0$, $u = 0$

At $t = 4s$, $v = u + at$

$\therefore v = 0 + (1.2 \times 4) = 4.8\ m/s$

Now, power = force × vel.

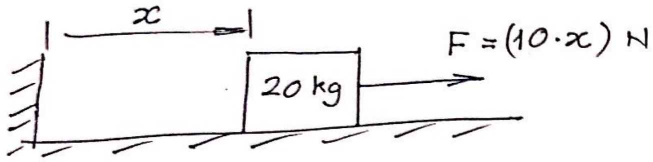
$P = F \times V$

$\therefore P = (30 \times \cos 36.87° \times 4.8)$

$P = 115$ Watts.

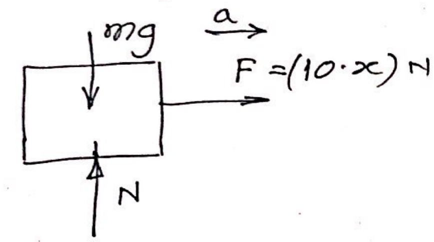
Scanned with CamScanner

② F 14·8/pg·822/RCH (14th Ed.)



when $x = 0$, $v = 1$ m/s

$\therefore$ $x = 5$ m, $v = ?$



$$\Sigma F_x = m \cdot a_x$$

$$10 \cdot x = 20 \cdot a_x$$

$$a_x = a = (0.5)x = f(x)$$

Now, $\int v \cdot dv = \int a \cdot dx$

$$\therefore \int_{1\,m/s}^{V} v \cdot dV = \int_{0}^{5m} (0.5)x \cdot dx$$

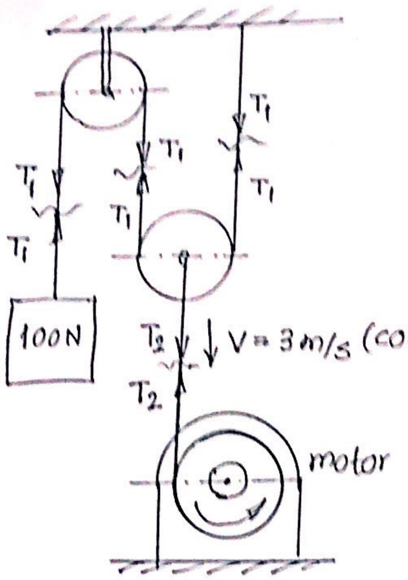
$$V = 3.674 \text{ m/s}$$

Now, Power, $P = F.V$

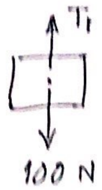
$$P = (10 \times 5 \times 3.674)$$

$$\therefore P = 184 \text{ Watts}$$

(3) F14.9/pg.822/RCH (14th Ed)



$\eta = 0.8$



For the hanging weight,

$\Sigma F_y = m \cdot a_y = 0$

(as $a_y = 0$)

$T_1 - 100 = 0$

$\therefore T_1 = 100$ N

For the hanging weight,

$T_2 = 2 \cdot T_1 = 200$ N

$\therefore$ Output power $= T_2 \cdot V$

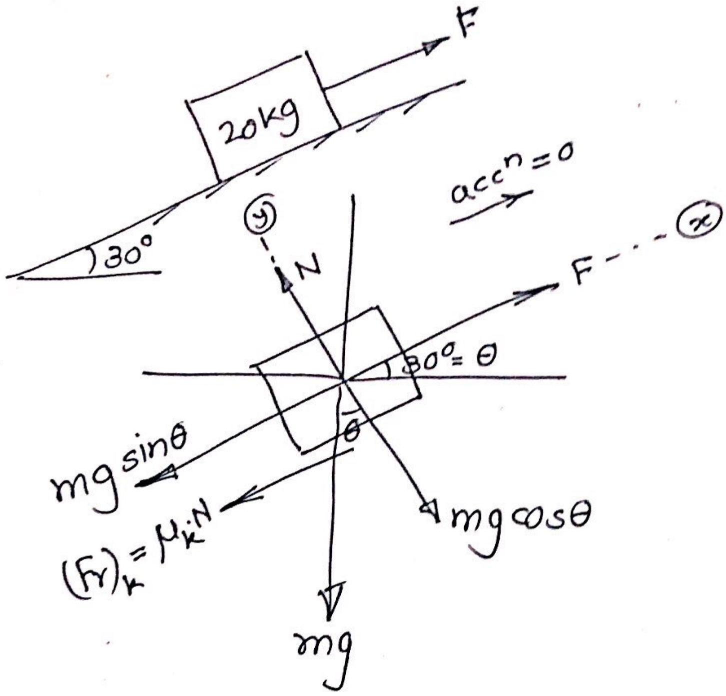
$= (200 \times 3) = 600$ Watt.

