Chapter-16

16.1:

$$\vec{F} = t^3\,\vec{i} + 4t\,\vec{j}$$

$$m = 5 \text{ kg}$$

$$t = 0 \quad \text{to} \quad t = 4s$$

$$\vec{I} = \int_0^4 \vec{F}\cdot dt = \left[\frac{t^4}{4}\vec{i} + \frac{4t^2}{2}\vec{j}\right]$$

$$= 64\,\vec{i} + 32\,\vec{j}$$

$$\therefore \qquad I = 71.55 \text{ N.s}$$

$$\vec{I} = m\,[\vec{v} - v_o] = 5\vec{v}$$

$$\Rightarrow \qquad \vec{v} = \frac{\vec{I}}{m}$$

$$v = \frac{I}{m} = 14.31 \text{ m/s}$$

16.2:

$$\vec{F} = 5t\,\vec{i} + t^2\,\vec{j}$$

$$\vec{I} = \int_0^3 \vec{F}\cdot t = \left[\frac{5t^2}{2}\vec{i} + \frac{t^3}{3}\vec{j}\right]_o^3 = 22.5\,\vec{i} + 9\,\vec{j}$$

$$\vec{I} = m\,[\vec{v} - \vec{v}_o]$$

$$\vec{v} = \frac{\vec{I}}{m}$$

$$v = \frac{I}{m} = \frac{\sqrt{(22.5)^2 + 9^2}}{2} = 12.12 \text{ m/s}$$

16.3:

$$\vec{v}_i = 5\vec{i} + 3\,\vec{j}$$

$$\vec{v}_f = -\,2\vec{i} + 4\,\vec{j}$$

$$\vec{F}\cdot t = m\,[\vec{v}_t - \vec{v}_i]$$

$$\Rightarrow \qquad \vec{F} = \frac{m}{t}\,[\vec{v}_f - \vec{v}_i] = \frac{2}{1/100}\,[-2\vec{i} + 4\,\vec{j} - (5\vec{i} + 3\,\vec{j})]$$

$$= 200\,[-\,7\vec{i} + \vec{j}]$$

16.4:

(i) $$I = \int F\cdot \mathrm{dt} = \frac{1}{2}(10)\,(2) + 10 \times 2 = 30 \text{ N.s}$$

$$I = m\,[v - v_o]$$

$$\Rightarrow \qquad v = \frac{I}{m} = \frac{30}{5} = 6 \text{ m/s.}$$

(ii) $I = \int F \cdot dt = \frac{1}{2}(15)(1) + 15(2) + \frac{1}{2}(15)(1) = 45$ N.s

$v = \frac{I}{m} = \frac{45}{5} = 9$ m/s

16.5:

(i) $I = \int F \cdot dt = \frac{1}{2}(20) = (2) = 20$ Ns

$I = m(v - v_o)$

$\Rightarrow \quad v = \frac{I}{m} + v_o = \frac{20}{5} + 2 = 6$ m/s

(ii) $I = \int F\, dt = (20)(2) + \frac{1}{2}(20)(2) = 60$ N.s

$I = m[v - v_o]$

$\Rightarrow \quad v = \frac{I}{m} + v_o = \frac{60}{5} + 2 = 14$ m/s

(iii) $I = \int F\, dt = (15)(1) + \frac{1}{2}(25)(1) + 10 \times 1 = 37.5$ N.s

$I = m[v - v_o]$

$\Rightarrow \quad v = \frac{I}{m} + v_o = \frac{37.5}{5} + 2 = 9.5$ m/s

16.6:

$v_i = 3$ m/s

$v_f = 0$

$t = 1/100^{\text{th}}$ of a second

(i) $I = m[v_f - v_t]$

$= 10[0 - 3] = -30$ N.s

(ii) $F = \frac{I}{t} = \frac{30}{1/100} = 3$ kN

16.7:

$v_i = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 10} = 14.01$ m/s

$I = F \cdot t = m[v_f - v_i]$

$\Rightarrow \quad F = \frac{m}{t}[v_f - v_i]$

$= \frac{20}{1/60}[0 - 14.01]$

$= 16.81$ kN < 20 kN. Hence, she will survive.

