

Indian National Physics Olympiad - 2011

Solutions

Please note that alternate/equivalent solutions may exist. Brief solutions are given below.

1. (a) $F_x = \frac{-\mu_0 e v_y I}{2\pi x}$
 $F_y = \frac{\mu_0 e v_x I}{2\pi x}$

(b) $v_x = \sqrt{v_0^2 - \left(\frac{e\mu_0 I}{2\pi m} \log \frac{x}{a} \right)^2}$

(c) $x_{max} = a \exp(2\pi v_0 m / e\mu_0 I)$

2. (a) $\Delta x = \frac{\mu_l y d}{D} - (\mu_g - \mu_l) t_g$

Also acceptable: $\Delta x = (\mu_g - \mu_l) t_g - \frac{\mu_l y d}{D}$ or $\frac{y d}{D} - \left(\frac{\mu_g}{\mu_l} - 1 \right) t_g$

(b) $y = \frac{t-4}{10-t} \times 1.8 \times 10^{-2} \text{ m}$ for $t \leq 5 \text{ s}$
 $= 3.6 \times 10^{-3} \text{ m}$ for $t > 5 \text{ s}$

(c) $t_m = 4 \text{ s}$

(d) $v = 3.0 \times 10^{-3} \text{ m}\cdot\text{s}^{-1}$

(e) $\Delta t = 6.7 \times 10^{-2} \text{ s}$

3. (a)

$P_1 = \frac{R\alpha T_0}{V_0}$	$P_2 = \frac{RT_0 \alpha^{\gamma/\gamma-1}}{nV_0}$	$P_3 = \frac{RT_0}{nV_0}$	$P_4 = \frac{RT_0}{V_0 \alpha^{1/\gamma-1}}$
$V_1 = V_0$	$V_2 = \frac{nV_0}{\alpha^{1/\gamma-1}}$	$V_3 = nV_0$	$V_4 = \alpha^{1/\gamma-1} V_0$
$T_1 = \alpha T_0$	$T_2 = \alpha T_0$	$T_3 = T_0$	$T_4 = T_0$

(b) $W_{12} = R\alpha T_0 \log \frac{n}{\alpha^{1/\gamma-1}}$

$W_{23} = \frac{RT_0(1-\alpha)}{\gamma-1}$

$W_{34} = RT_0 \log \left(\frac{\alpha^{1/\gamma-1}}{n} \right)$

$W_{41} = -\frac{RT_0(\alpha-1)}{\gamma-1}$

(c) $Q = R\alpha T_0 \log \left(\frac{n}{\alpha^{1/\gamma-1}} \right)$

Also acceptable: $Q = RT_0(\alpha-1) \log \left(\frac{n}{\alpha^{1/\gamma-1}} \right)$

4. (a) Taking $q_1 = q_2 = e$, $r_n = n^2 a_0 - \beta$

(b) $E_n = \frac{q_1 q_2}{-8\pi\epsilon_0(n^2 a_0 - \beta)}$

(c) $\Delta E = 11.5 \text{ eV}$ ($\pm 0.15 \text{ eV}$ acceptable)

5. (a) $m \frac{d\vec{v}}{dt} = -e \left(\vec{E} + \vec{v} \times \vec{B} \right) - \frac{m\vec{v}}{\tau}$
 (b) $\omega_c = eB/m = 10^{12} \text{ rad} \cdot \text{s}^{-1}$
 (c) $\sigma_0 = ne^2\tau/m = 5.8 \times 10^7 \text{ (ohm} \cdot \text{m)}^{-1}$
 (d)

$$\sigma_{xy} = -\frac{\sigma_0\tau\omega_c}{1 + \omega_c^2\tau^2}; \quad \sigma_{xz} = 0$$

$$\sigma_{yy} = \frac{\sigma_0}{1 + \omega_c^2\tau^2}; \quad \sigma_{yz} = 0$$

$$\sigma_{zy} = 0; \quad \sigma_{zx} = \sigma^0$$

- (e) See Fig. (1). Either of Fig. (1a) or (1b) or (1c) is acceptable.