Efficiency $= \left(\frac{\text{power output}}{\text{power input}}\right)$

$\therefore$ Input power $= \left(\frac{600}{0.8}\right)$

$= 750$ Watts.

4 F 14·10/ pg. 822/RCH (14th Ed.)



$\Sigma F_y = m \cdot a_y$

$N - (20 \times 9.81 \times \cos 30°) = 0$

$N = 169.91 \text{ N}$

$\Sigma F_x = m \cdot a_x$

$F - (20 \times 9.81 \times \sin 30°) - (0.2 \times 169.91) = 0$

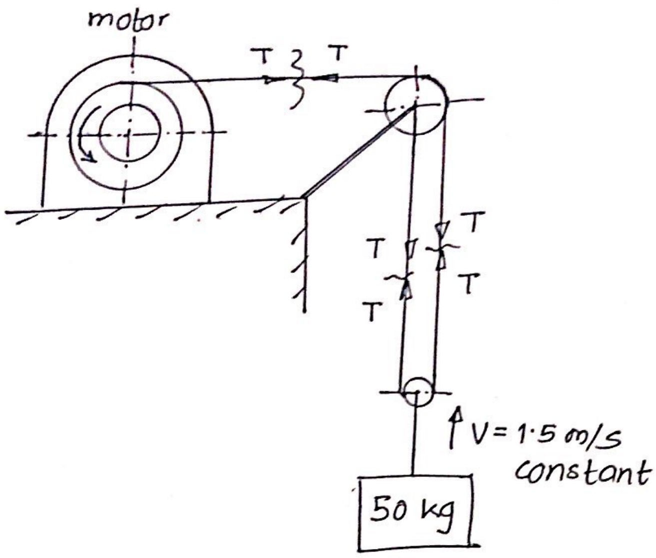
$\therefore F = 132.08 \text{ N}$

Power, $P = F \cdot V$

$= (132.08 \times 5)$

$= 660$ Watts.

⑤ F 14·11/Pg. 822/RCH (14th Ed.)



For the hanging body, $\Sigma F_y = m \cdot a_y$

$$2T - (50 \times 9.81) = 0$$

$$T = 245.25 \text{ N}$$

Output power $= T \cdot V$

$$= (245.25 \times 1.5)$$

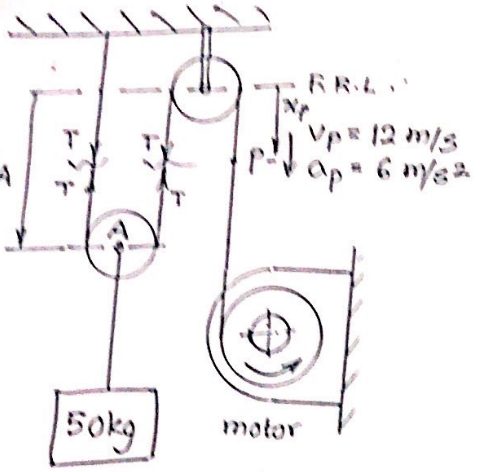
$$= 367.875 \text{ Watts.}$$

Input power $= \left(\dfrac{367.875}{0.8}\right)$

$$= 459.84 \text{ Watts.}$$

Scanned with CamScanner

⑥ F 14·12/Pg. 822/RCH (14th Ed.)



