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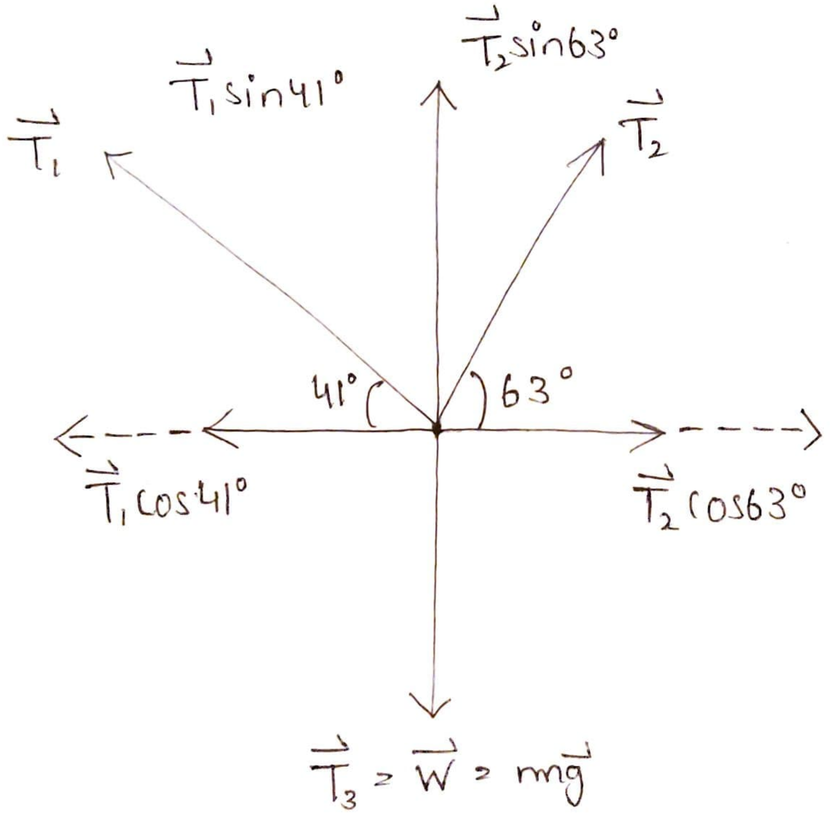
Homework 5:- Application's of Newton's Laws

26. Free body diagram of the Traffic signal is,



From F.B.D,

$T_3 - W = 0$

$T_3 = W$

Substitute 200 N for W

$T_3 = 200\ N$

Using $\sum F_H = 0$

$T_1 \cos 41^\circ - T_2 \cos 63^\circ = 0$

Rearrange the above eq.

$T_1 \cos 41^\circ = T_2 \cos 63^\circ$

$$T_1 = T_2 \left(\frac{\cos 63^\circ}{\cos 41^\circ} \right) = (0.601) T_2$$

Using $\sum F_V = 0$

$T_1 \sin 41^\circ + T_2 \sin 63^\circ - T_3 = 0$

$T_1 \sin 41^\circ + T_2 \sin 63 = T_3$

Substitute $(0.601)T_2$ for T_1 and 200N for T_3 in above eq. and solve

$$(0.601)T_2 \sin 41^\circ + T_2 \sin 63^\circ = 200\,N$$

$$(0.394)T_2 + T_2 (0.891) = 200\,N$$

$$1.285\,T_2 = 200\,N$$

$$T_2 = 155.64\,N$$

Substitute 155.64 N for T_2 in the equation $T_1 = (0.601)T_2$ and solve for T_1

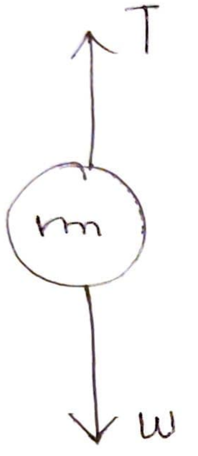
$$T_1 = (0.601)(155.64\,N)$$

$$= 93.54\,N$$

Hence, the tension in each of the three cables is

$T_1 = 93.54\ N$, T_2 $155.64\ N$ and $T_3 = 200\ N$

37. (a) The free body diagram of the elevator is,



From the above diagram,

$T - mg = ma$

Substitute $1700\ kg$ for m, $9.8\ m/s^2$ for g and $1.20\ m/s^2$ for a.