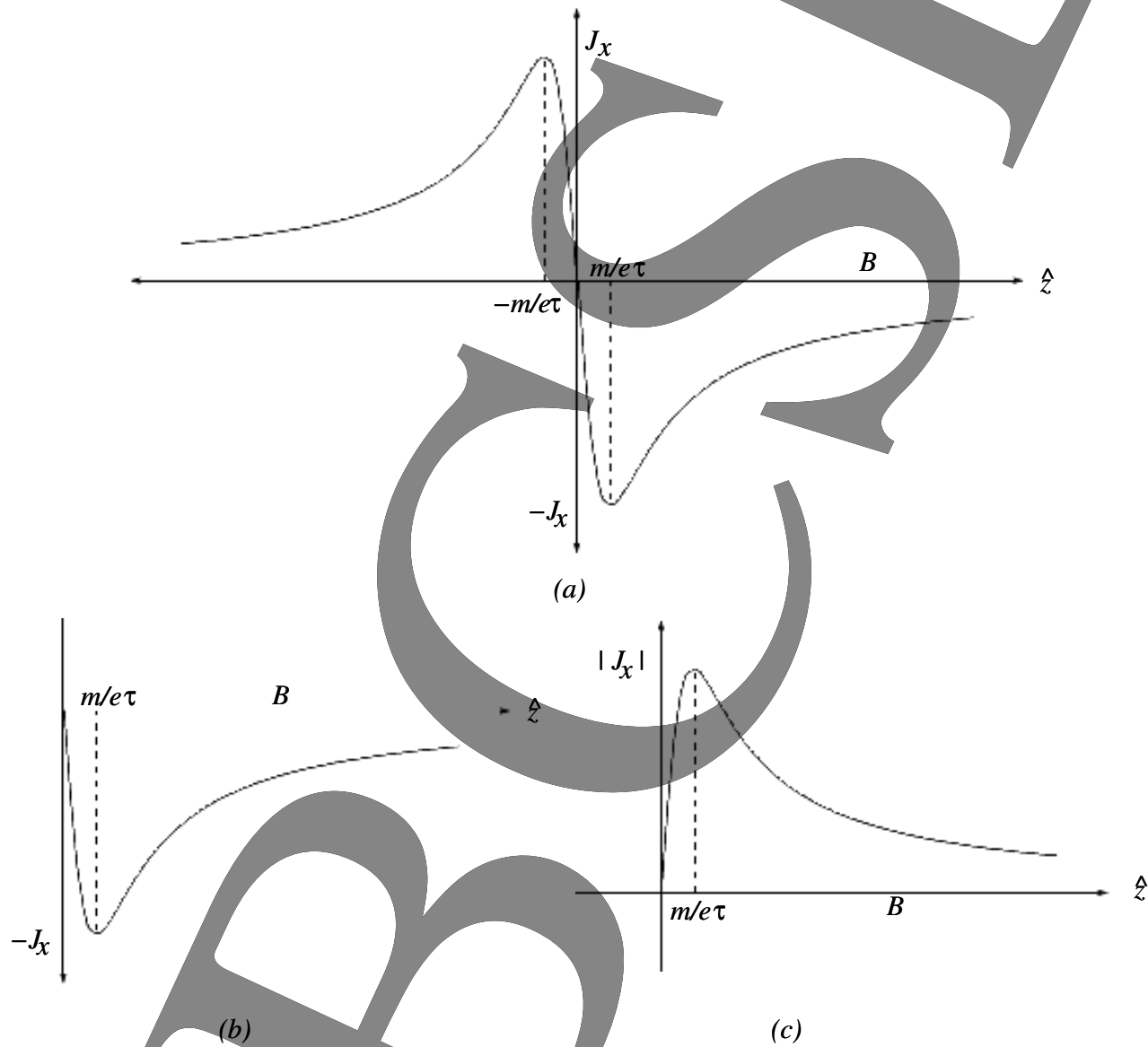


Figure 1: j_x vs B

- (f) $B = 229 \text{ T}$
 6. (a) $V_A = \frac{1 - \gamma}{1 + \gamma} V_0$
 $V_B = \frac{2V_0}{1 + \gamma}$
 $V_C = 0$
 (b) See Fig. (2) for free body diagrams.
 Equations of motion:
 $m \frac{d^2 x^B}{dt^2} = -F_B$ and $m \frac{d^2 x^C}{dt^2} = F_C$

