Solutions
Indian National Physics Olympiad - 2010

Please note that equivalent methods/solutions may exist.

PART - A

1. (a) $\vec{P}_A = 80\,\hat{i}$ kg·m·s^{-1}, also acceptable $\vec{P}_A = 70\,\hat{i}$ kg·m·s^{-1};
$\vec{P}_B = -70\,\hat{i}$ kg·m·s^{-1}

   (b) $\vec{P}_A = 20\,\hat{i}$ kg·m·s^{-1};
$\vec{P}_B = -10\,\hat{i}$ kg·m·s^{-1}, also acceptable $\vec{P}_B = -70/8\,\hat{i}$ kg·m·s^{-1}

   (c) Number of tosses by A = 1 ; Number of tosses by B = 1

   (d) See Fig. (1).

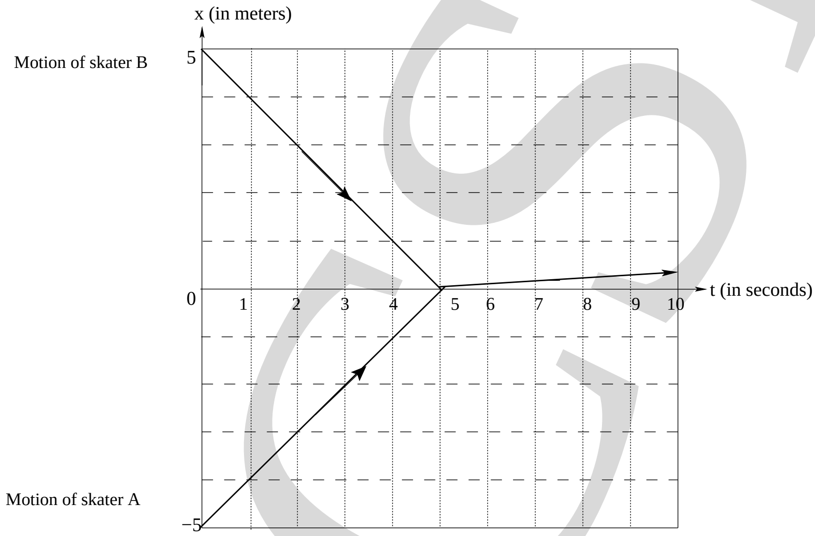

Figure 1:

   (e) See Fig. (2).

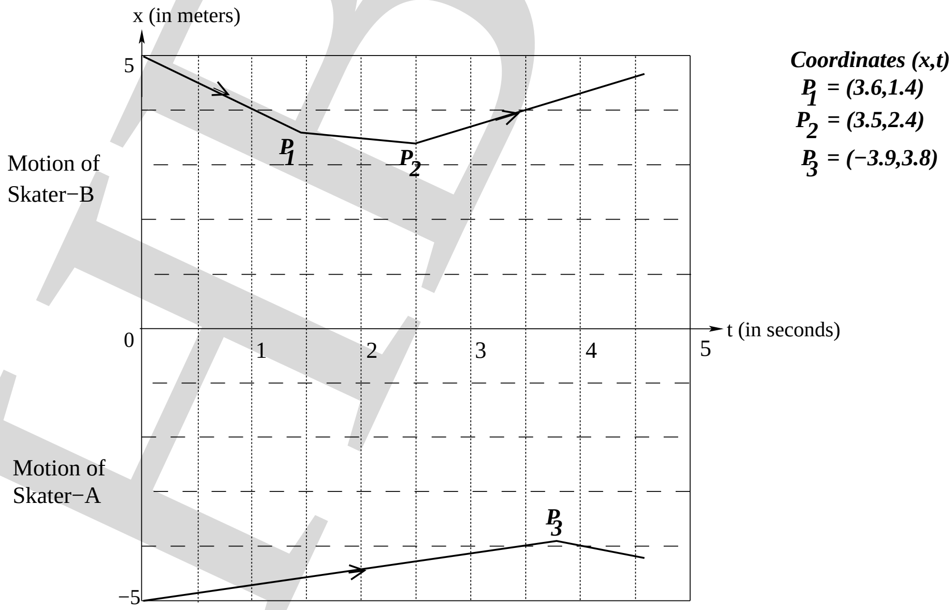

Figure 2:

2. (a) $P_1 = \dfrac{243}{32} P_0$; $P_2 = \dfrac{243}{32} P_0$; $P_3 = \dfrac{243}{32} P_0$

$V_1 = \dfrac{65}{27} V_0$; $V_2 = \dfrac{8}{27} V_0$; $V_3 = \dfrac{8}{27} V_0$

$T_1 = \dfrac{585}{32} T_0$; $T_1 = \dfrac{9}{4} T_0$; $T_1 = \dfrac{9}{4} T_0$

(b) Work done $= \dfrac{15}{4} P_0 V_0$

(c) Heat supplied $= \dfrac{1899}{64} P_0 V_0$

(d) Entropy change in $A_2 + A_3 = 0$

Entropy change in $A_1 = \dfrac{3R}{2} \ \ln \dfrac{585}{32} + R \ \ln \dfrac{65}{27}$

3. (a) $A_F = 4.76\ ^0$

(b) $\Delta_D = -2.1\ ^0$

(c) See Fig. (3). Note that all angles are expressed in degrees.

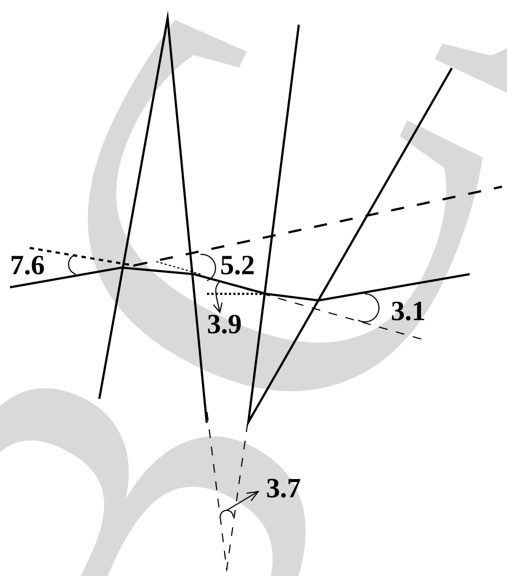

Figure 3:

4. (a) $\alpha = \dfrac{mgR}{I + mR^2}$

(b) $\omega = \sqrt{\dfrac{2\alpha H}{R}}$

(c) $K = mgH$

(d) $\vec{B} = \dfrac{\mu_0}{2\pi} \dfrac{Q\omega'}{l} \hat{i}$ for $r < R$

$= 0$ for $r > R$

(e) $E = \dfrac{\mu_0 Q R^2 \alpha\,'}{4\pi l r}$ for $r \geq R$

$= \dfrac{\mu_0 Q r \alpha\,'}{4\pi l}$ for $r < R$

(f) $\tau_{em} = QER$

(g) $$\alpha' = \frac{mgR}{I + mR^2 + \frac{\mu_0 Q^2 R^2}{4\pi l}}$$

(h) $$K' = \frac{mgH(I + mR^2)}{I + mR^2 + \frac{\mu_0 Q^2 R^2}{4\pi l}}$$

(i) $$K' - K = -\frac{B^2}{2\mu_0}\pi R^2 l$$

(j) Some possible interpretations are

i. It is the magnetic energy stored in shell.
magnetic energy = magnetic energy density$(B^2/2\mu_0) \times$ Volume $(\pi R^2 l)$
and/or

ii. It is the self inductance energy $(1/2\ Li^2)$ of the system.
and/or

iii. Poynting vector argument can also show that it is magnetic energy.
$$(2\pi Rl)\left(\frac{1}{\mu_0}\int \bar{E} \times \bar{B} dt\right) = K\,' - K = \frac{-B^2 \pi R^2 l}{2\mu_0}$$

5. (a) $\lambda_k = 0.12$ hr^{-1}

(b) $A = 3.70 \times 10^4$ s^{-1}, also acceptable $A = 2.62 \times 10^4$ s^{-1}.

(c) 5.0 liters

PART - B

1. b
2. e
3. d
4. d
5. e
6. d
7. a
8. c
9. b
10. c
11. e
12. e
13. b
14. e
15. d
16. c
17. c
18. d
19. c
20. a