16.8:

$$v = 60 \text{ kmph} = 16.67 \text{ m/s}$$
$$\mu = 0.5$$
$$[-\mu mg]\, t = m\, [v - v_o]$$
$$\Rightarrow \quad t = \frac{m\,[v - v_o]}{-\mu mg} = [v - v_o] = \frac{0 - 16.67}{-(0.5)\,(9.81)} = 3.4 \text{ s}$$

16.9:

$$m = 10 \text{ kg}$$
$$h = 20 \text{ m}$$
$$-F \cdot t = \text{m}\, [v - v_o]$$
$$-F \cdot (1) = 10\left[0 - \sqrt{2gh}\right]$$
$$\Rightarrow \quad F = 10\sqrt{2gh} = \mathbf{198.1\ N}$$

16.10:

$$m = 2 \text{ tons}$$
$$v_o = 45 \text{ kmph} = 12.5 \text{ m/s}$$
$$t = 1/6$$
$$F \cdot t = m\, [v - v_o]$$
$$\Rightarrow \quad F = \frac{2 \times 10^3 [0 - 12.5]}{1/6} = 150 \text{ kN}$$

16.11:

$$m = 1.5 \text{ tons}$$
$$h = 6 \text{ m}$$
$$t = 1/60$$
$$F \cdot t = m\, [v_f - v_i]$$
$$= m\left[0 - \sqrt{2gh}\right]$$
$$\Rightarrow \quad F = \frac{-m\sqrt{2gh}}{t} = -\frac{1.5 \times 10^3}{1/60}\sqrt{2 \times 9.81 \times 6} = -976.5 \text{ kN}$$

16.12:

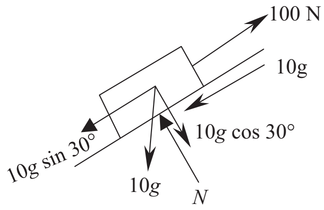
$m = 100$ g

$v_i = 30$ m/s $\qquad F \cdot t = m\,[v_f - v_i]$

$t = 1/60 \Rightarrow \qquad = \dfrac{m}{t}\,[v_f - v_i]$

$v_f = 0 \qquad = \dfrac{0.1}{1/60}\,[0 - 30] = -180$ N

16.13:



$\Sigma F_y = 0 \Rightarrow$

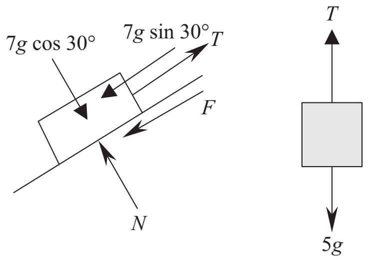
$N - 10\text{ g} \cos 30° = 0$

$[100 - 10\,g \sin 30° - \mu_k\, 10\,g \cos 30]\, t = 10\,[v - 0]$

$[100 - 10\,g\,(\sin 30° + 0.2 \cos 30°)]\, t = (10)\,(10)$

$\Rightarrow \quad t = \mathbf{2.94\ s}$

16.14:



$F \cdot t = m\,[v_f - v_i]$

$[T - 7g \sin 30° - (0.2)\, 7\,g \cos 30°]\, t = 7\,[v - 0]$

$[5g - T]t = 5\,[v - 0]$

$\Rightarrow \quad [5g - 7g\,(\sin 30° + 0.2 \cos 30°)]\, t = 12\,v$

$\Rightarrow \quad v = 0.71$ m/s

16.15:

$6g - T = 6\text{a}$ ...(1)

$T - 4g = 4a$ ...(2)