$$T = 1700kg\,(9.8\ m/s^2 + 1.20\ m/s^2)$$
$$= 18700\ N$$
$$= 1.87 \times 10^4\ N$$

Therefore, the tension in the wire is $1.87 \times 10^4\ N$

(b) Using $T - mg = ma$

Substitute 1700 kg for m, 9.8 m/s^2 for g and 0 m/s^2 for a

$$T = 1700\,kg\,(9.8\,m/s^2 + 0\,m/s^2)$$
$$= 16660\,N$$

Therefore, the tension in the wire is 1.67×10^4 N

(c) Using $T - mg = ma$

Substitute 1700 kg for m, 9.8 m/s^2 for g and 0.600 m/s^2 for a.

$$T = 1700\,kg\,(9.8\,m/s^2 - 0.600\,m/s^2)$$
$$= 15640\,N$$
$$= 1.56 \times 10^4\,N$$

Therefore the tension in the wire is 1.56×10^4 N

(d) Using

$$s = ut + 1/2\,at^2$$

Substitute 0 m/s for u, 1.20 m/s^2 for a and 1.50 s for t

$S_1 = (0\ m/s)(1.50\ s) + 1/2\,(1.20\ m/s^2)(1.50\ s)^2$

$= 1.35\ m$

Velocity after acceleration is:

$v = u + at$

$= 0\ m/s^2 + 1.20\ m/s^2 \times 1.50\ s$

$= 1.8\ m/s$

Using $S_2 = ut$

Substitute 1.8 m/s for u, 0 m/s² for a and 8.50 s for t

$S_2 = ut$

$= 1.8\ m/s \times 8.50\ s$

$= 15.3\ m$

Velocity after deceleration is:

$v = u + at$

Substitute 1.8 m/s for u, −0.600 m/s² for a and 3.00 s for t.

$v = 1.8\ m/s + (-0.600\ m/s^2)(3.00\ s)$

$= 1.8\ m/s - 1.8\ m/s$

$= 0\ m/s$

Substitute 1.8 m/s for u, $-0.600\ m/s^2$ for a and 3.00 s for t

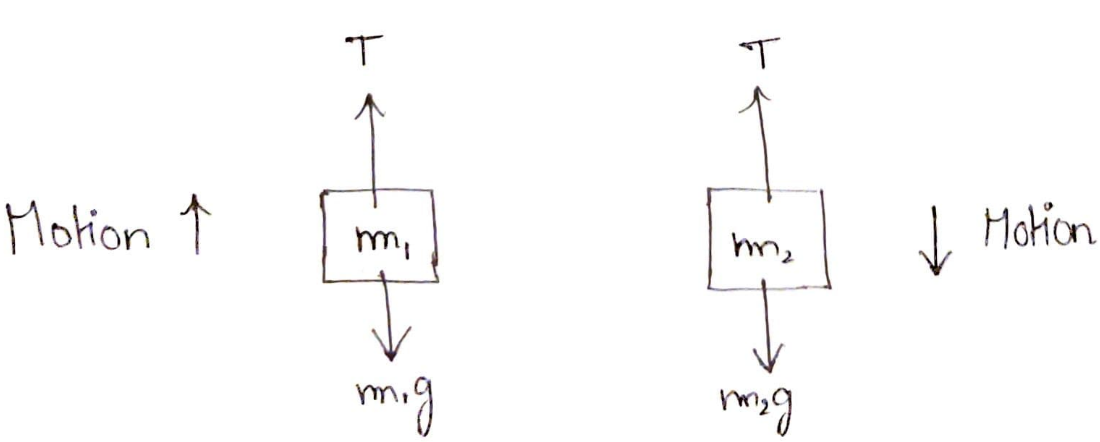
$$S_3 = (1.8\ m/s)(3.00\ s) + \frac{1}{2}(-0.600\ m/s^2)(3.00\ s)^2$$
$$= 2.7\ m$$

Total distance covered by the elevator is,

$$S = S_1 + S_2 + S_3$$
$$= 1.35\ m + 15.3\ m + 2.7\ m$$
$$= 19.4\ m$$

Therefore, the total distance covered is 19.4 m and the final velocity is 0 m/s.

