BBMerlion

Physics A Level

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QUIZ 3 SOLUTION

Electricity and Magnetism

Question 1

A. The bowl exerts a normal force on each bead, directed along the radius line or at 60.0° above the horizontal. Consider the free-body diagram shown for the bead on the left side of the bowl:

$$\sum F_y = n \sin 60 - mg = 0$$

or $n = \dfrac{mg}{\sin 60}$

also, $\sum F_x = -F_e + n \cos 60 = 0$

or $\dfrac{k_e q^2}{R^2} = n \cos 60 = \dfrac{mg}{\tan 60} = \dfrac{mg}{\sqrt{3}}$

Thus, $q = R\left(\dfrac{mg}{k_e\sqrt{3}}\right)^{\frac{1}{2}}$

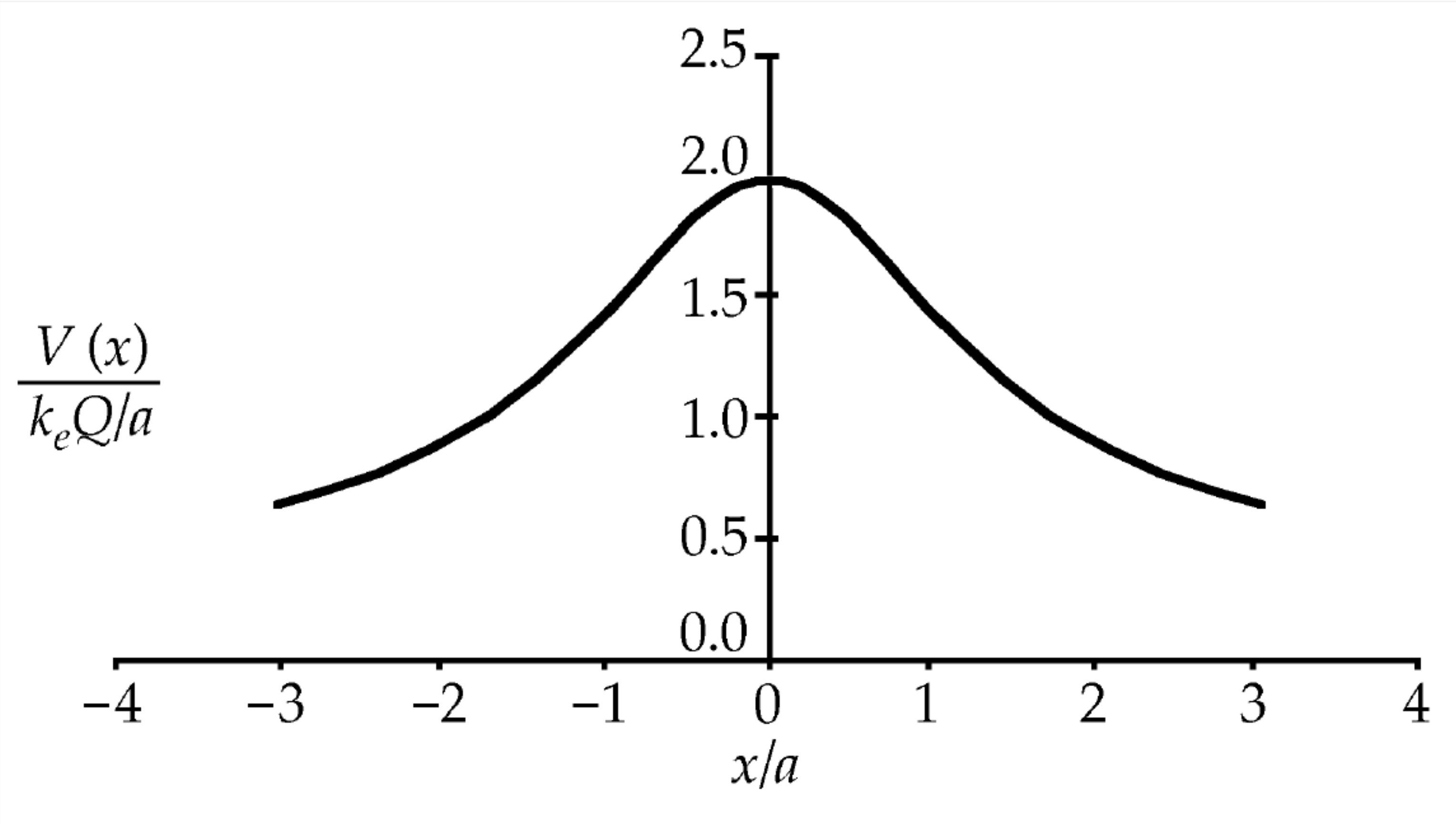
Question 1

B. i. $V(x) = \frac{k_e Q_1}{r_1} + \frac{k_e Q_2}{r_2} = \frac{k_e(+Q)}{\sqrt{x^2+a^2}} + \frac{k_e(+Q)}{\sqrt{x^2+(-a)^2}}$

$$V(x) = \frac{2k_e Q}{\sqrt{x^2 + a^2}} = \frac{k_e Q}{a}\left(\frac{2}{\sqrt{\left(\frac{x}{a}\right)^2 + 1}}\right)$$

$$\frac{V(x)}{\left(\frac{k_e Q}{a}\right)} = \frac{2}{\sqrt{\left(\frac{x}{a}\right)^2 + 1}}$$