$2g = 10a$

$\Rightarrow \quad a = \dfrac{g}{5}$

$v^2 = v_o^{\,2} + 2as$

$= 0 + 2\left(\dfrac{g}{5}\right)^4$

$= 1.6\,g$

$\Rightarrow \quad v = \sqrt{1.5g}$

$m[v_f - v_i] = -I.\ t$

$6[0 - \sqrt{1.5g}\,] = -I. \left(\dfrac{1}{100}\right)$

$\Rightarrow \quad I = 6 \times 3.96 \times 100$

$= 2376$ N

$s = \dfrac{v^2}{2g}$

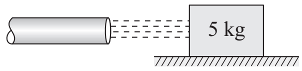
$= \dfrac{1.6g}{2g}$

$= 0.8.$

16.16:

$F_n = \rho a v^2$

$F_s = \mu_s\, mg$



$$\rho a v^2 = \mu_s mg$$

$$(1000)\left(\frac{\pi}{4}\right)(0.02)^2 v^2 = (0.2)(5)(9.81)$$

$\Rightarrow$ $$v = 5.6 \text{ m/s}$$

16.17:

$$F_n = 5 \text{ N}$$
$$d = 1 \text{ cm}$$
$$v = 10 \text{ m/s}$$
$$F_n = \rho a (v - u)^2$$
$$5 = (1000)\left(\frac{\pi}{4}\right)(0.01)^2 [10 - u]^2$$

$\Rightarrow$ $$u = 2.02 \text{ m/s}$$

16.18:

$$F_n = \rho a v^2 = \frac{\rho Q^2}{a} = \frac{(1000)(10^{-3})^2}{\frac{\pi}{4}(0.01)^2} = 12.73 \text{ N}$$

16.19:

$$d = 6 \text{ mm}$$
$$v = 15 \text{ m/s} \qquad F_n = \rho a (v - u)^2 \sin\theta$$
$$u = 6 \text{ m/s} \qquad = (1000)\left(\frac{\pi}{4}\right)(0.006)^2 (15 - 6)^2 \sin 60°$$
$$\theta = 60° \qquad = \mathbf{1.98\ N}$$

16.20:

$$d = 6 \text{ mm}$$
$$v = 15 \text{ m/s}$$
$$\theta = 180° - 105° = 75$$
$$F_n = \rho a v^2 (1 + \cos\theta)$$
$$= 1000 \times \frac{\pi}{4} \times (0.006)^2 \times 15^2 (1 + \cos 75°)$$
$$= \mathbf{8\ N}$$

16.21:

$$d = 5 \text{ cm}$$
$$Q = 0.005 \text{ m}^3/\text{s}$$
$$F_x = -\rho Q [v \cos 60° - v]$$
$$= \rho Q v [1 - \cos 60°]$$
$$= \frac{\rho Q^2}{a}[1 - \cos 60°]$$

$$= \frac{1000 \times (0.005)^2}{\frac{\pi}{4}(0.05)^2}[1 - \cos 60°]$$

$$= 6.37 \text{ N}$$

$$\therefore \qquad F = \sqrt{F_x^2 + F_y^2} = 12.74 \text{ N}$$

$$\alpha = \tan^{-1}\frac{F_y}{F_x} = 60°$$

$$F_y = \rho_Q[v \sin 60° - 0]$$

$$= \frac{\rho Q^2}{a}[\sin 60°]$$

$$= \frac{1000 \times (0.005)^2}{\frac{\pi}{4}(0.05)^2} \sin 60°$$

$$= 11.03 \text{ N}$$

16.22:

$$m = 10 \text{ gm}$$

$$M = 4 \text{ kg}$$

$$V = -0.5 \text{ m/s}$$

$$mv + MV = 0$$

$$(0.01)(v) + (4)(-0.5) = 0$$

$$\Rightarrow \qquad v = 200 \text{ m/s}$$

16.23:

$$m_1 = 10 \text{ tons} \qquad m_2 = 15 \text{ tons}$$

$$u_1 = 0 \qquad u_2 = 20 \text{ kmph} = 5.56 \text{ m/s}$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$\Rightarrow \qquad v = \frac{(10)(10) + (15)(5.56)}{(10 + 15)}$$

$$= 12 \text{ kmph}$$

16.24:

$$m_1 = 2 \text{ tons} \qquad m_2 = 6 \text{ tons}$$

$$u_1 = 30 \text{ kmph} \qquad u_2 = 0$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$\Rightarrow \qquad v = \frac{(2)(30) + (6)(0)}{2 + 6} \; 7.5 \text{ kmph}$$