42. The Free Body diagram of the blocks is as follows:



(a) From the free body diagram, the forces acting on the blocks are as follows:

$$T - m_1 g = m_1 a$$

$$T = m_1 a + m_1 g$$

$$m_2 g - T = m_2 a$$

$$T = m_2 g - m_2 a$$

From the above two eq:-

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

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

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

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

Hence the required acceleration is $\frac{(m_2 g - m_1)g}{(m_1 + m_2)}$

(b) From the above equation,

$$T = m_1 a + m_1 g$$

Substitute $\frac{(m_2 - m_1) g}{(m_1 + m_2)}$ for a

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

$$= m_1 g\left(1 + \frac{(m_2 - m_1)}{(m_1 + m_2)}\right)$$

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

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

Hence, the tension on the string is $\frac{2 m_1 m_2 g}{m_1 + m_2}$

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

Substitute 2 kg for m_1, 4.0 kg for m_2; 9.8 m/s^2 for g in the equation.

$$a = \frac{(4.0\ kg - 2.0\ kg)}{(4.0\ kg + 2.0\ kg)}(9.8\ m/s^2)$$

$$= 3.27\ m/s^2$$

Hence, the acceleration of block is $3.27\ m/s^2$

The tension on the string is,

$$T = \frac{2 m_1 m_2 g}{m_1 + m_2}$$

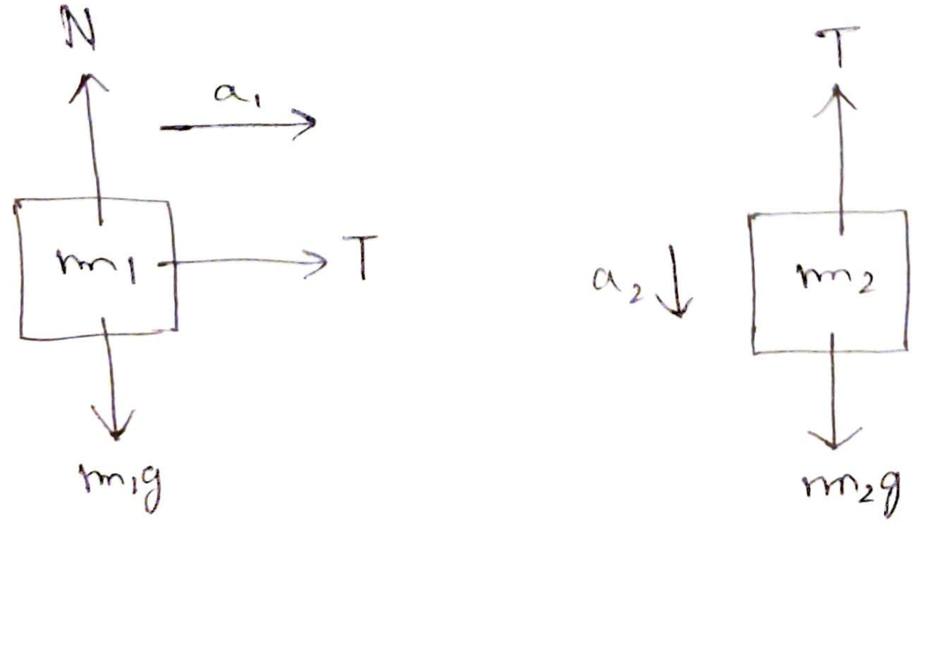
Substitute the value, 2.0 kg for m_1, 4.0 kg for m_2, 9.8 m/s^2 for g in the above equation.

$$T = \frac{2(2.0 \text{ kg})(4.0 \text{ kg})(9.8 \text{ m/s}^2)}{2.0 \text{ kg} + 4.0 \text{ kg}}$$

$$= 26.13 \text{ N}$$

Hence, the required tension is 26.13 N

43. Free body diagram of mass m_1 and m_2 is



(a) From F.B.D of mass m_1,

$F_{net} = m_1 a$

$T = m_1 a$

From F.B.D of mass m_2, net force acting along direction of motion is given as

$F_{net} = m_2 a$

$m_2 g - T = m_2 a$

$T = m_2 g - m_2 a$

For the same string, the tension of string will be same.