Question 1



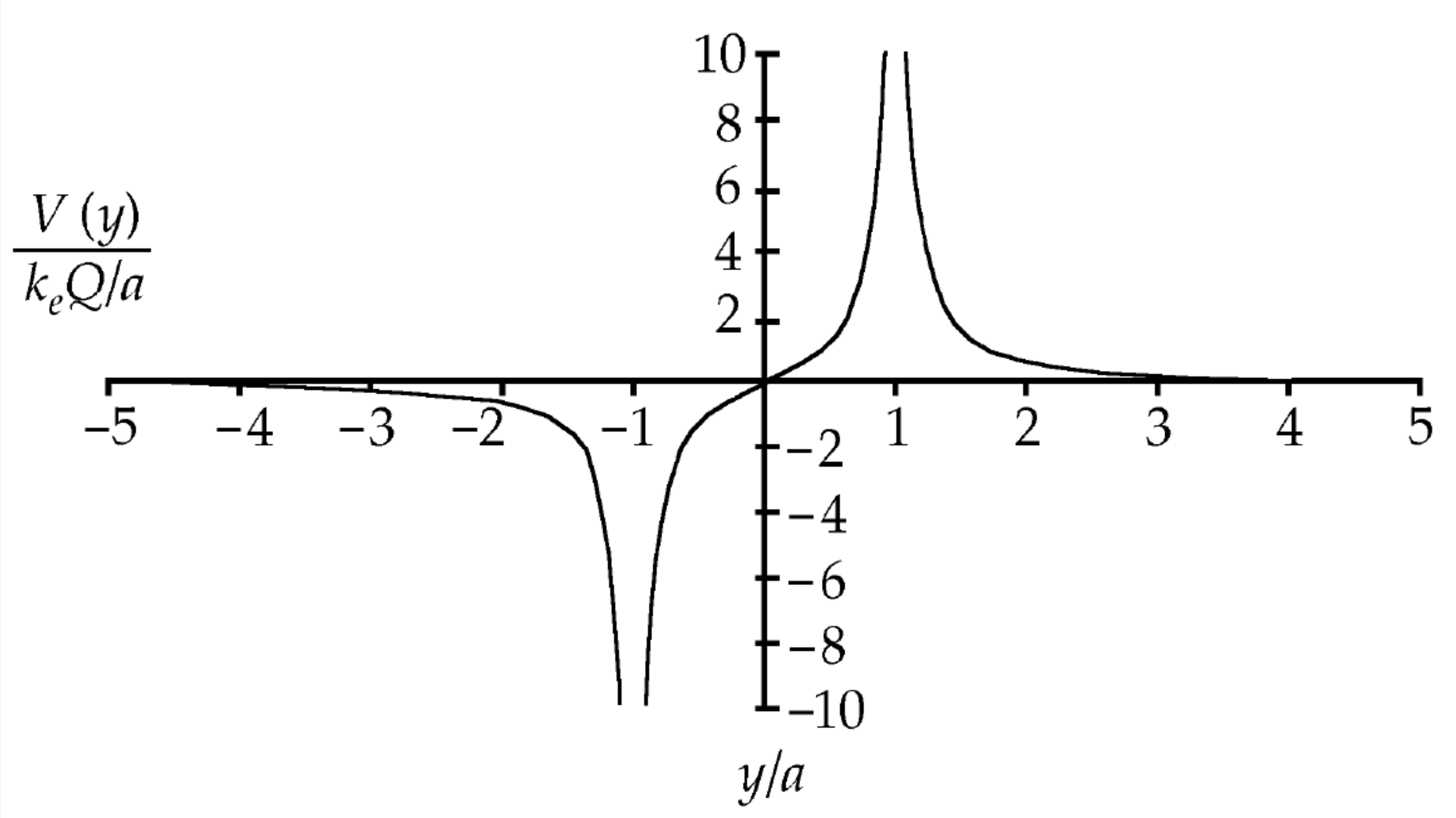
Question 1

ii. $$V(y) = \frac{k_e Q_1}{r_1} + \frac{k_e Q_2}{r_2} = \frac{k_e(+Q)}{|y-a|} + \frac{k_e(-Q)}{|y+a|}$$

$$V(y) = \frac{k_e Q}{a}\left(\frac{1}{\left|\frac{y}{a} - 1\right|} - \frac{1}{\left|\frac{y}{a} + 1\right|}\right)$$

$$\frac{V(y)}{\left(\frac{k_e Q}{a}\right)} = \frac{1}{\left|\frac{y}{a} - 1\right|} - \frac{1}{\left|\frac{y}{a} + 1\right|}$$

Question 1



Question 2

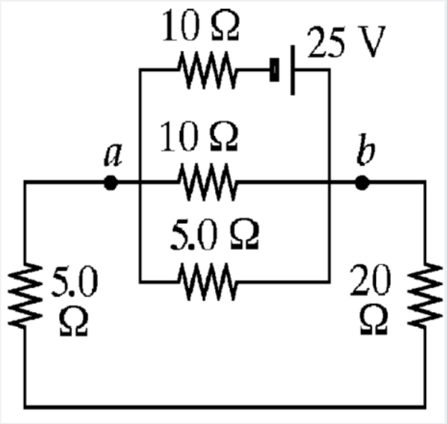
