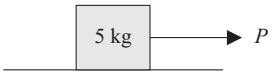
Chapter-15

15.1:

$\mu_k = 0.15$

$a = 1 \text{ m/s}^2$

$s = 5 \text{ m}$



$F = \mu_k mg = 7.36 \text{ N}$

$P - F = ma$

$\Rightarrow \quad P = 7.36 + 5\ (1)$

$= 12.36 \text{ N}$

$\therefore \quad W_P = (12.36)\ (5) = 61.8 \text{ J}$

$W_F = -\ (7.36)\ (5) = -\ 36.8 \text{ J}$

15.2:

$m = 187 \text{ tons.} \qquad F = 1 \text{ kN/ton.}$

$s = 91 \text{ m}$

$t = 1 \text{ min } 27.7$

$W = (F)\ s$

$= (1 \times 10^3 \times 187)\ (91)$

$= 17.02 \text{ MJ}$

$$P = \frac{W}{t} = \frac{17.02}{87.7} = 0.19407 \text{ MW}$$

$= 194.1 \text{ kw}$

15.3:

$h = 80 \text{ m}$

$P = 10 \text{ kw}$

$\gamma = 9810 \text{ N/m}^3$

$P = \gamma Q h$

$$\Rightarrow \quad Q = \frac{10 \times 10^3}{9810 \times 80} = 0.013 \text{ m}^3/\text{s}$$

15.4:

$m = 7 \text{ tons}$

$F = 0.25 \text{ kN/ton.}$

$s = 15 \text{ m}$

$W = (0.25) \times 7 \times 15 = 26.25 \text{ kJ}$

15.5:

$m = 5 \text{ kg}$

$\Delta = 10 \text{ cm}$

$$k = \frac{mg}{\Delta} = 490.5 \text{ N/m}$$

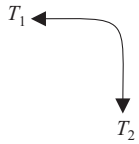
$$W = \frac{1}{2} kx^2 = \frac{1}{2} \times (490.5)(0.05)^2 = 0.613 \text{ J}$$

15.6:

$mg = 500$ N

$h = 6$ m

$\mu = 0.2$



$$\frac{T_2}{T_1} = e^{\mu k \beta}$$

$T_2 = 500$ N

$$\Rightarrow \quad T_1 = \frac{500}{e^{(0.2)\left(\frac{\pi}{2}\right)}} = 365.2 \text{ N.}$$

$\therefore \quad W = (T_1)\,(h) = (365.2)\,(6) = 2.2$ kJ.

15.7:

$P = (1000)$ g

$s_1 = 2$ m

$s_2 = 5$ m

$s_3 = 1$ m

$W = P(s_1) + 0 - P(s_3)$

$= P\,(s_1 - s_2)$

$= (1000)$ g

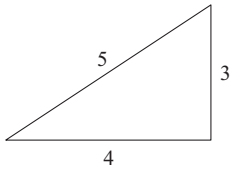
$= 9810$ J

15.8:

$m = 20$ kg

$s = 3$ m

$T = mg$



(i) $W = (\text{mg})\,(3)$

$= (20 \times 9.81)\,(3)$

$= 588.6$ J

(ii) $W = (\text{mg} \sin \theta)\,(5)$

$$= \left(20 \times 9.81 \times \frac{3}{5}\right) 5$$

$= 588.6$ J

15.9:

$m = 500$ kg

$s = 4$ m

$\theta = 15°$

$\mu = 0.2$

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

$= mg [\sin \theta + \mu \cos \theta]$

$W = T \times s = mg [\sin \theta + \mu \cos \theta] s$

$= 500 \times 9.81 [\sin 15° + (0.2) \cos 15°] [4]$

$=$ **8.87 kJ**

15.10:

$m = 40$ tons.

$v = 270$ kmph $= 75$ m/s

$t = 90$

$F = 0.5$ kN/ton $\times$ 40 tons $= 20$ kN

$P - F = ma$

$P = F + ma$

$$= (20 \times 103) + \left(40 \times 10^3 \times \frac{75}{90}\right)$$

$= 53.33$ kN

$\therefore$ Power $= (53.33)\, v$

$=$ **4 MW**

15.11:

$m = 300$ tons.