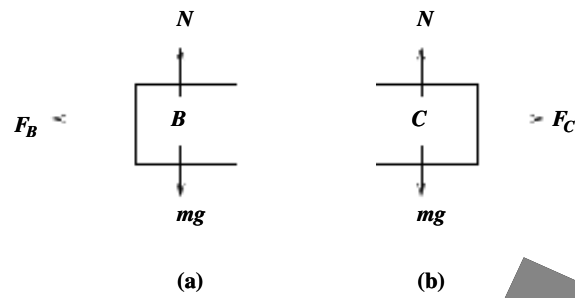
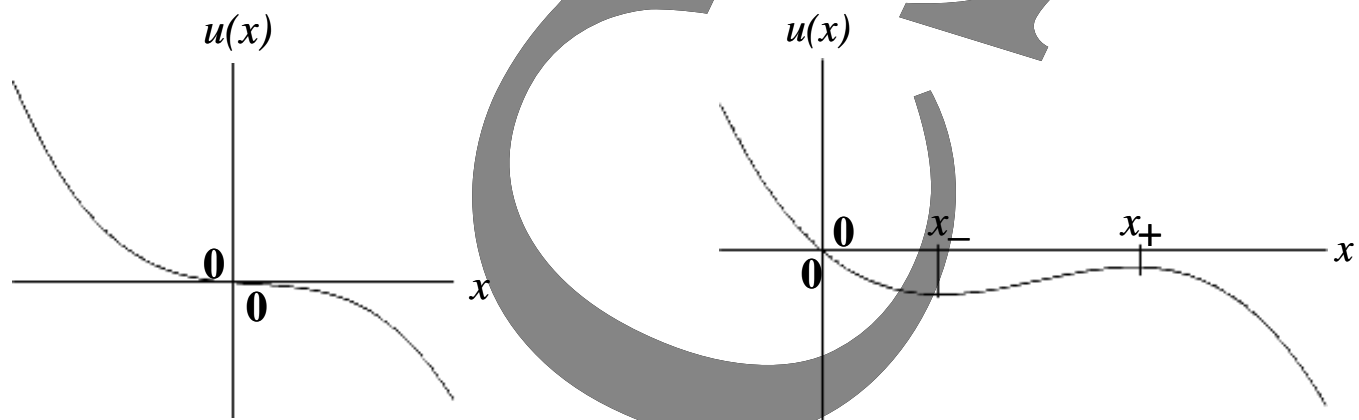


Figure 2: (a) Free body diagram for the block B . Here $F_B = k(L - (x_C - x_B))$ (b) Free body diagram for the block C . Here $F_C = k(L - (x_C - x_B))$.