16.25:

$$m = 10 \text{ kg}$$
$$v = 1 \text{ m/s}$$
$$0 = (10 \times 1) + (110)V$$
$$\Rightarrow \quad V = \frac{-10}{110} = \frac{-1}{11} \text{ m/s}$$
$$[110]\, v_1 = [10 \times 1] + 100\, v_2$$
$$-(10 \times 1) = (10 \times 1) + 100\, v_2$$
$$\Rightarrow \quad v_2 = \frac{-20}{100} = -\,0.2 \text{ m/s}$$

16.26:

$$v_o = 200 \text{ m/s}$$
$$\alpha = 45°$$

At the highest point, its velocity = 200 cos 45° (horizontal)

If $2m$ is the total mass of the bomb then

$$2m\,(200 \cos 45°) = m \cdot o + m \cdot v$$
$$\Rightarrow \quad v = 400 \cos 45° = \frac{400}{\sqrt{2}} \text{ m/s}$$
$$\text{Max } ht = \frac{v_o^2 \sin^2 45°}{2g} = \frac{(200)^2 \sin^2 45°}{2g} = \frac{(200)^2}{4g}$$
$$y = x \tan \beta - \frac{1}{2} \frac{g x^2}{v_o^2 \cos^2 \beta}$$
$$\frac{-(200)^2}{4g} = 0 - \frac{1}{2} \frac{g \cdot x^2}{\frac{(400)^2}{2}}$$
$$\frac{(200)^2}{4g} = \frac{g x^2}{(400)^2}$$
$$\Rightarrow \quad x = \frac{200 \times 400}{2 \cdot g} = 4.08 \text{ km.}$$
$$\text{Initial range} = \frac{v_o^2 \sin 2\alpha}{g} = \frac{(200)^2 \sin 90°}{9.81} = 4.08 \text{ km}$$
$$\therefore \quad \text{Distance from the cannon} = \frac{4.08}{2} + 4.08 = 6.12 \text{ km}$$

16.27:

Velocity of the ball at the lowest position, $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 1} = 4.43$ m/s

$$(1 \times 4.43) + (2 \times 0) = (1 \times v_1) + (2 \times v_2)$$
$$4.43 = v_1 + 2\, v_2 \qquad \text{...(1)}$$

$$-e = \frac{v_1 - v_2}{4.43 - 0}$$

$$\Rightarrow \quad v_1 - v_2 = -4.43 \qquad \ldots(2)$$

$$3\, v_2 = 8.86$$

$$v_2 = 2.95 \text{ m/s}$$

$$\Rightarrow \quad v_1 = -1.48 \text{ m/s}$$

16.28:

$$m = 20 \text{ gm}$$

$$M = 2 \text{ kg}$$

$$\theta = 30°$$

$$mu + M \cdot 0 = (m + M)v$$

$$v = \sqrt{2gh}$$

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

$$(0.02)u = (2 + 0.02)\sqrt{2 \times 9.81 \times 2(1 - \cos 30°)}$$

$$\Rightarrow \quad u = 231.6 \text{ m/s}$$

16.29:

$$m = 20 \text{ gm}$$

$$M = 5 \text{ kg}$$

$$s = 0.5 \text{ m}$$

$$\mu = 0.15$$

$$\frac{1}{2}(M + m)\, v^2 = \mu(M + m)gs$$

$$\Rightarrow \quad v = \sqrt{2\mu gs}$$

$$mu + M \cdot 0 = (M + m)\, v$$

$$\Rightarrow \quad u = \frac{M + m}{m} \cdot v$$

$$= \frac{M + m}{m} \cdot \sqrt{2\mu gs}$$

$$= \frac{5.02}{0.02}\sqrt{2 \times 0.15 \times 9.81 \times 0.5}$$

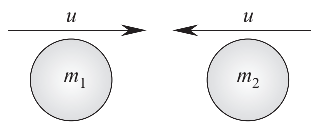
$$= 304.5 \text{ m/s}$$

16.30:

$$m_1\, u - m_2\, u = m_1\, v_1 + m_2\, v_2$$

$$= m_2\, v_2$$

$$-e = \frac{v_1 - v_2}{u - (-u)} = \frac{0 - v_2}{2u}$$



$$\Rightarrow \quad v_2 = 2\,eu$$

$$m_1\,u - m_2\,u = m_2\,2eu$$

$$m_1\,u = m_2\,u\,[1 + 2e]$$

$$\frac{m_1}{m_2} = 1 + 2e$$

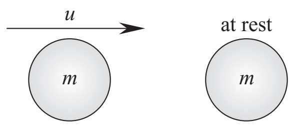
16.31:

$$u_1 = u \qquad v_1 = 0$$

$$u_2 = 0 \qquad v_2 = u$$

$$-e = \frac{v_1 - v_2}{u_1 - u_2} = \frac{0 - u}{u - 0} = -1$$

$$\Rightarrow \quad e = 1$$



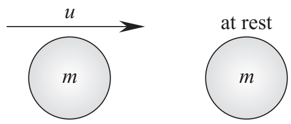
16.32:

$$mu + m\cdot 0 = mv_1 + mv_2$$

$$\Rightarrow \quad u = v_1 + v_2 \qquad \text{...(1)}$$

$$-e = \frac{v_1 - v_2}{u - o}$$

$$\Rightarrow \quad v_1 - v_2 = -eu \qquad \text{...(2)}$$



$$\frac{v_1 + v_2}{v_1 - u_2} = \frac{1}{-e}$$

$$\Rightarrow \quad \frac{2v_1}{2u_2} = \frac{1-e}{1+e}$$

$$\therefore \quad \frac{v_1}{v_2} = \frac{1-e}{1+e}$$

$$v_1 = \left[\frac{1-e}{2}\right]\cdot u = \frac{u}{8}$$

$$v_2 = \frac{1+e}{2}\cdot u = \frac{7u}{8}$$

16.33:

$$m_1 u_1 + m_2\,u_2 = (m_1 + m_2)\,v$$

$$(2 \times 60) + (3 \times 0) = (2 + 3)\,v$$

$$\Rightarrow \quad v = 24 \text{ kmph}$$

16.34:

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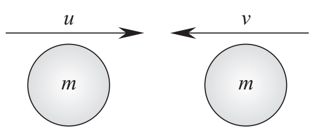
16.35:

$$mu - mv = m\cdot o + m\cdot v$$

$$u - v = V$$



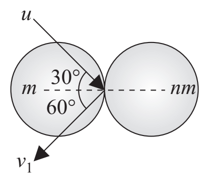
$$-e = \frac{o - V}{u - (-u)}$$

$$u + v = \frac{V}{e}$$

$$\frac{u - v}{u + v} = \frac{e}{1} \qquad \Rightarrow \quad \frac{2u}{2v} = \frac{1 + e}{1 - e}$$

$$\therefore \quad \frac{u}{v} = \frac{1 + e}{1 - e}$$

16.36:



$$u \sin 30° = v_1 \sin 60°$$

$$u = \sqrt{3}\, v_1$$

$$m\, u \cos 30° + (nm)\, o = -\, m \cdot v_1 \cos 60° + nmv_2 \cos \phi$$

$$u \cos 30° = -\, v_1 \cos 60° + n\, v_2 \cos \phi$$

$$-e = \frac{-v_1 \cos 60° - v_2 \cos \phi}{u \cos 30° - 0} \qquad ...(2)$$

$$u \cos 30° + \frac{u}{\sqrt{3}} \cos 60° = n\, v_2 \cos \phi$$

$$eu \cos 30° - v_1 \cos 60° = v_2 \cos \phi$$

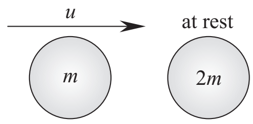
$$eu \cos 30° - \frac{u}{\sqrt{3}} \cos 60° = v_2 \cos \phi$$

