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Chapter 6

- **6.1** (b) **6.2** (c) **6.3** (d) 6.4 (c) **6.5** (c) **6.6** (c) 6.7 (c) 6.8 (b) **6.9** (b) 6.10 (b) (b) as displacement $\alpha t^{3/2}$ 6.11 **6.12** (d) **6.13** (d) 6.14 (a) 6.15 (b) 6.16 (d) 6.17 (b) 6.18 (c) 6.19 (b), (d) 6.20 (b), (d), (f) **6.21** (c) 6.22 Yes, No. 6.23 To prevent elevator from falling freely under gravity.
- **6.24** (a) Positive, (b) Negative **6.25**
- Work done against gravity in moving along horizontal road is zero.6.26 No, because resistive force of air also acts on the body which is a non-conservative force. So the gain in KE would be smaller than the loss in PE.
- **6.27** No, work done over each closed path is necessarily zero only if all the forces acting on the system are conservative.

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6.28 (b) Total linear momentum.

While balls are in contact, there may be deformation which means elastic potential energy which came from part of KE. Momentum is always conserved.

6.29 Power
$$= \frac{mgh}{T} = \frac{100 \times 9.8 \times 10}{20}$$
 W = 490W
6.30 $P = \frac{\Delta E}{\Delta t} = \frac{0.5 \times 72}{60} = 0.6$ watts

- 6.31 A charged particle moving in an uniform magnetic field.
- 6.32 Work done = change in KE Both bodies had same KE and hence same amount of work is needed to be done. Since force aplied is same, they would come to rest within the same distance.
- 6.33 (a) Straight line: vertical, downward
 - (b) Parabolic path with vertex at C.
 - (c) Parabolic path with vertex higher than C.



6.35 (a) For head on collission:

Conservation of momentum $\Rightarrow 2mv_0 = mv_1 + mv_2$

Or
$$2v_0 = v_1 + v_2$$

and $e = \frac{v_2 - v_1}{2v_0} \Rightarrow v_2 = v_1 + 2v_0 e$
 $\therefore \quad 2v_1 = 2v_0 - 2ev_0$
 $\therefore \quad v_1 = v_0(1 - e)$

Since $e < 1 \Rightarrow v_1$ has the same sign as v_0 , therefore the ball moves on after collission.

(b) Conservation of momentum \Rightarrow **p** = **p**₁+ **p**₂

But KE is lost
$$\Rightarrow \frac{p^2}{2m} > \frac{p_2^2}{2m} + \frac{p_2^2}{2m}$$

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:. $p^2 > p_1^2 + p_2^2$

Thus \mathbf{p} , \mathbf{p}_1 and \mathbf{p}_2 are related as shown in the figure.

 θ is acute (less than 90°) $(p^2 = p_1^2 + p_2^2 \text{ would give } \theta = 90^\circ)$

6.36 Region A : No, as KE will become negative.

Region B : Yes, total energy can be greater than PE for non zero K.E. Region C : Yes, KE can be greater than total energy if its PE is negative. Region D : Yes, as PE can be greater than KE.

6.37 (a) Ball A transfers its entire momentum to the ball on the table and does not rise at all.

(b)
$$v = \sqrt{2gh} = 4.42 \text{m/s}$$

6.38 (a) Loss of PE =
$$mgh = 1 \times 10^{-3} \times 10 \times 10^{-3} = 10J$$

- (b) Gain in KE = $\frac{1}{2}mv^2 = \frac{1}{2} \times 10^{-3} \times 2500 = 1.25J$
- (c) No, because a part of PE is used up in doing work against the viscous drag of air.



6.40 $m = 3.0 \times 10^{-5} \text{ kg}$ $\rho = 10^{-3} \text{ kg/m}^2 v = 9 \text{ m/s}$

$$A = 1m^{2} \qquad h = 100 \text{ cm} \implies n = 1m^{3}$$
$$M = \rho v = 10^{-3} \text{ kg}, E = \frac{1}{2} M v^{2} = \frac{1}{2} \times 10^{3} \times (9)^{2} = 4.05 \times 10^{4} \text{ J}$$

Answers

6.41
$$KE = \frac{1}{2}mv^2 \cong \frac{1}{2} \times 5 \times 10^4 \times 10^2$$

= 2.5 × 10⁵ J.

10% of this is stored in the spring.

$$\frac{1}{2}kx^2 = 2.5 \times 10^4$$
$$x = 1 \text{ m}$$

 $k = 5 \times 10^4 \text{ N/m}.$

- 6.42 In 6 km there are 6000 steps.
 - $\therefore E = 6000 \ (mg)h$
 - $= 6000 \times 600 \times 0.25$
 - $= 9 \times 10^5 \text{J}.$

This is 10 % of intake.