$m_1 a = m_2 g - m_2 a$

$m_1 a + m_2 a = m_2 g$

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

Substitute 4.0 kg for m_1, 1.0 kg for m_2, 10.0 m/s² for g.

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

$$= \frac{(1.0\ kg)}{(4.0\ kg + 1.0\ kg)}(10.0\ m/s^2)$$

$$= \frac{10.0}{5.0}\ m/s^2$$

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

Hence, acceleration of system of blocks is $2\ m/s^2$

(b) Using the exp. of the force obtained for the mass m_1

Substitute 4.0 kg for m_1, 1.0 kg for m_2 and $2\ m/s^2$ for a

$$T = m_1 a$$

$$= (4.0\ kg)(2.0\ m/s^2)$$

$$= 8\ N$$

Hence, tension in the rope is 8N

(c) Using $v^2 = u^2 + 2as$

Substitute $2.0\ m/s^2$ for a, $1.0\ m$ for s, $0\ m/s$ for u.

$= 0 + 2(2.0\ m/s^2)(1.0\ m)$

$= 4\ m^2/s^2$

Further solve

$v = \sqrt{4 m^2/s^2}$

$= 2\ m/s$

Hence, final velocity of hanging mass hits from the floor is $2\ m/s$.

48. (a) Using $w = mg$

Substitute $120\ kg$ for m and $9.8\ m/s^2$ for g,

$w = (120\ kg)(9.8\ m/s^2)$

$= 1176\ N$

Using $f = \mu_s N$

Substitute 0.5 for μ_s and $1176\ N$ for N in eq.

$f = (0.5)(1176\ N)$

$= 588\ N$

Hence, the maximum force that can be exerted without moving the crate is 588 N

(b) Using $f = \mu_K N$

Substitute 0.3 for μ_s and 1176 N for N in equation,

$f = (0.3)(1176\ N)$

$= 352.8\ N$

As the external force acting on the crate is 588 N, therefore apply Newton's second law as, $F - f = ma$

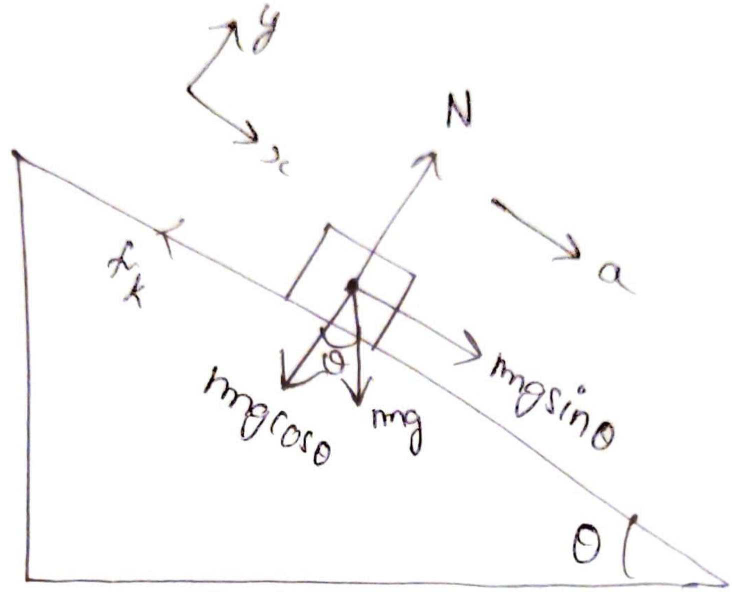
Substitute 588 N for F, 352 N for f and 120 kg for m,

$$\frac{588\ N - 352.8\ N}{120\ kg}$$

$= 1.96\ m/s^2$

Hence, the acceleration of the crate is $1.96\ m/s^2$

The free body diagram of a body on incline Surface as below:



The forces in the y direction are:

$F_y = 0$

$N - mg\cos\theta = 0$

$N = mg\cos\theta$

The forces in the x direction are:

$F_x = ma$

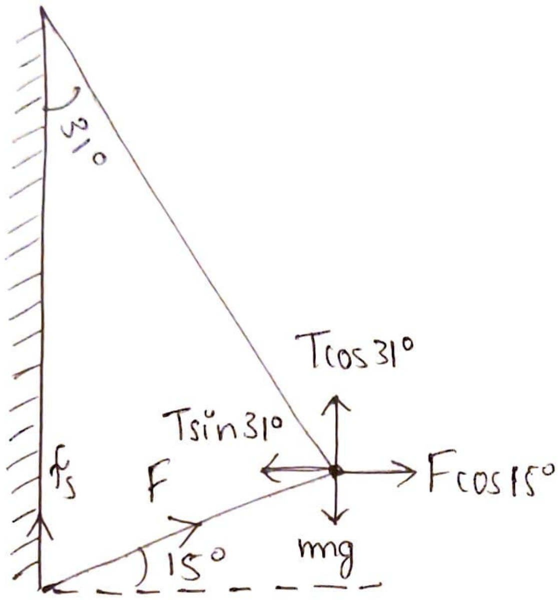
$mg\sin\theta - \mu_k mg\cos\theta = ma$

$m(g\sin\theta - \mu_k g\cos\theta) = ma$

$a = g\sin\theta - \mu_k g\cos\theta$

Hence the acceleration of the body is $a = g(\sin\theta - \mu_k\cos\theta)$

61. (a) Free body diagram,



$F_x = 0$

$F\cos 15° - T\sin 31° = 0$

$F\cos 15° = T\sin 31°$

$$F = \frac{T\sin 31°}{\cos 15°} \quad \ldots\ldots (1)$$

Balancing the force in the y direction.

$T\cos 31° + F\sin 15° = (52.0\ \text{Kg})(9.8\ \text{m/s}^2)$

$T\cos 31° + F\sin 15° = 509.6\ \text{N}$

Put the value of F from equation (1),

$$T\cos 31° + \left(\frac{T\sin 31°}{\cos 15°}\right)\sin 15° = 509.6\ \text{N}$$

$$T\left[\cos 31^\circ \cdot \cos 15^\circ + \sin 31^\circ \cdot \sin 15^\circ\right) = (509.6)(\cos 15^\circ)$$

$$T = \frac{(509.6)\cdot(\cos 15^\circ)}{(\cos 31^\circ \cdot \cos 15^\circ + \sin 31^\circ \cdot \sin 15^\circ)} = 512\ N$$

Put the value of T in equation (1) and solve for F,

$$F = \frac{(512\ N)\sin 31^\circ}{\cos 15^\circ} = 273\ N$$

Hence, the force in the legs is 273 N and the tension in the rope is 512 N

$N = F\cos 15^\circ$ and $f_s = \mu_s N$

The vertical component of force in the legs is,

$F' = F\sin 15^\circ$

Thus equating the two forces,

$\mu_s F \cos 15^\circ \geq F\sin 15^\circ$

$\mu_s \geq \tan 15^\circ$

$\mu_s \geq 0.268$

Hence, the minimum coefficient of friction is 0.268

67. Using $\tan\theta = \dfrac{v^2}{rg}$

Convert velocity from km/h to m/s

$$v = (105 \text{ km/h})\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)$$

$$= 29.17 \text{ m/s}$$

Angle θ is calculated as,

Take $\tan^{-1}$ on both sides

$$\theta = \tan^{-1}(v^2/rg)$$

Substitut 29.17 m/s for v, 1200 m for r and 9x80 m/s² for g,

$$\theta = \tan^{-1}\left\{\frac{(29\times17 \text{ m/s})^2}{(1200 \text{ m})(9\times80 \text{ m/s}^2)}\right\} = 4.14^\circ$$