As the length of the rope is constant,

$$2x_A + x_P = L$$

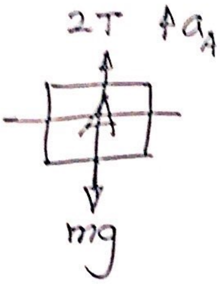
$$\therefore 2V_A + V_P = 0$$

$$\therefore 2a_A + a_P = 0$$

$$\therefore 2 \cdot a_A + 6 = 0$$

$$a_A = -3 \text{ m/s}^2$$

$$= 3 \text{ m/s}^2 \ (\uparrow)$$



$$\Sigma F_y = m \cdot a_y$$

$$2T - (50 \times 9.81) = (50 \times 3)$$

$$2T - (490.5) = 150$$

$$T = 320.25 \text{ N}$$

$$\text{Output power} = T \times V$$

$$= (320.25)(12)$$

$$= 3843 \text{ Watts.}$$

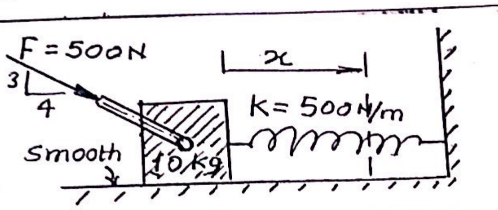
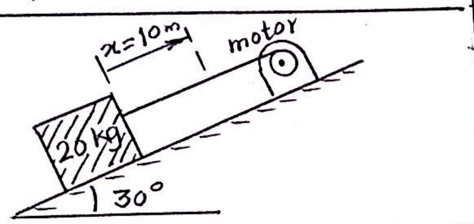
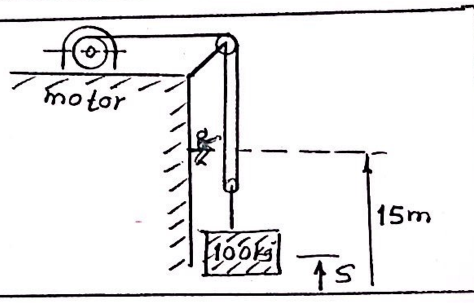
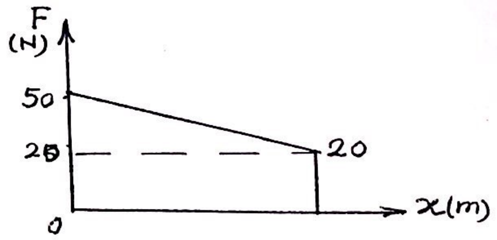
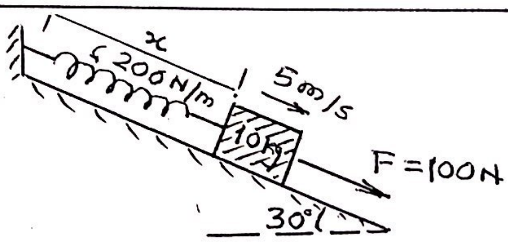
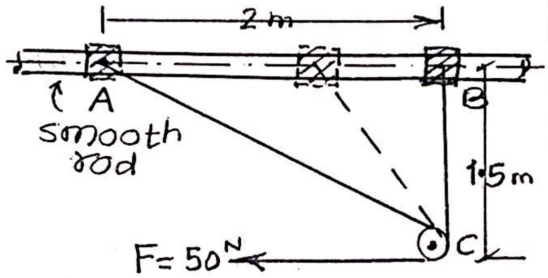
$$\text{Input power} = \left(\frac{3843}{0.8}\right)$$

$$= 4803.75 \text{ Watts.}$$

Scanned with CamScanner

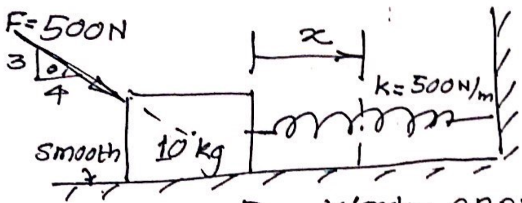
Lecture No:

Work-Energy Principle

1	The spring is placed between the wall and the 10-kg. block. If the block is subjected to a force of F = 500 N, determine its velocity when s = 0.5 m. When s = 0, the block is at rest and the spring is uncompressed. The contact surface is smooth.	
2	If the motor exerts a constant force of 300 N on the cable, determine the speed of the 20 kg crate when it travels s = 10 m up the plane, starting from rest. The coefficient of kinetic friction between the crate and the plane is μ_k = 0.3	
3	If the motor exerts a force of F = (600 + 2s^2) N on the cable, determine the speed of the 100-kg crate when it rises to s = 15m. The crate is initially at rest on the ground.	
4	The 1.8 Mg dragster is travelling 125 m/s when, the engine is shut off and the parachute is released. If the drag force of the parachute can be approximated by the graph, determine the speed of the dragster when it has travelled 400m.	
5	When s = 0.6 m, the spring is unstretched and the 10-kg block has a speed of 5 m/s down the smooth plane. Determine the distance s when the block stops.	
6	The 2.5- kg collar is pulled by a cord is that passes around small peg at C. If the cord is subjected to a constant force of F = 50 N, and the collar is at rest when it is at A, determine its speed when it reaches B. Neglect friction.	

Lecture No. 12 Work-Energy Principle

1. F 14.1/pg. 808/RCH (14th Ed)



when $x = 0$, $v = 0$

$x = 0.5m$, $v = ?$

$\tan\theta = \frac{3}{4}$

$\theta = 36.87^\circ$

By Work-energy principle,

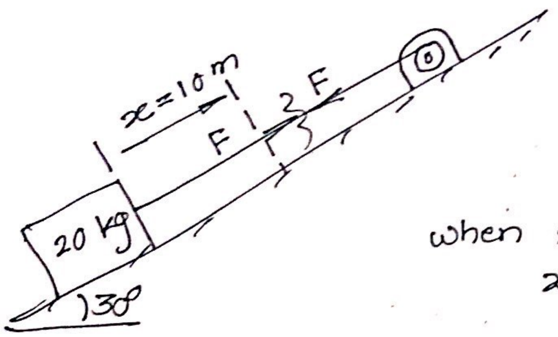
$$U_{1-2} = T_2 - T_1$$

$$(F\cos\theta)(x) - \left(\frac{1}{2}kx^2\right) = \frac{1}{2}mv^2 - 0$$

$$(500 \cdot \cos 36.87^\circ \times 0.5) - \left(\frac{1}{2}\times 500 \times 0.5^2\right) = \frac{1}{2}\times 10 \times V^2$$

$$\therefore \quad V = 5.24 \text{ m/s}$$

② F 14.2 / pg. 808 / RCH (14th Ed.)



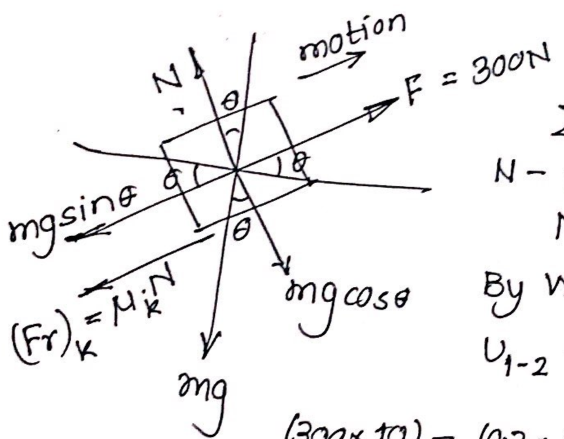
$F = 300\,N$

$m = 20\,kg$

$\mu_k = 0.3$

when $x = 0$, $v = 0$

$x = 10\,m$, $v = ?$



Applying N.S.L.M. along 'y' axis,

$$\Sigma F_y = m \cdot a_y$$

$$N - (20 \times 9.81 \times \cos 30^\circ) = 0$$

$$N = 169.91\,N$$

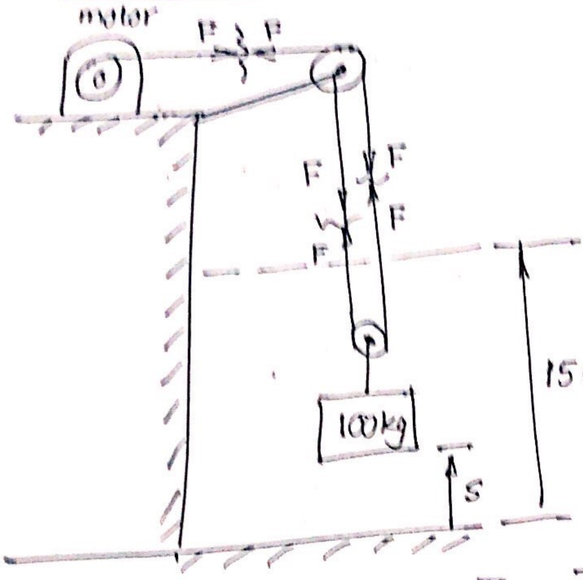
By W-E. Prin.

$$U_{1-2} = T_2 - T_1$$

$$(300 \times 10) - (0.3 \times 169.91)(10) - (20 \times 9.81 \times \sin 30^\circ)(10) = \frac{1}{2} \times 20 \times V^2$$

$$V = 12.3\ m/s$$

(3) F 14.3 / pg. 208 / RCH (14th Ed)



$F = (600 + 2s^2)\ N$

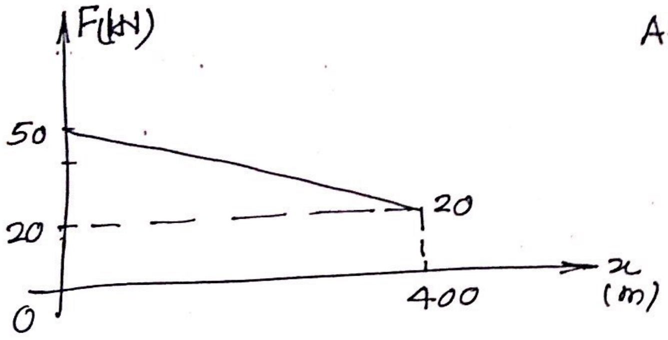
$W.D. = \int F\, ds$

$$U_{1-2} = T_2 - T_1$$

$$2\left[\int_0^{15} (600 + 2s^2)\cdot ds\right] - (100 \times 9.81 \times 15) = \left(\frac{1}{2} \times 100 \times V^2\right)$$

$$V = 12.5\ m/s$$

(4) F14·4/pg. 808/ RCH (14th Ed)



At $x = 0$, $V = 125$ m/s

$x = 400$ m, $V = ?$

$m = 1.8$ Mg

$m = 1.8 \times 10^6$ gm

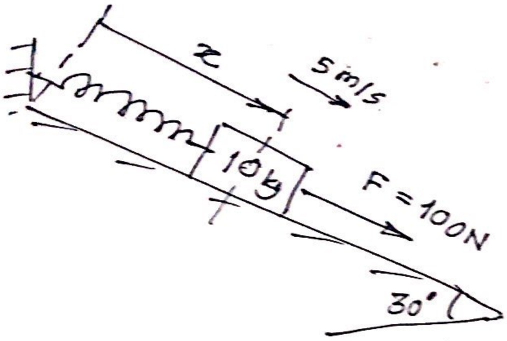
$m = 1800$ kg

$$U_{1-2} = T_2 - T_1$$

$$-\left(\frac{50{,}000 + 20{,}000}{2}\right)(400) = \left(\frac{1}{2} \times 1800 \times V^2\right) - \left(\frac{1}{2} \times 1800 \times 125^2\right)$$

$$V = 8.33 \text{ m/s}$$

(5) F 14.5/Pg. 808/RCH (14th Ed.)



when, $v = 5\,m/s$, $x = 0.6\,m$

$v = 0$, $x = ?$

$$V_{1-2} = T_2 - T_1$$

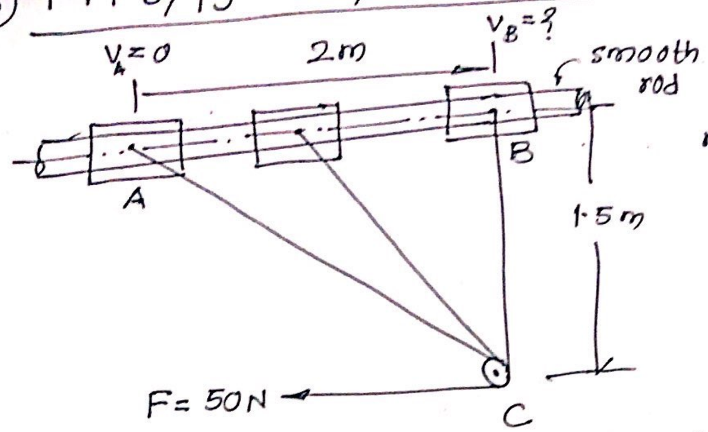
$$(100 \cdot x') + (10 \times 9.81 \times \sin 30^\circ)(x') - \frac{1}{2} \times 200 \times (x')^2 = 0 - \left(\frac{1}{2} \times 10 \times 5^2\right)$$

$x' = 2.09\ m$ (elongation of spring)

$x = 0.6 + 2.09 = 2.69\ m$

(elongated length of the spring)

⑥ F 14.6/pg. 808/RCH (14^{th} Ed.)



$m = 2.5\ kg$

x = dist. travelled by the chord, when the collar moves from A to B = (AC − BC)

$$\therefore \quad x = \left(\sqrt{2^2 + 1.5^2}\right) - (1.5) =$$

$$T_1 = \frac{1}{2} m v_A^2 = 0$$

$$T_2 = \frac{1}{2} \times (2.5) \times V_B^2$$

$$U_{1-2} = F \cdot x = 50 \cdot x$$

$$U_{1-2} = T_2 - T_1$$

$$(50 \cdot x) = \left(\frac{1}{2} \times 2.5 \times V_B^2\right) - 0$$

$$\therefore \quad V_B = 6.32\ m/s$$