- \therefore Intake energy = 10 E = 9 ×10⁶J.
- **6.43** With 0.5 efficiency, 1 litre generates $1.5 \times 10^7 \text{J}$, which is used for 15 km drive.
 - :. $F d = 1.5 \times 10^7$ J. with d = 15000 m
 - \therefore F = 1000 N : force of friction.
- **6.44** (a) $W_g = mg \sin\theta d = 1 \times 10 \times 0.5 \times 10 = 50 \text{ J}.$
 - (b) $W_f = \mu \ mg \cos\theta \ d = 0.1 \times 10 \times 0.866 \times 10 = 8.66 \text{ J}.$
 - (c) $\Delta U = mgh = 1 \times 10 \times 5 = 50 \text{ J}$
 - (d) $a = \{F (mg\sin\theta + \mu mg\cos\theta)\} = [10 5.87]$
 - $= 4.13 \text{ m/s}^2$

$$v = u + at \text{ or } v^2 = u^2 + 2ad$$

$$\Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mad = 41.3 \text{ J}$$

$$2$$
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(e)
$$W = F d = 100 \text{ J}$$

- **6.45** (a) Energy is conserved for balls 1 and 3.
 - (b) Ball 1 acquires rotational energy, ball 2 loses energy by friction. They cannot cross at C. Ball 3 can cross over.

Exemplar Problems–Physics

6.

(c) Ball 1, 2 turn back before reaching C. Because of loss of energy, ball 2 cannot reach back to A. Ball 1 has a rotational motion in "wrong" sense when it reaches B. It cannot roll back to A, because of kinetic friction.

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$$(KE)_{t+\Delta t} = \frac{1}{2} (M - \Delta m) (v + \Delta v)^{2} + \frac{1}{2} \Delta m (v - u)^{2}$$

rocket gas
$$= \frac{1}{2} M v^{2} + M v \Delta v - \Delta m v u + \frac{1}{2} \Delta m u^{2}$$

$$(KE)_{t} = \frac{1}{2} M v^{2}$$

$$(KE)_{t+\Delta t} - (KE)_{t} = (M \Delta v - \Delta m u)v + \frac{1}{2} \Delta m u^{2} = \frac{1}{2} \Delta m u^{2} = W$$

(By Work - Energy theorem)

Since
$$\left(\frac{Mdv}{dt} = \left(\frac{dm}{dt}\right)(|u|)\right) \Rightarrow (M\Delta v - \Delta m u) = 0$$

Hooke's law : $\frac{F}{A} = Y \frac{\Delta L}{L}$

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where A is the surface area and *L* is length of the side of the cube. If *k* is spring or compression constant, then $F = k \Delta L$

$$\therefore k = Y \frac{A}{L} = YL$$

Initial KE = $2 \times \frac{1}{2} mv^2 = 5 \times 10^{-4} J$

Final PE =
$$2 \times \frac{1}{2} k (\Delta L)^2$$

$$\therefore \quad \Delta L = \sqrt{\frac{KE}{k}} = \sqrt{\frac{KE}{YL}} = \sqrt{\frac{5 \times 10^{-4}}{2 \times 10^{11} \times 0.1}} = 1.58 \times 10^{-7} \text{m}$$

6.48 Let *m* , *V*, ρ_{He} denote respectively the mass, volume and density of helium baloon and ρ_{air} be density of air

Volume V of baloon displaces volume V of air.

So, V
$$\left(\rho_{air} - \rho_{He}\right)g = ma$$
 (1)

Integrating with respect to t,

$$V(\rho_{air} - \rho_{He})gt = mv$$

$$\Rightarrow \frac{1}{2}mv^{2} = \frac{1}{2}m\frac{V^{2}}{m^{2}}(\rho_{air} - \rho_{He})^{2}g^{2}t^{2} = \frac{1}{2m}V^{2}(\rho_{air} - \rho_{He})^{2}g^{2}t^{2} \quad (2)$$

Answers

If the baloon rises to a height *h*, from
$$s = ut + \frac{1}{2}at^2$$
, we get $h = \frac{1}{2}at^2$
 $s = ut + \frac{1}{2}at^2$, we get $h = \frac{1}{2}at^2 = \frac{1}{2}\frac{V(\rho_{air} - \rho_{he})}{m}gt^2$
(3)

From Eqs. (3) and (2),

$$\frac{1}{2}mv^{2} = \left[V\left(\rho_{a} - \rho_{He}\right)g\right] \left[\frac{1}{2m}V\left(\gamma_{a} - \gamma_{He}\right)gt^{2}\right]$$
$$= V\left(\rho_{a} - \rho_{He}\right)gh$$

Rearranging the terms,

$$\Rightarrow \frac{1}{2}mv^{2} + V\rho_{He}gh = V\rho_{air}hg$$

$$\Rightarrow KE_{baloon} + PE_{baloon} = \text{change in } PE \text{ of air.}$$

So, as the baloon goes up, an equal volume of air comes down, increase in PE and KE of the baloon is at the cost of PE of air [which comes down].