$v = 100$ kmph $= 27.78$ m/s

$f = (2$ kN/ton$)\,(300$ tons$) = 600$ kN

$F - f = 0 \Rightarrow F = 600$ kN

$\therefore$ Power, $P = F \cdot v = 16.67$ MW

work done $= F \cdot s = (600)\,(500) = 300$ MJ

15.12:

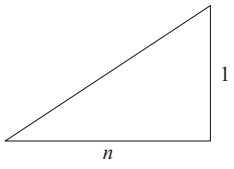
$P - mg \sin \theta = ma$

$P = mg \sin \theta + ma$

$= m [g \sin \theta + a]$

Power $= mv [g \sin \theta + a]$

$$= mv\left[\frac{g}{n} + a\right]$$

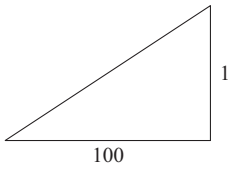


15.13:

$m = 8$ tons

$v_o = 0$

$v = 30$ kmph $= 30 \times \dfrac{5}{18} = 8.33$ m/s.



$F = 1.5$ kN/ton $\times$ 8 = 12 kN.

$P - mg \sin\theta - F = ma$

$P = mg \sin\theta + F + ma$

$$= (8 \times 10^3)(9.81)\frac{1}{100} + (12 \times 10^3) + (8 \times 10^3)\left(\frac{8.33}{30}\right)$$

= 15.006 kN.

Power = (15.006) (8.33)

= 125 kW.

15.14:

$m = 2$ tons.

$v_o = 45$ kmph = 12.5 m/s

$s = 100$ m

$t = 6s$

$F = (0.6$ kN/ton$) \times (2) = 1.2$ kN

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

$$100 = (12.5)\, t + \frac{1}{2}\, a(t^2)$$

$$= (12.5)\,(6) + \frac{1}{2}\, a\,(6)^2$$

$\Rightarrow$ $a = 1.39$ m/s^2

$P - F = ma$

$P = F + ma$

$= (1.2 \times 10^3) + (2 \times 10^3)(1.39)$

= 3.98 kN

$v = v_o + at$

$= 12.5 + (1.39)\,(6)$

$= 20.84$ m/s

$W = P \cdot v = (3.98)\,(20.84)$

= **82.9 kW**

15.15:

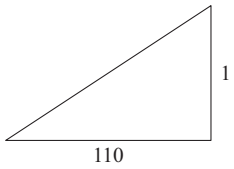
$m = 2$ tons.

$v = 80$ kmph $= 80 \times \frac{5}{18} = 22.22$ m/s.

$f = (0.8$ kN/ton$)\,(2$ tons$)$

$= (0.8)\,(2)$

= 1.6 kN



$F - f = ma = 0$

$\Rightarrow$ $F = 1.6$ kN

(i) Power $= F \cdot v = (1.6 \times 10^3)\ (22.22)$

$= 35.6$ kw.

(ii) $F - f - mg \sin\theta = 0$

$F = f + mg \sin\theta$

$= (1.6 \times 10^3) + (2 \times 10^3)\ (9.81)\left(\frac{1}{110}\right)$

$= 1778.4$ N

$P = F.v$

$\Rightarrow \quad v = \frac{P}{F} = \frac{35.6 \times 10^3}{1778.4} = 20.22$ m/s (or) 72.07 kmph

15.16:

$m = 6$ tons.

$F = (0.4$ kN/ton$) \times 6 \times 2 = 4.8$ kN

$v = 1$ m/s

(i) $P - F - mg \sin\theta = 0$

$\Rightarrow \quad P = F + mg \sin\theta$

$= (4.8 \times 10^3) + \left(12 \times 10^3 \times 9.81 \times \frac{1}{40}\right)$

$= 7.74$ kN.

$\therefore$ Power $= P \cdot v = (7.74)\ (1) =$ **7.74 kw.**

(ii) $P + mg \sin\theta - F = 0$

$\Rightarrow \quad P = F - mg \sin\theta$

$= (4.8 \times 10^3) - \left(12 \times 10^3 \times 9.81 \times \frac{1}{40}\right)$

$= 1.86$ kN.

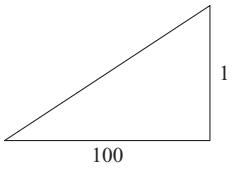
$\therefore$ Power $= P.v =$ **1.86 kw.**

15.17:

$m = 2.5$ tons.

$v = 45$ kmph

$= 45 \times \frac{5}{18} = 12.5$ m/s



$f = (0.5$ kN/ton$)\ (2.5) = 1.25$ kN

$F - f - mg \sin\theta = 0$

$\Rightarrow \quad F = f + mg \sin\theta$

$= (1.25 \times 10^3) + (2.5 \times 10^3)\ (9.81)\frac{1}{100}$

$= 1495.25$ N

$\therefore$ $P = F \cdot v = 18.69$ kW.

$F - f = 0$

$\Rightarrow$ $F = f = 1.25$ kN

$P = F \cdot v$

$\Rightarrow$ $v = \dfrac{P}{F} = \dfrac{18.69 \times 10^3}{1.25 \times 10^3} = 14.95$ m/s (or) 53.82 kmph

15.18:

$m = 5$ tons.

$v = 60$ kmph $= 16.67$ m/s

$s = 40$ m

$\text{K} \cdot E_f - K \cdot E_1 =$ work done

$\dfrac{1}{2} m [0 - v^2] = - F \cdot s$

$\Rightarrow$ $F = \dfrac{mv^2}{2.s} = \dfrac{5 \times 10^3 \times (16.67)^2}{2 \times 40}$ 17.4 kN.

15.19:

$m = 20$ gm

$v_i = 300$ m/s $\qquad\qquad$ $v_f = 200$ m/s

$t = 3$ cm

$\dfrac{1}{2} m [v_f^2 - v_i^2] = - F \cdot t$

$\dfrac{1}{2} \times 20 \times 10^{-3} [(200)^2 - (300)^2] = -F \times 3 \times 10^{-2}$

$\Rightarrow \quad F = 16.67$ kN

$\dfrac{1}{2} \times 20 \times 10^{-3} [0 - (300)^2] = -F \times (3 \times 10^{-2})\, n$

$\Rightarrow$ $n = 2$ plates.

15.20:

$k = 200$ N/m

$\Delta = 10$ cm $= 0.1$ m

$m = 200$ g $= 0.2$ kg

$\dfrac{1}{2} k\Delta^2 = \text{mgh}$

$h = \dfrac{k\Delta^2}{2 \cdot mg} = \dfrac{200 \times (0.1)^2}{2 \times 0.2 \times 9.81} = 510$ mm

15.21:

$m = 2$ tons.

$v = 60$ kmph $= 16.67$ m/s

$$F = 0.75 \text{ kN/ton} = 0.75 \times 4 = 3 \text{ kN}$$

$$\frac{1}{2}(2)\,(16.67)^2 = F \cdot s.$$

$$\Rightarrow \quad s = \frac{\frac{1}{2} \times (2)\,(16.67)^2}{3} = 92.6 \text{ m}$$

15.22:

$$m = 200 \text{ tons.}$$
$$v_o = 50 \text{ m/s}$$
$$s = 500 \text{ m}$$

$$\frac{1}{2} m v_o^{\,2} = F \cdot s$$

$$\Rightarrow \quad F = 500 \text{ kN}$$
$$v^2 = v_o^{\,2} - 2as$$
$$0 = (50)^2 - 2(a)\,(500)$$
$$\Rightarrow \quad a = 2.5 \text{ m/s}^2$$

15.23:

$$v_{max} = 80 \text{ kmph} = 22.22 \text{ m/s}$$
$$s = 100 \text{ m}$$
$$m = 2 \text{ tons}$$
$$F = (0.6 \text{ kN/ton})\,(2 \text{ tons}) = 1.2 \text{ kN}$$

$$-F \cdot s = \frac{1}{2} m [v^2 - v_{max}^{\,2}]$$

$$-(1.2 \times 10^3)\,(100) = \frac{1}{2}(2 \times 10^3)\,[v^2 - 22.22^2]$$

$$\Rightarrow \quad v = 19.33 \text{ m/s or } 70 \text{ kmph}$$

15.24:

$$v_{max} = 2.4 \text{ m/s}$$
$$t = 2s$$
$$m = 1 \text{ ton}$$
$$F = 1 \text{ kN}$$

$$a = \frac{v - v_o}{t} = \frac{2.4}{2} = 1.2 \text{ m/s}^2$$

$$T - mg - F = ma$$

$$\Rightarrow \quad T = mg + F + ma$$
$$= 10^3\,(9.81 + 1.2) + 10^3$$
$$= 12.01 \text{ kN}$$

$$\therefore \quad P = T \cdot v = 12.01 \times 2.4 \times 10^3$$
$$= 28.8 \text{ kW}$$

15.25:

$$mg - T - F = ma$$

$$\Rightarrow \quad T = m\,[g - a] - F$$

$$= 10^3\,[9.81 - 1.2] - 10^3$$

$$= 7.61 \text{ kN}$$

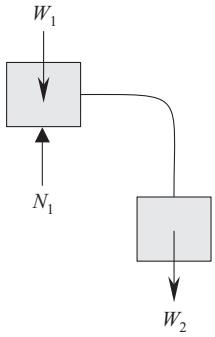
$$\therefore \quad P = T \cdot v = 7.61 \times 2.4 \times 10^3$$

$$= 18.3 \text{ kw}$$

15.26:

$$w_2\, h = \frac{1}{2}\left[\frac{w_1 + w_2}{g}\right] v^2$$

$$= \frac{1}{2}\left[\frac{w_1 + w_2}{g}\right] 2\, a\, h$$



$$\Rightarrow \quad a = \frac{w_2}{w_1 + w_2} \cdot g$$

$$w_2 - T = \frac{w_2}{g} \cdot a$$

$$\Rightarrow \quad T = \frac{w_2}{g}[g - a]$$

$$= w_2 - \frac{w_2}{g} \cdot \frac{w_2}{w_1 + w_2} g$$

$$= \frac{w_1\, w_2}{w_1 + w_2}$$

15.27:

Motion along the incline:

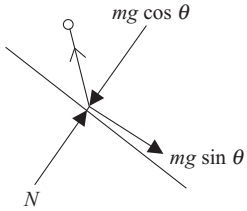
$$[\mu g \sin \theta]\, s = \frac{1}{2} m\, [v^2 - v_o{}^2]$$

$$2\, g \sin \theta \cdot s = v^2$$

$$v = \sqrt{2gs \sin \theta}$$

$$= \sqrt{2 \times 9.81 \times 60 \times \sin 10}$$

$$= 14.3 \text{ m/s}$$



Motion along horizontal plain:

$$v_o = 14.3 \text{ m/s}$$

$$\frac{1}{2} m[v^2 - v_o{}^2] = -F \cdot s$$

$$\frac{1}{2} \times 80\, [0 - (14.3)^2] = -F\,(75)$$

$$\Rightarrow \quad F = 109.1 \text{ N}$$

15.28:

$$\text{pt.B:}\quad m\,g\,[h_A - h_B] = \frac{1}{2}\,m\,[v_B^2 - v_A^2]$$

$$2g\,[10 - 2] = v_B^2 - 0$$

$$\Rightarrow \qquad v_B = 12.53 \text{ m/s}$$

$$\text{pt.C:}\quad m\,g\,[h_A - h_C] = \frac{1}{2}m\,[v_C^2 - v_A^2]$$

$$2g\,[10 - 6] = v_C^2 - 0$$

$$\Rightarrow \qquad v_C = 8.86 \text{ m/s}$$

15.29:

Speed of block as it enters the rough horizontal plane is:

$$v^2 = 2gh \qquad \Rightarrow \quad v = \sqrt{2\,gh}$$

$$-f \cdot s = \frac{1}{2}\,m\,[v_f^2 - v_i^2]$$

$$= \frac{1}{2}\,m\,[0 - 2\,gh]$$

$$= -ma\,h$$

$$\Rightarrow \qquad fs = mgh$$

$$\mu mgs = mgh$$

$$\therefore \qquad s = \frac{h}{\mu} = \frac{3}{0.25} = 12 \text{ m}$$

15.30:

$$v^2 = 2gh$$

$$-f\,(8 + x) - \frac{1}{2}\,kx^2 = \frac{1}{2}\,m\,[v_f^2 - v_i^2]$$

$$-\mu mg\,[8 + x] - \frac{1}{2}\,(250)x^2 = \frac{1}{2}\,m\,[0 - 2gh]$$

$$-(0.25)\,(3)\,(9.81)\,[8 + x] - 125\,x^2 = -\frac{1}{2}\,(3)\,(2 \times 9.81 \times 3)$$

$$125\,x^2 + 7.36\,x - 29.43 = 0$$

$$x = \mathbf{456.7\ mm}$$

15.31:

$$mg = k \cdot \Delta$$

$$4\,g = k \cdot (0.2)$$

$$\Rightarrow \qquad k = 196.2 \text{ N/m}$$

$$\frac{1}{2}\,kx^2 = \frac{1}{2}\,mv^2$$

$$v = \sqrt{\frac{k}{m}}\, x = \sqrt{\frac{196.2}{5}} \times 0.5 = 3.13 \text{ m/s}$$

15.32:

$$\frac{1}{2} kx^2 = \frac{1}{2} mv^2 + \mu mg \cdot x$$

$$\frac{1}{2} (196.2)\,(0.5)^2 = \frac{1}{2} (5)\, v^2 + (0.2)\,(5)\,(9.81)\,(0.5)$$

$$\Rightarrow \qquad v = 2.8 \text{ m/s}$$