A. $v_d = \frac{I}{nq\pi r^2} = \frac{1000}{8.46\times10^{28}(1.6\times10^{-19})\pi(10^{-2})^2} = 2.35 \times 10^{-4}\,\frac{m}{s}$

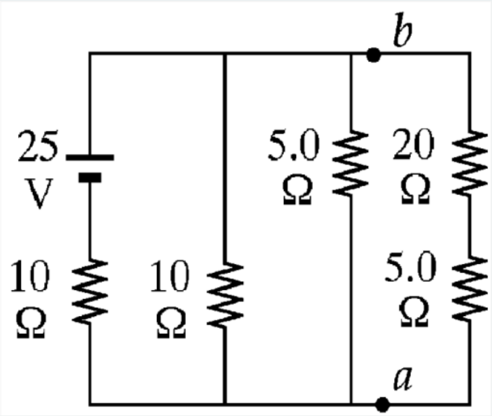
$$v = \frac{x}{t}$$

$$t = \frac{x}{v} = \frac{200 \times 10^3}{2.35 \times 10^{-4}} = 8.5 \times 10^8\ s$$

Question 2

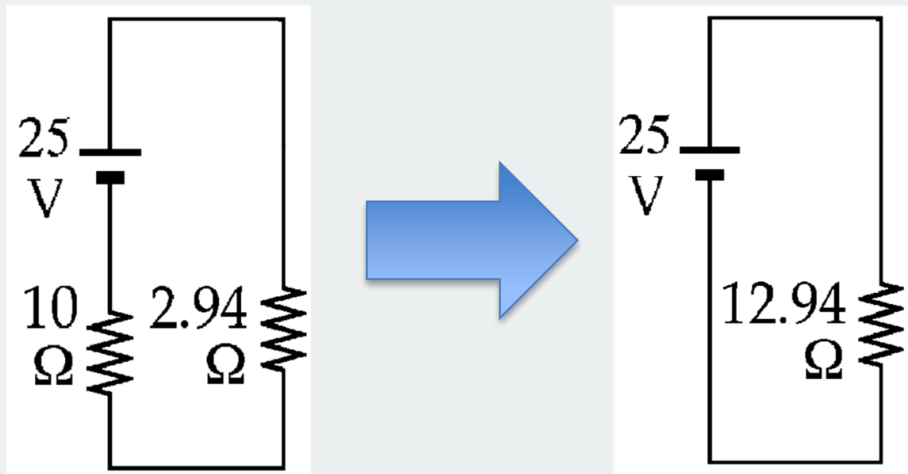
We simplify the circuit as follows:





$$R_{eq} = \frac{1}{\frac{1}{10\Omega} + \frac{1}{5\Omega} + \frac{1}{25\Omega}} = 2.94\Omega$$