Therefore, the banking angle is 4.14°

71. (a) Rearrange the equation of banking angle in terms of v as,

$$v = \sqrt{rg\tan\theta}$$

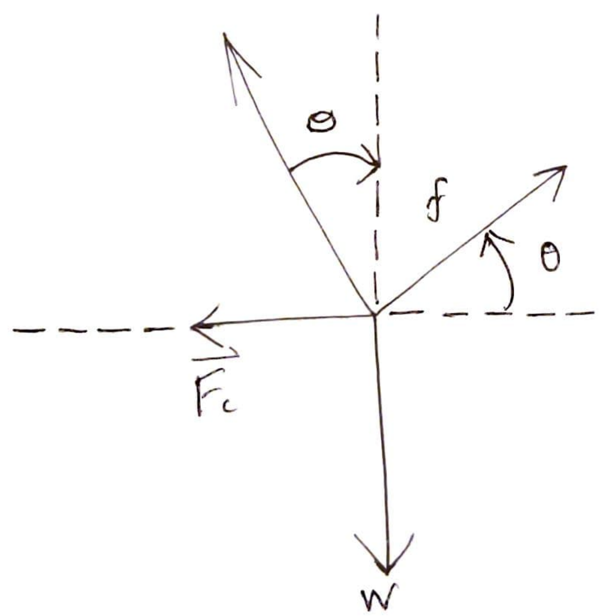
Substitute 100 m for r, 9.80 m/s² for g and 15°5 for θ.

$$v = \sqrt{(100\ \text{m})(9.80\ \text{m/s}^2)(\tan 15.5^\circ)}$$

$$= 16.2\ \text{m/s}$$

Therefore, the linear velocity is 16.2 m/s

(b) The free body diagram is



From the F.B.D,

$N\cos\theta + f\sin\theta = W$

And,

$\sin\theta = a$
$\cos\theta = b$

Substitute $\mu_s N$ for f, a for $\sin\theta$ and b for $\cos\theta$ in $N\cos\theta + f\sin\theta = w$

$N(b + \mu_s a) = w$

Rearrange the equation in terms of N,

$$N = \frac{w}{b + \mu_s a}$$

Also,

$N\sin\theta - f\cos\theta = F_c$

Substitute $\mu_s N$ for f, a for $\sin\theta$ and b for $\cos\theta$

$Na - \mu_s Nb = F_c$

Rearrange the equation in terms of μ_s

$$\mu_s = \frac{Na - F_c}{Nb}$$

Substitute $\frac{w}{b + \mu_s a}$ for N,

$$\mu_s = \frac{wa/(b + \mu_s a) - F_c}{bw/(b + \mu_s a)}$$

$$= a/b - F_c\left(\frac{b + \mu_s a}{bw}\right)$$

$$= a/b - \frac{F_c b}{bw} - \frac{\mu_s F_c a}{bw}$$

Solve the equation,

$$\mu_s\left(1+\frac{F_c a}{bw}\right) = a/b - \frac{F_c}{w}$$

Rearrange the equation,

$$\mu_s = \frac{(a/b - F_c/w)}{(1+(a/b)(F_c/w))}$$

Substitute $\tan\theta$ for a/b,

$$\mu_s = \frac{\tan\theta - (F_c/w)}{1+(\tan\theta)(F_c/w)}$$

Using $F_c = \frac{mv^2}{r}$ and $w = mg$

Substitute w/g for m in $F_c = \frac{mv^2}{r}$

$$F_c = \frac{(w/g)v^2}{r}$$

$$F_c/w = \frac{v^2}{gr}$$

Convert linear velocity from km/h to m/s

$$v = (20\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)$$

$$= 5.56\ \text{m/s}$$

Substitute 5.56 m/s for v, 9.80 m/s² for g and 100 m for r in $\frac{F_c}{W} = \frac{v^2}{gr}$

$$\frac{F_c}{W} = \frac{(5.56\ \text{m/s})^2}{(9.80\ \text{m/s}^2)(100\ \text{m})}$$
$$= 0.0315$$