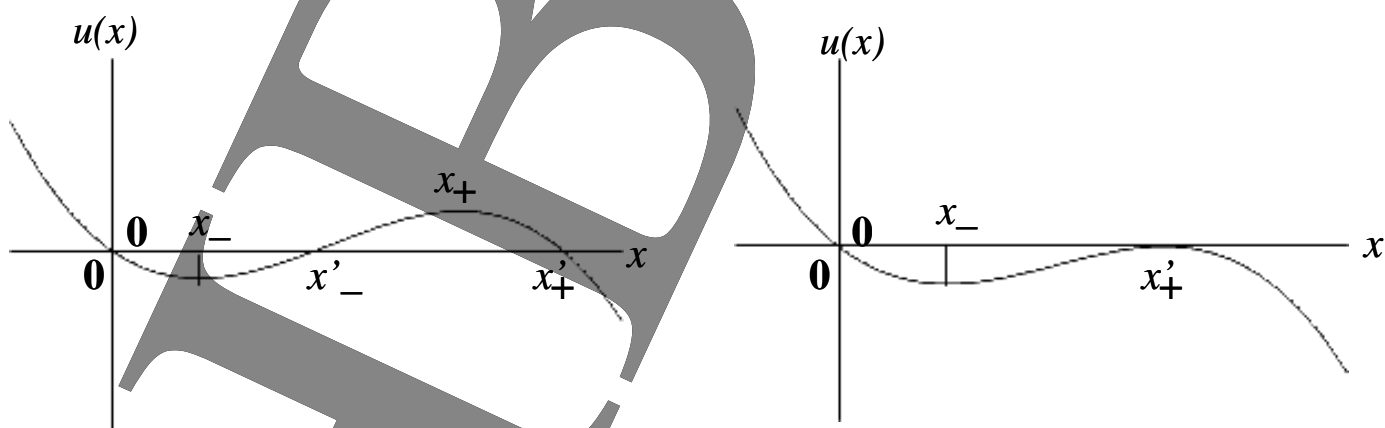
(c) $\omega = \sqrt{\frac{2k}{m}}$
 $\alpha = \frac{V_0}{1 + \gamma}$
 $\beta = \frac{V_0}{\omega(1 + \gamma)}$
(d) $0 < \gamma < 2/3\pi$

7. (a) We can define $D = m^2\omega^4 - 4\alpha\delta$ and $D' = m^2\omega^4 - \frac{16}{3}\alpha\delta$. There are four possibilities. See Fig. (3) for detailed graphs.



(a) $D < 0, D' < 0$

(b) $D > 0, D' < 0$



(c) $D > 0, D' > 0$

(d) $D > 0, D' = 0$

Figure 3: Here $x_{\pm} = (m\omega^2 \pm \sqrt{D})/2\alpha$ and $x'_{\pm} = 3(m\omega^2 \pm \sqrt{D'})/4\alpha$.

- (b) See Fig. (4).

For $0 < x < 0.6$ motion is bounded on the left and periodic.
 $x \in [2.4, \infty[$ motion is partially bounded and not periodic.
 $x < 0$ and $0.6 < x < 2.4$ forbidden motion.

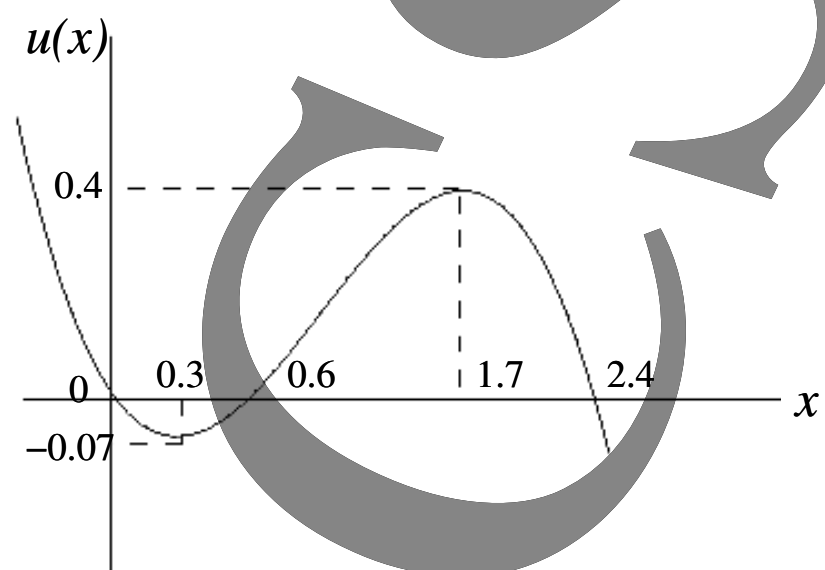


Figure 4: