Physics 1004 Practice Questions and Solutions

Section A: Multiple Choice

Answer all questions. Each question is worth 1 mark. Please circle your answer in the box.

A1

A 12.0 N force with a fixed orientation does work on a particle, as the particle moved through a displacement **d** = (2.00 m)**i** - (4.00 m)**j** + (3.00 m)**k**. The change in the particle's kinetic energy is +30.0 J. What is the angle between the force vector and the displacement vector?

(A) 12.1°	(B) 16.8°	(C) 21.9°	(D) 46.1°	(E) 62.3°

Solution:

Using the work-kinetic energy theorem, we have

$$\Delta K = W = \vec{F}\cdot\vec{d} = Fd\cos\phi.$$

In addition, $F = 12\ \mathrm{N}$ *and* $d = \sqrt{(2.00\ \mathrm{m})^2 + (-4.00\ \mathrm{m})^2 + (3.00\ \mathrm{m})^2} = 5.39\ \mathrm{m}$.

If $\Delta K = +30.0\ \mathrm{J}$, *then*

$$\phi = \cos^{-1}\left(\frac{\Delta K}{Fd}\right) = \cos^{-1}\left(\frac{30.0\ \mathrm{J}}{(12.0\ \mathrm{N})(5.39\ \mathrm{m})}\right) = 62.3^{\circ}.$$

Answer (E)

A2

If a metal conductor has a charge -1.45×10^{-7} C, how many excess electrons are there on it?

(A) 1.44×10^{-3}	(B) 2.40×10^{8}	(C) 9.05×10^{11}	(D) 8.31×10^{13}	(E) 1.05×10^{18}

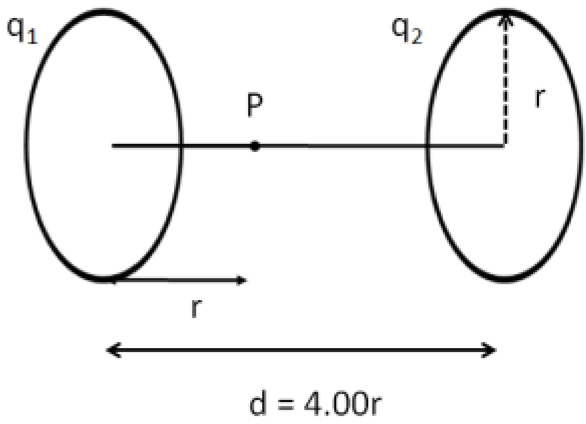
Solution

The charge on the electron is $1.602{\times}10^{-19}$ C, so to make up a charge of $-1.45{\times}10^{-7}$ C

$$n = \frac{-1.45\times10^{-7}\text{ C}}{-1.602\times10^{-19}\text{C}} = 9.05\times10^{11}$$

A3

The figure shows two parallel non-conducting rings with their central axes along a common line. Ring 1 has a uniform charge q_1 and ring 2 has a uniform charge q_2. Both disks have a radius R, and the separation between the disks is 4R. The net electric field is zero at point P, which is R away from disk 1 and 3R from disk 2. What is the charge ratio q_1/q_2?



(A) 0.268	(B) 0.333	(C) 0.500	(D) 0.750	(E) 1.00

Solution

We use Eq. 22-16, assuming both charges are positive. At *P*, we have for the magnitudes of E

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 R}{(R^2+R^2)^{\frac{3}{2}}}$$

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_2 3R}{((3R)^2+R^2)^{\frac{3}{2}}}$$

And these magnitudes are equal at the point P

$$\frac{1}{4\pi\varepsilon_0}\frac{q_2 3R}{(10R)^{\frac{3}{2}}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 R}{(2R)^{\frac{3}{2}}}$$

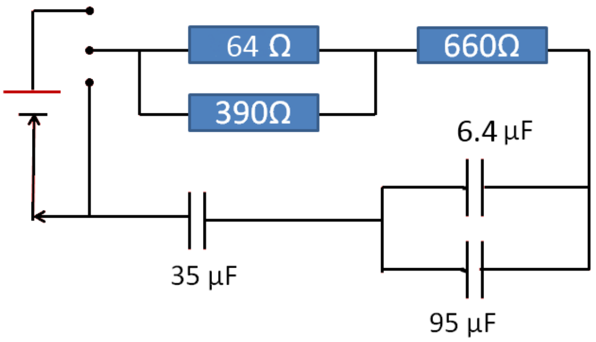
$$\frac{q_2 3}{(10R)^{\frac{3}{2}}} = \frac{q_1}{(2R)^{\frac{3}{2}}}$$

$$3\left(\frac{2}{10}\right)^{\frac{3}{2}} = \frac{q_1}{q_2} = 0.268$$

Answer (A)

A4

What is the time constant of this RC circuit?



(A) 26 μs	(B) 19 ms	(C) 1.2 s	(D) 11 s	(E) 230 s

Solution:

Equivalent capacitance of the parallel capacitors: $C_{\parallel} = 6.4\mu F + 95\mu F = 101.4\mu F$

Equivalent capacitance of the series

$$\frac{1}{C_{eq}} = \frac{1}{101.4\mu F} + \frac{1}{35\mu F}$$

$$C_{eq} = 26.0\mu F$$

Equivalent resistance of the parallel resistors

$$\frac{1}{R_p} = \frac{1}{64\Omega} + \frac{1}{390\Omega}$$

$$R_p = 55.0\Omega$$

Equivalent resistance of the series.

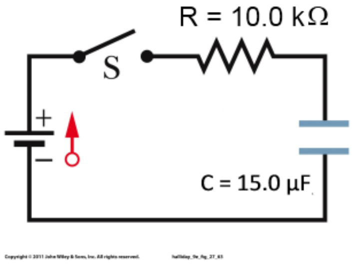
$$R_{eq} = 55\Omega + 660\Omega = 715\Omega$$

Time constant: RC = 715Ω × 26.0 μF = 19 ms

Answer (b)

A5

The switch S in the circuit pictured on the right is closed at t = 0 and the uncharged capacitor (C = 15.0 μF) starts to charge. At what point does the potential across the resistor (R = 10.0 kΩ) equal that of the capacitor?



(A) 525 μs	(B) 950 μs	(C) 0.100 ms	(D) 0.208 ms	(E) 0.350 ms

Solution:

The battery emf as V. Then the requirement stated in the problem that the resistor voltage be equal to the capacitor voltage becomes $iR = V_{cap}$, or

$$Ve^{-t/RC} = V(1 - e^{-t/RC})$$

$$e^{\frac{-t}{RC}} = 0.5$$

$$t = -RC\ln(0.5) = RC\ln(2) = 0.208\,\text{ms}$$

where Eqs. 27-34 and 27-35 have been used. **Answer (D)**

A6

A solenoid of length 15 cm, and with 45 turns, has a current of 1.25 amps flowing in it. What is the magnitude of the magnetic field inside the solenoid?

(A) 1.0×10^{-5} T	(B) 1.2×10^{-4} T	(C) 3.8×10^{-3} T	(D) 7.0×10^{-3} T	(E) 9.5×10^{-2} T

Solution

$$B = \mu_0 in = (4\pi\times10^{-7}\,N.m^2)(1.25A)\frac{45\text{ turns}}{15\times10^{-2}\text{ m}} = 1.2\times10^{-4}T$$

Answer (B)

A6

A coil is connected in series with a 10.0 kΩ resistor. An ideal 50.0V battery is connected across the two devices, and the current reaches 2.00 mA after 5.00 milliseconds. Find the inductance of the coil.

(A) 97.9 H	(B) 108 H	(C) 979 H	(D) 2.61×10^{3} H	(E) 2.61×10^{6} H

Solution:

If the battery is applied at time t = 0 the current is given by

$$i = \frac{\varepsilon}{R}\left(1 - e^{\frac{-t}{\tau_L}}\right)$$

$$1 - \frac{iR}{\varepsilon} = e^{\frac{-t}{\tau_L}}$$

$$\ln\left[1 - \frac{iR}{\varepsilon}\right] = \frac{-t}{\tau_L}$$

$$\tau_L = -\frac{t}{\ln\left[1 - \frac{iR}{\varepsilon}\right]} = -\frac{5.00\times10^{-3}s}{\ln\left[1 - \frac{(2.00\times10^{-3}\,\text{A})(10.0\times10^{3}\,\Omega)}{50.0\ \text{V}}\right]} = 9.79\times10^{-3}s$$

$$L = \tau_L R = 9.79\times10^{-3}s\times10.0\times10^{3}\Omega = 97.9\ \text{H}$$

Answer (A)

A7

In an oscillating LC circuit with L = 65 mH and C = 4.0μF. The current is initially a maximum. How long will it take before the capacitor is fully charged for the first time?

(A) 7.1×10^{-7} s	(B) 2.6×10^{-6} s	(C) 4.0×10^{-5} s	(D) 6.4×10^{-4} s	(E) 8.0×10^{-4} s

Solution: The time required is $t = T/4$, where the period is given by $T = 2\pi/\omega = 2\pi\sqrt{LC}.$

$$t = \frac{T}{4} = \frac{2\pi\sqrt{LC}}{4} = \frac{2\pi\sqrt{(0.065\ \text{H})(4.0\times10^{-6}\ \text{F})}}{4} = 8.0\times10^{-4}\ \text{s}$$

Answer (E)

Section B: Longer Questions

B1

23.31 Two long, charged, thin-walled, concentric, cylindrical shells have radii of 3.0 cm and 6.0 cm. The charge per unit length is 5.0×10^{-6} C/m^2 on the inner cylinder, and -7.0×10^{-6} C/m^2 on the outer cylinder.

(a) Calculate the magnitude and direction of the electric field at radial distance r = 4.0 cm (5 marks)

(b) Calculate the magnitude and direction of the electric field at radial distance r = 8.0 cm (5 marks)

Solution

. We denote the inner and outer cylinders with subscripts *i* and *o*, respectively.

(a) Since $r_i < r = 4.0$ cm $< r_o$,

$$E(r) = \frac{\lambda_i}{2\pi\varepsilon_0 r} = \frac{5.0\times10^{-6}\ \text{C/m}}{2\pi(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2)(4.0\times10^{-2}\ \text{m})} = 2.3\times10^6\ \text{N/C}.$$

The electric field $\vec{E}(r)$ points radially outward.

(b) Since $r > r_o$,

$$E(r = 8.0\ \text{cm}) = \frac{\lambda_i + \lambda_o}{2\pi\varepsilon_0 r} = \frac{5.0\times10^{-6}\ \text{C/m} - 7.0\times10^{-6}\ \text{C/m}}{2\pi(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2)(8.0\times10^{-2}\ \text{m})} = -4.5\times10^5\ \text{N/C},$$

or $|E(r = 8.0\ \text{cm})| = 4.5\times10^5\ \text{N/C}.$

The minus sign indicates that E(r) points radially inward.

B2

The electric potential in a region of space is given by the equation:

$$V = (2.0\ \mathrm{V/m^2})x^2 + (1.5\ \mathrm{V/m})x - (3.0\ \mathrm{V/m})y + (4.0\ \mathrm{V/m^2})z^2$$

(a) Find the equation for the electric field in this region of space (7 marks)

(b) Find the electric field at the point (3.0 m, 2.0 m, 1.5 m). (3marks)

Solution:

$$E_x = -\frac{\partial V}{\partial x} \qquad E_y = -\frac{\partial V}{\partial y} \qquad E_z = -\frac{\partial V}{\partial z} \qquad \mathbf{E} = -\left(\frac{\partial V}{\partial x}\mathbf{i} + \frac{\partial V}{\partial y}\mathbf{j} + \frac{\partial V}{\partial z}\mathbf{k}\right)$$

Differentiate the potential function w.r.t. x to get the x-component of E $E_x = \frac{\partial V}{\partial x} = 2(2.0\ \mathrm{V/m^2})x + (1.5\ \mathrm{V/m})$

Differentiate the potential function w.r.t. y to get the y-component of E $E_y = \frac{\partial V}{\partial y} = -(3.0\ \mathrm{V/m})$

Differentiate the potential function w.r.t. z to get the z-component of E $E_z = \frac{\partial V}{\partial z} = 2(4.0\ \mathrm{V/m^2})z$

At x = 3.0 m, $E_x = \frac{\partial V}{\partial x} = 2(2.0\ \mathrm{V/m^2})(3.0\ \mathrm{m}) + (1.5\ \mathrm{V/m}) = 13.5\ \mathrm{V/m}$

At y = 2.0 m $E_y = \frac{\partial V}{\partial y} = -(3.0\ \mathrm{V/m})$

At z = 1.5 m $E_z = \frac{\partial V}{\partial z} = 12\ \mathrm{V/m}$

$$\mathbf{E} = (13.5\ \mathrm{V/m})\mathbf{i} - (3.0\ \mathrm{V/m})\mathbf{j} + (12\ \mathrm{V/m})\mathbf{k}$$

B3

A 2.0 μF capacitor and a 4.0 μF capacitor are connected in parallel across a 240 V potential difference. The 4.0 μF capacitor has a parallel plate configuration, with a surface area of 110 cm^2, and a dielectric material (paper) between the plates with κ = 3.5

(a) Calculate the total charge stored on the capacitors (3 marks)

(b) Calculate the total energy stored in the capacitors (3 marks)

(c) Calculate the spacing between the plates in the 4.0 μF capacitor. (4 marks)

Solution:

(a) The capacitors are in parallel, so the equivalent capacitance is the sum = 6.0 μF

$$C = \frac{q}{V}$$

$$q = CV = (6.0\times10^{-6}\,F)(240\text{ V}) = 1.44\times10^{-3}\,C$$

(b) $U = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(6.0\times10^{-6}\,F)(240\text{ V})^2 = 0.17\text{ J}$

(c) The capacitance is related to the capacitor dimensions by

$$C = \frac{\kappa\varepsilon_0 A}{d}$$

$$d = \frac{\kappa\varepsilon_0 A}{C} = \frac{3.5\times(8.85\times10^{-12}\,\text{F/m})\times(110\times10^{-4}\text{ m}^2)}{6.0\times10^{-6}\,\text{C}} = 5.7\times10^{-8}\,m$$

B4

An electrical cable consists of 125 identical strands of copper wire, each with a resistance of 265 mΩ. The same potential difference is applied between the ends of all the strands and results in a total current of 65.0 mA

(a) What is the current in each strand of wire?

(b) What is the applied potential difference?

(c) What is the resistance of the cable?

(d) How much power is dissipated in the cable?

Solution

(a) The current flows equally through each strand so

$$i = \frac{65.0\times10^{-3}A}{125} = 5.2\times10^{-4}A$$

(b) The Potential difference can be calculated using Ohm's law applied to one strand

$$V = 5.2\times10^{-4}A\times2.65\times10^{-3}\,\Omega = 1.38\times10^{-6}\text{ V}$$

(c) The total resistance can be calculated from the equivalent resistance for parallel resistors

$$\frac{1}{R_{eq}} = \frac{125}{R}$$

$$R_{eq} = \frac{2.65\times10^{-3}\Omega}{125} = 2.12\times10^{-5}\Omega$$

(d) The power lost in the cable is $P = IV = (65.0\times10^{-3}A)(1.38\times10^{-6}V) = 8.9\times10^{-6}\text{ W}$

B5

A proton (mass 1.67×10^{-27} kg) is travelling through uniform magnetic and electric fields. The electric field is (4.00 V/m)**k** and the magnetic field is **B** = (-2.50 mT)**i**. If the velocity of the proton is (3450 m/s)**k** , then using unit vector notation, calculate

(a) The electric force on the proton *(3marks)*

(b) The magnetic force on the proton *(4 marks)*

(c) The net acceleration on the proton *(3 marks)*

Solution

(a) The electric force is defined as $\mathbf{F_E} = e\mathbf{E}$

$$\mathbf{F_E} = e\mathbf{E} = (1.602\times10^{-19}C)(4.00\ \mathrm{V/m})\mathbf{k} = (6.41\times10^{-19}\ \mathrm{N})\mathbf{k}$$

(b) The magnetic force is defined as

$$\mathbf{F} = \mathrm{q}(\mathbf{v}\times\mathbf{B}) = \mathrm{e}(4.00\ \mathrm{V/m})\mathbf{k}\times(-2.50\times10^{-3}T)\mathbf{i}$$

$$\vec{c} = \vec{a}\times\vec{b} = (a_y b_z - b_y a_z)\mathbf{i} + (a_z b_x - b_z a_x)\mathbf{j} + (a_x b_y - b_x a_y)\mathbf{k}$$

$$\vec{a}\times\vec{b} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 0 & 0 & 3450\ \mathrm{m/s} \\ -2.50mT & 0 & 0 \end{vmatrix}$$

$$\mathbf{F} = \mathrm{q}(\mathbf{v}\times\mathbf{B}) = \mathrm{e}(3450\ \mathrm{m/s})(2.50\times10^{-3}T)\mathbf{j} = (1.38\times10^{-19}\ \mathrm{N})\mathbf{j}$$

(c) **a** = **F**/m = $\mathbf{a} = \frac{\mathbf{F}}{\mathrm{m}} = \frac{1}{1.67\times10^{-27}kg}\left[(1.38\times10^{-19}\ \mathrm{N})\mathbf{j} + (6.41\times10^{-19}\ \mathrm{N})\mathbf{k}\right]$

$$\mathbf{a} = \frac{\mathbf{F}}{\mathrm{m}} = \left[8.26\times10^{7}\ \mathrm{m/s^2})\mathbf{j} + (3.84\times10^{8}\ \mathrm{m/s^2})\mathbf{k}\right]$$