Substitute 15° for θ in tan θ

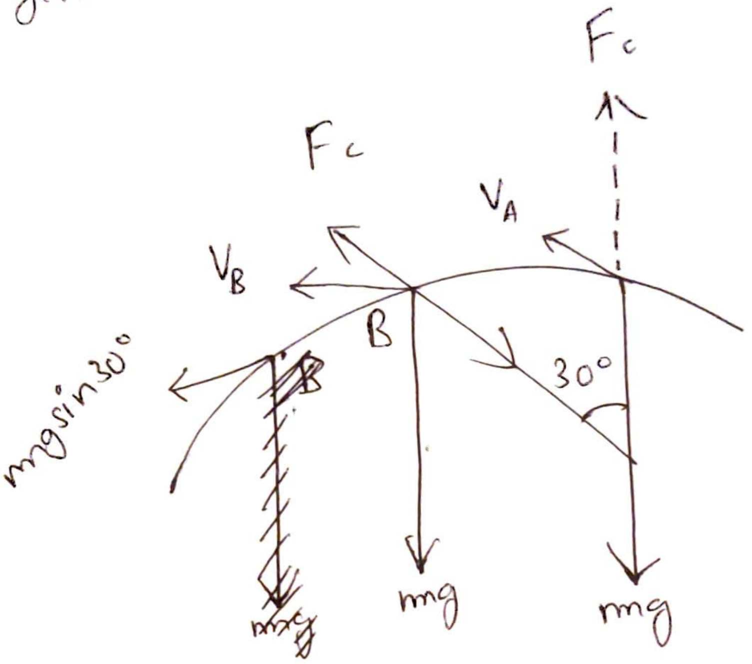
$$\tan\theta = \tan 15^\circ$$
$$= 0.2679$$

Substitute 0.2679 for tan θ and 0.0315 for F_c/W in $\mu_s = \frac{\tan - (F_c/W)}{1 + (\tan\theta)(F_c/W)}$

$$\mu_s = \frac{(0.2679) - (0.0315)}{1 + (0.2679)(0.0315)} = 0.234$$

Therefore, the coefficient of friction is 0.234

73. Diagramm for force acting in point A and B is given as follows:



(a) From the diagramm:-

$F_A = F_c - mg$

$F_A = \frac{mv_A^2}{r} - mg$

Substitute the value, 40.0 kg for m, 10.0 m/s² for v_A, 7.0 m for r, 9.80 m/s² for g in the expression.

$$F_A = \frac{mv_A^2}{r} - mg = \frac{(40.0\,kg)(10.0\,m/s^2)^2}{7.0\,m} - (40.0\,kg)(9.80\,m/s^2)$$

$$= (571\,N) - (392\,N) = 179\,N$$

Hence, force of car seat on the child at point A is 179 N

(b) From diagram,

$$F_B = F_c - mg$$

$$F_B = \frac{mv_B^2}{r} - mg\cos 30^\circ$$

Substitute the value, 40.0 kg for m, 10.5 m/s² for v_A, 7.0 m for r and 9.8 m/s² for g in the expression

$$F_B = \frac{mv_B^2}{r} - mg\cos 30^\circ$$

$$= \frac{(40.0\,kg)(10.5\,m/s^2)^2}{7.0\,m} - (40.0\,kg)(9.8\,m/s^2)\cos 30^\circ$$

$$= 630\,N - 339.48\,N = 290\,N$$

Hence, force of car seat on the child at point B is 290 N

(c) $F_A = mg$

$$\frac{mv_A^2}{r} = mg$$

$$v_A^2 = rg$$

$$v_A = \sqrt{rg}$$

Substitute the value, 7.0 m for r, 9.8 m/s² for g in the expression

$$v_A = \sqrt{rg}$$

$$= \sqrt{(7.0\,m)(9.8\,m/s^2)}$$

$$= \sqrt{(68.6\,m^2/s^2)} = 8.3\,m/s$$

Hence, minimum velocity at point A is 8.3 m/s

79. $mg = \frac{1}{2}\rho C A v^2$

Rearrange equation in terms of v

$$v = \sqrt{\frac{2mg}{\rho C A}}$$

Substitute 80 kg for m, 9.81 m/s² for g, 1.21 kg/m³ for ρ, 0.7 for C and 0.140 m² for A.

$$v = \sqrt{\frac{2(80\,kg)(9.81\,m/s^2)}{(1.21\,kg/m^3)(0.7)(0.140\,m^2)}}$$

The conversion of the terminal velocity from m/s to km/h is:

$$v = 115\,m/s\left(\frac{10^{-3}\,km}{1\,m}\right)\left(\frac{3600\,s}{1\,h}\right) = 414\,km/h$$

Hence, the terminal velocity of the skydiver is 115 m/s and 414 km/h.