Question 2



$$I = \frac{\Delta V}{R} = \frac{25}{12.94} = 1.93\ A$$

$$V_{2.94} = 1.93 \times 2.94 = 5.68\ V$$

ii. $V_{2.94} = V_{ab} = 5.68\ V$

i. $I = \frac{5.68}{25} = 0.227\ A$

Question 3

A.

i. as to the initial velocity, and with $\hat{\imath} \times \hat{k} = -\hat{\jmath}$ as the direction of the initial force.

ii. $r = \frac{mv}{qB} = \frac{(1.67\times10^{-27})(20\times10^{6})}{(1.6\times10^{-19})(0.3)} = 0.696\ m$

iii. The path is a quarter circle, of length $\left(\frac{\pi}{2}\right)0.696 = 1.09\ m$

iv. $\Delta t = \frac{1.09}{20\times10^{6}} = 54.7\ ns$

Question 3

B. Let v_x and $v_\perp$ be the components of the velocity of the positron parallel to and perpendicular to the direction of the magnetic field.

i. The pitch of trajectory is the distance moved along x by the positron during each period, T (determined by the cyclotron frequency):

$$p = v_x T = (v\cos 85)\left(\frac{2\pi m}{Bq}\right)$$

$$p = \frac{5\times 10^{6}\cos 85\,(2\pi)(9.11\times 10^{-31})}{(0.15)(1.6\times 10^{-19})} = 1.04\times 10^{-4}$$

ii. The equation about circular motion in a magnetic field still applies to the radius of the spiral:

$$r = \frac{mv_\perp}{Bq} = \frac{mv\sin 85}{Bq}$$

$$r = \frac{(9.11\times 10^{-31})(5\times 10^{6})(\sin 85)}{(0.15)(1.6\times 10^{-19})} = 1.85\times 10^{-4}\ m$$

Question 4

A. The emf induced between the ends of the moving bar is

$$\mathcal{E} = Blv = (2.5)(0.350)(8) = 7\ V$$

The left-hand loop contains decreasing flux away from you, so the induced current in it will be clockwise, to produce its own field directed away from you. Let I_1 represent the current flowing upward through the 2.00-Ω resistor. The right-hand loop will carry counterclockwise current. Let I_3 be the upward current in the 5.00-Ω resistor.

Question 4

i. Kirchhoff's loop rule then gives: $7\ V - I_1(2\Omega) = 0.$

$I_1 = 3.5\ A$

and $7\ V - I_3(5\ \Omega) = 0$ $\quad I_3 = 1.4\ A$

ii. The total power converted in the resistors of the circuit is

$$P = \mathcal{E}I_1 + \mathcal{E}I_3 = \mathcal{E}(I_1 + I_3) = 7(3.5 + 1.4) = 34.3\ W$$

iii. The current in the sliding conductor is downward with value

$I_2 = 3.5 + 1.4 = 4.9\ A$. The magnetic field exerts a force of $F_m = IlB = (4.9)(0.35)(2.50) = 4.29\ N$ directed toward the right on this conductor. An outside agent must exert a force of 4.29 N to the left to keep the bar moving.

Question 4

B. i. $\Phi_B = BA = \mu_0 nIA = \frac{\mu_0 N}{l} IA$

$$L = \frac{N\Phi_B}{I} = \mu \frac{N^2}{l} A$$

ii. $L = 4\pi \times 10^{-7} \frac{(300)^2}{25\times10^{-2}} \left(4 \times 10^{-4}\right)$

$$= 1.81 \times 10^{-4}\ H$$

iii. $\mathcal{E}_L = -L\frac{dI}{dt} = -\left(1.81 \times 10^{-4} H\right)(-50)$

$$= 9.05\ mV$$

Reference

- Physics for Scientist and Engineer, 6th ed, Serway Jewett