$$u\left[\cos 30° + \frac{\cos 60°}{\sqrt{3}}\right] = n\, v_2 \cos \phi$$

$$u\left[e \cos 30° + \frac{\cos 60°}{\sqrt{3}}\right] = v_2 \cos \phi$$

$$n = \frac{\cos 30° + \dfrac{\cos 60°}{\sqrt{3}}}{e \cos 30° - \dfrac{\cos 60°}{\sqrt{3}}} = 2$$

16.37:



$$mu + (2m)0 = mv_1 + 2\, mv_2$$

$$u = v_1 + 2\, v_2 \qquad ...(1)$$

$$-e = \frac{v_1 - v_2}{u - o}$$

$$\Rightarrow \qquad v_1 - v_2 = -\, e\mu \qquad ...(2)$$

$$3\, v_2 = (1 + e)u$$

$$\Rightarrow \qquad v_2 = \frac{u}{3}(1 + e)$$

$$v_1 = \frac{u}{3}(1 - 2e)$$

(i) $e = 0 \Rightarrow v_1 = \frac{u}{3}, \quad v_2 = \frac{u}{3}$

(ii) $e = 1/4 \Rightarrow v_1 = \frac{u}{6}, \quad v_2 = \frac{5u}{12}$

(iii) $e = 1/2 \Rightarrow v_1 = 0 \quad v_2 = \frac{u}{2}$

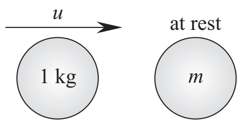
(iv) $e = 3/4 \Rightarrow v_1 = \frac{-u}{6}, \quad v_2 = \frac{7u}{12}$

(v) $e = 1 \Rightarrow v_1 = \frac{-u}{3}, \quad v_2 = \frac{2a}{3}$

16.38:

$$u_1 = u \qquad u_2 = o$$

$$v_1 = \frac{-u}{2}$$



$$1 \cdot u + m \cdot o = 1 \cdot v_1 + mv_2$$

$$= -\frac{-u}{2} + mv_2$$

$$\Rightarrow \quad mv_2 = \frac{3u}{2} \qquad ...(1)$$

$$-e = \frac{v_1 - v_2}{u_1 - u_2} = \frac{\frac{-u}{2} - v_2}{u - o}$$

$$\frac{-2}{3} = \frac{-\left[\frac{u}{2} + v_2\right]}{u}$$

$$\Rightarrow \quad v_2 = \frac{u}{6} \qquad ...(2)$$

From (1) & (2), $m = 9$ kg

16.39:

$$u_2 = \text{kmph} = 8.33 \text{ m/s.}$$

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$2(-2) + 6(8.33) = 2v_1 + 6v_2 \text{ ...(1)}$$

$$-e = \frac{v_1 - v_2}{u_1 - u_2}$$

$$-0.5 = \frac{v_1 - v_2}{-2 - 8.33}$$

$\therefore \quad 5.165 = v_1 - v_2$ ...(2)

From (1) and (2), $v_1 = 9.625 \text{ m/s} \approx 9.63 \text{ m/s}$

$v_2 = 4.456 \text{ m/s} \approx 4.46 \text{ m/s}$

$$(\text{K.E})_i = \frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2$$

$$= \frac{1}{2}(2)(2)^2 + \frac{1}{2}(6)(8.33)^2$$

$$= 212.2 \text{ J}$$

$$(\text{K.E})_f = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$$

$$= \frac{1}{2}(2)(9.63)^2 + \frac{1}{2}(6)(4.46)^2$$

$$= 152.4$$

$$\Delta \text{ K.E} = (\text{K.E})_f - (\text{K.E})_i = 59.8 \text{ J}$$

16.40:

$m_1 = 15$ tons $\qquad m_2 = 10$ tons

$u_1 = 9$ kmph $\qquad u_2 = 0$

$e- = 3/4$

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$(15)(9) + (10)(0) = 15 v_1 + 10 v_2$$

$$27 = 3 v_1 + 2v_2 \qquad \text{...(1)}$$

$$-e = \frac{v_1 - v_2}{u_1 - u_2}$$

$$\frac{-3}{4} = \frac{v_1 - v_2}{9 - o}$$

$$\Rightarrow \quad v_1 - v_2 = \frac{-27}{4} \qquad \text{...(2)}$$

$$5 v_1 = 27 - \frac{27}{2} = 13.5$$

$$\Rightarrow \quad v_1 = 2.7 \text{ kmph} = 0.75 \text{ m/s}$$

$$5 x_2 = 27 + \frac{27(3)}{4}$$

$$v_2 = 9.45 \text{ kmph} = 2.625 \text{ m/s}$$

16.41:

$m_1 = 6$ tons $\qquad m_2 = 2$ tons

$u_1 = 60$ kmph

(i) $\quad u_2 = 0$

$m_1u_1 + m_2u_2 \quad = m_1v_1 + m_2v_2$

$(6 \times 60) + 0 \quad = 6\ v_1 + 2\ v_2$

$180 = 3\ v_1 + v_2$ ... (1)

$$-e = \frac{v_1 - v_2}{u_1 - u_2}$$

$$-\frac{2}{3} = \frac{v_1 - v_2}{60 - 0}$$

$\Rightarrow \quad v_1 - v_2 = -\ 40$ ...(2)

From (1) & (2) $v_1 = 35$ kmph

$v_2 = 75$ kmph

(ii)$(6 \times 60) + (2 \times 45) = 6\ v_1 + 2v_2$

$\Rightarrow \quad 3\ v_1 + v_2 = 225$ ...(1)

$$\frac{-2}{3} = \frac{v_1 - v_2}{60 - 45}$$

$\Rightarrow \quad v_1 - v_2 = -\ 10$ ...(2)

$\therefore \quad v_1 = 53.75$ kmph, $\quad v_2 = 63.75$ kmph.

(iii) $\quad (6 \times 60) - (2 \times 45) = 6\ v_1 + 2\ v_2$

$\Rightarrow \quad 3\ v_1 + v_2 = 135$ ...(1)

$$\frac{-2}{3} = \frac{v_1 - v_2}{60 - (-45)}$$

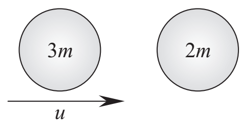
$\Rightarrow \quad v_1 - v_2 = -\ 70$ ...(2)

$\Rightarrow \quad v_1 = 16.25$ kmph, $\ v_2 = 86.25$ kmph

16.42:

$(3\ m)\ u + (2m)\ o = 3\ m \cdot v_1 + 2m\ v_2$

$3u = 3v_1 + 2v_2$ ...(1)



$$-e = \frac{v_1 - v_2}{u - o}$$

$-eu = v_1 - v_2$ ...(2)

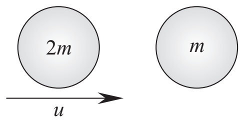
$\therefore \quad 5v_2 = 3\ u + 3\ eu$

$= 3\ u\ (1 + e)$

$$\Rightarrow \quad v_2 = \frac{3u}{5}(1 + e)$$

$2\ mu + m(0) = 2\ mv_1 + mv_2$

$2\ u = 2v_1 + v_2$ ...(1)



$$-e = \frac{v_1 - v_2}{u - o}$$

$\Rightarrow \quad -eu = v_1 - v_2$ ...(2)

$3\ v_2 = 2u + 2\ eu$

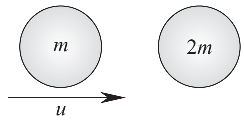
$$= 2u\,(1 + e)$$

$$\therefore \qquad v_2 = \frac{2u}{3}(1 + e)$$

$$= \frac{2}{3}\cdot\frac{3}{5}(1 + e)^2\, u$$

$$= \frac{2}{5}(1 + e)^2\, u$$

16.43:



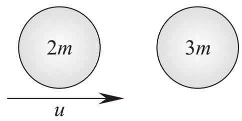
$$mu + 2m\,(0) = mv_1 + 2mv_2$$

$$u = v_1 + 2v_2 \qquad ...(1)$$

$$-e = \frac{v_1 - v_2}{u - o} \Rightarrow -eu = v_1 - v_2 \qquad ...(2)$$

$$3\,v_2 = (1 + e)\,u$$

$$\therefore \qquad v_2 = (1 + e)\,\frac{u}{3}$$



$$2m\cdot u + 3\,m(0) = 2\,m\cdot v_1 + 3mv_2$$

$$2u = 2v_1 + 3v_2 \qquad ...(1)$$

$$-e = \frac{v_1 - v_2}{u - o} \Rightarrow -eu = v_1 - v_2$$

$$5v_2 = 2u\,(1 + e)$$

$$\therefore \qquad v_2 = \frac{2u}{5}(1 + e)$$

$$= \frac{2}{5}\cdot\frac{u}{3}\,(1 + e)^2$$

$$= \frac{2}{15}u\,(1 + e)^2$$

16.44:

$$u = \sqrt{2gh} \qquad v = \sqrt{2gh_2}$$

$$-e = \frac{-v - o}{u - o}$$

$$\Rightarrow \qquad e = \frac{v}{a} = \sqrt{\frac{h_2}{h_1}} = 0.89$$

16.45:

I-rebound:

$$h_1 = 5\text{m}$$

$$u_1 = \sqrt{2gh}$$

$$v_1 = eu_1$$

II-rebound:

$$v_2 = ev_1 = e^2 u_1$$

III-rebound:

$$v_3 = ev_2 = e^3 u_1$$

IV-rebound:

$$v_4 = ev_3 = e^4 u_1$$
$$= e^4 \sqrt{2gh_1}$$
$$\sqrt{2gh} = \left(\frac{3}{4}\right)^2 \sqrt{2 \times 9.81 \times 5}$$
$$\Rightarrow \quad h = \left(\frac{3}{4}\right)^2 \times 5 = 0.5 \text{ m}$$

16.46:

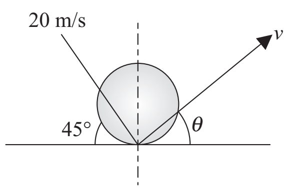
$$h_1 = 15 \text{ m}$$
$$h_2 = \frac{2}{3} \times 15 = 10 \text{ m}$$
$$v = eu$$
$$\sqrt{2gh_2} = e\sqrt{2gh_1}$$
$$\Rightarrow \quad e = \sqrt{\frac{h_1}{h_2}} = \mathbf{0.816}$$

II-ball:

$$u = \sqrt{2gh_1}$$
$$v = \sqrt{2gh_2}$$
$$v = eu$$
$$\sqrt{2gh_2} = e\sqrt{2gh_1}$$
$$h_2 = e^2 h_1$$
$$= (0.816)^2 \times 10 = 6.67 \text{ m}$$

16.47:

$$-e = \frac{-v \sin \pi - o}{u \sin 45 - o}$$



$$\Rightarrow \quad v \sin \theta = \frac{2}{3} \times 20 \sin 45° = \frac{40}{3} \sin 45°$$
$$v \cos \theta = 20 \cos 45°$$
$$\tan \theta = \frac{40/3}{20} \cdot 1 = \frac{2}{3}$$
$$\Rightarrow \quad \theta = 33.7°$$
$$\therefore \quad v = 17 \text{ m/s}$$