1. PSES 24.P.010. [317713] The electric field everywhere on the surface of a thin spherical shell of radius 0.750 m is measured to be 910 N/C and points radially toward the center of the sphere.

(a) What is the net charge within the sphere's surface?

\[ Q = \frac{\text{nC}}{60} \]

(b) What can you conclude about the nature and distribution of the charge inside the spherical shell?

- The positive charge has an asymmetric charge distribution
- The positive charge has a spherically symmetric charge distribution
- The negative charge has an asymmetric charge distribution
- The negative charge has a spherically symmetric charge distribution

\[ \int \vec{E} \cdot d\vec{a} = \frac{9\varepsilon_0}{Q} \]

\[ E \cdot 4\pi R^2 = \frac{9\varepsilon_0}{Q} \Rightarrow \frac{9\varepsilon_0}{Q} = \frac{E \cdot 4\pi R^2 \varepsilon_0}{Q} = (9\cdot10^9) \cdot 4\pi \cdot (0.75)^2 \cdot (8.85 \times 10^{-12}) \]

\[ |Q| = 56.9 \text{ nC} \Rightarrow \quad Q = -56.9 \text{ nC} \]

b) Negative charge, spherically symmetric b/c its points radially inward.

2. PSES 23.QQx.002. [348710] Two point charges, \( q_1 = +q \) and \( q_2 = -2q \), are fixed at positions on the x-axis, as shown below. If you were to place a third point charge somewhere so that the force on it would be zero, you should place that charge at which location?

- Off of the x-axis
- On the x-axis to the right of the two charges
- On the x-axis in between the two charges
- On the x-axis to the left of the two charges

\[ \vec{F}_1 \text{ will be attractive, } \vec{F}_2 \text{ will be repulsive and } |\vec{F}_1| > |\vec{F}_2| \text{ for equal distances.} \]

\[ q \text{ must be placed to the left of the 2 charges.} \]
3. PSEB 23.QX.003. [345706] Many types of molecules may be modeled as dipoles. For example, two molecules modeled as simple dipoles are aligned on the x-axis, as shown. Each dipole consists of a positive charge $q$ and negative charge $-q$, separated by a distance $d$. The distance between the centers of the two dipoles is $x$. Considering the forces due to all four charges, the net force of one dipole on the other will be which of the following?

- zero
- it depends on the relative distances $d$ and $x$
- attractive
- repulsive

By Forces

Look at the 4 forces:

2 are repulsive:

$F_{13} = kq^2 \left( \frac{1}{(x+d)^2} \right) x^3$

$F_{24} = kq^2 \left( \frac{1}{(x-d)^2} \right) x^3$

Total repulsive force:

$F_{rep} = F_{13} + F_{24} = kq^2 \left( \frac{2}{(x+d)^2} \right)$

2 are attractive:

$F_{31} = -kq^2 \left( \frac{1}{x^2} \right) x^3$

$F_{42} = -kq^2 \left( \frac{1}{(x+2d)^2} \right) x^3$

Total attractive force:

$F_{attractive} = F_{31} + F_{42} = -kq^2 \left( \frac{1}{(x+d)^2} + \frac{1}{x^2} \right)$

Combining the two:

$F_{net} = -kq^2 \left( \frac{6d^2x^2 + 12d^3x - 4dx^4}{x^2(x+2d)^2(x+d)^2} \right)$

By Energy

$U = -\vec{p} \cdot \vec{E}$

$\vec{p} =$ dipole of one, $\vec{E} =$ electric field of the other.

Energy wants to be minimized. If the dipoles move apart, $\vec{E}$ decreases $(E = \frac{1}{d})$ and $U$ becomes less negative, so energy increases.

If the dipoles move together, $\vec{E}$ increases and $U$ becomes more negative, so energy decreases.

\[ \therefore \text{dipoles want to move together and the force is attractive} \]
4. PSEB 25.CQ.002. [328502] A negative charge moves in the direction of a uniform electric field. Does the potential energy of the charge increase or decrease?

- decrease
- increase

Does it move to a position of higher or lower potential?

- higher potential

\[ \Delta V = - \int_A^B E \cdot dl \]

For uniform \( E \):

\[ \Delta V_{AB} = -Ed, \quad \text{so} \quad \Delta V_{AB} \text{ will be negative} \]

\[ \Delta U_{AB} = q \Delta V_{AB} \quad \text{which will be positive} \]

\[ \therefore \text{potential energy will increase} \]

However, the charge moves to a position of lower potential.

5. PSEB 25.P.006. [317788] The difference in potential between the accelerating plates in the electron gun of a TV picture tube is about 25040 V. If the distance between these plates is 1.50 cm, find the magnitude of the uniform electric field in this region.

\[ |E| = \frac{\Delta V}{d} = \frac{25040 V}{0.015 m} = 1.67 \times 10^6 \text{ N/C} \]

= 1.67 MN/C
6. Two conductors of the same length and radius are connected across the same potential difference. One conductor has twice the resistance of the other. To which conductor is more power delivered?
   - Equal amount of power delivered to both conductors,
   - conductor with higher resistance
   - conductor with lower resistance

   \[
   P_1 = \frac{V^2}{R_1} \quad P_2 = \frac{V^2}{R_2}
   \]

   \[ R_2 = 2R_1 \quad \text{so} \quad P_2 = \frac{V^2}{2R_1} \]

   \[ P_1 = 2P_2 \quad \text{and conductor of lower resistance gets more power} \]

7. An electric current is given by the expression \( I(t) = 120 \sin(120 \pi t) \), where \( I \) is in amperes and \( t \) is in seconds. What is the total charge carried by the current from \( t = 0 \) to \( t = \frac{1}{360} \) s?

   \[
   I(t) = 120 \sin(120 \pi t)
   \]

   \[ I = \frac{dQ}{dt} \Rightarrow dQ = I \, dt \Rightarrow Q = \int I \, dt \]

   \[
   Q = \int_{0}^{\frac{1}{360}} 120 \sin(120 \pi t) \, dt
   \]

   \[ = \left. \frac{120}{120 \pi} \cos(120 \pi t) \right|_{0}^{\frac{1}{360}} \]

   \[ = \frac{120}{120 \pi} (0.5 - 1) = \frac{1}{2 \pi} (-0.5) = \frac{1}{180} \text{C} \]

   \[ = 0.159 \text{C} \]
8. PSE6 28.QQ.009. Consider the circuit in Figure 28.19 and assume that the battery has no internal resistance.

![Circuit Diagram](image)

**Figure 28.19**

Just after the switch is closed, the potential difference across which of the following is equal to the emf of the battery?

---Select---

After a very long time, the potential difference across which of the following is equal to the emf of the battery?

---Select---

a) Just after switch is closed, there is no charge on the capacitor and \( V_c = 0 \). So, the potential across the resistor equals the emf of the battery.

b) A long time after the switch is closed, no current is flowing so \( V_R = 0 \). The potential across the capacitor equals the emf.
9. Consider the circuit in Figure 28.22 and assume that the battery has no internal resistance.

![Figure 28.22](image)

Just after the switch is closed, the current in the battery is which of the following?

- zero
- \( \frac{v}{2R} \)
- \( 2v / R \)
- \( v / R \)
- impossible to determine

At \( t=0 \), the capacitor acts like a wire.

\[
\frac{1}{R_0} = \frac{1}{R} + \frac{1}{R} \Rightarrow R_0 = \frac{R}{2}
\]

\[
I = \frac{V}{R_0} \Rightarrow I = \frac{2v}{R}
\]

After a very long time, the current in the battery is which of the following?

- zero
- \( \frac{v}{2R} \)
- \( 2v / R \)
- \( v / R \)
- impossible to determine

As \( t \to \infty \), the capacitor acts like an open circuit.

\[
I = \frac{V}{R}
\]
10. PSE6.30.P038 [317980] A 0.250 A current is charging a capacitor that has circular plates 15.0 cm in radius.

(a) If the plate separation is 4.00 mm, what is the time rate of increase of electric field between the plates?

\[ \frac{dE}{dt} \text{ V/m} \cdot \text{s} \]

(b) What is the magnetic field between the plates 5.00 cm from the center?

\[ B = 1.11 \times 10^{-7} \text{T} \]

\[ C = \frac{A \varepsilon_0}{d} = \frac{\pi (15.0 \text{cm})^2 \varepsilon_0}{(4.00 \text{mm})} = 1.56 \times 10^{-10} \text{F} \]

\[ E = \frac{V}{d} \]

\[ \frac{dE}{dt} = \frac{dV}{dt} = \frac{I}{C} \]

\[ V = \frac{Q}{C} \]

\[ dV = \frac{C}{Q} \]

\[ \frac{dV}{dt} = \frac{(dE)}{C} = \frac{I}{C} \]

\[ E = \frac{V}{d} \]

\[ \frac{dE}{dt} = \frac{(dV)}{dt} = \frac{I}{C} = \frac{1.250 \text{H}}{1.56 \times 10^{-10} \text{F}} = 8.00 \times 10^8 \text{V/m} \]

\[ \frac{dE}{dt} = 4.00 \times 10^8 \text{V/m} \]

\[ B = \frac{\mu_0}{2\pi r} \frac{dE}{dt} \]

\[ B = 1.25 \times 10^{-6} \text{T} \]

\[ B = 1.11 \times 10^{-7} \text{T} \]
11. PSE630Q3002 [328215] For \( i_1 = 2 \) A and \( i_2 = 6 \) A in Figure 30.8, which of the following is true?

\[
\begin{align*}
F_1 &= F_2 / 3 \\
F_1 &= F_2 \\
F_1 &= 3F_2
\end{align*}
\]

\[ F = I \vec{l} \times \vec{B} = I l B \quad \text{w/} \quad \vec{l} \perp \vec{B} \]

\[
\begin{align*}
B_1 &= \frac{M_0 I_1}{2\pi a} \\
B_2 &= \frac{M_0 I_2}{2\pi a}
\end{align*}
\]

**Figure 30.8**

Force on 1 due to 2:

\[
F_{12} = \frac{I_1 l M_0 I_2}{2\pi a}
\]

Force on 2 due to 1:

\[
F_{21} = \frac{I_2 l M_0 I_1}{2\pi a}
\]

\[ F_{12} = F_{21} \]
12. Rank the magnitudes of $\oint \mathbf{B} \cdot d\mathbf{s}$ for the closed paths in Figure 30.10, from greatest to least. (Use only the symbols $>$ or $=$, for example $a > b = c = d$.)

![Figure 30.10](image)

\[
\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{enc}
\]

For:
- $a$: $I_{enc} = 1A + 5A - 2A = 4A$
- $b$: $I_{enc} = 1A - 2A = -1A$
- $c$: $I_{enc} = 1A + 5A = 6A$
- $d$: $I_{enc} = 5A - 2A = 3A$

\[
\oint \mathbf{B} \cdot d\mathbf{s} = 4\mu_0, -\mu_0, 6\mu_0, 3\mu_0
\]

\[c > a > d > b\]

13. Consider the AC circuit in Figure 33.8. The frequency of the AC source is adjusted while its voltage amplitude is held constant. The lightbulb will glow the brightest at which of the following?

- the brightness will be the same at all frequencies
- low frequencies
- high frequencies

\[Z = \sqrt{R^2 + (X_L - X_C)^2}\]

\[X_C = 0, \quad X_L = \omega L\]

\[Z = \sqrt{R^2 + (\omega L)^2}\]

\[I_p = \frac{V_L}{Z}\]

Minimizing $Z$ will maximize $I_p$, which will maximize brightness.

Minimum $Z$ occurs when $\omega$ is minimized, so want low frequencies.

![Figure 33.8](image)
14. Label each part of Figure 33.17 as being \( X_L > X_C \), \( X_L = X_C \), or \( X_L < X_C \).

(a) \[ \text{Select}\]
(b) \[ \text{Select}\]
(c) \[ \text{Select}\]

See graph on p. 869

1. at \( \omega = \omega_0 \), \( X_L = X_C \) and phase difference is zero \( (\phi = 0) \)
2. for \( \omega < \omega_0 \), \( X_C > X_L \) and current leads voltage \( (\phi < 0) \)
3. for \( \omega > \omega_0 \), \( X_L > X_C \) and voltage leads current \( (\phi > 0) \)

a) \( X_L > X_C \) \( (3^{rd} \text{ situation}) \)

b) \( X_C > X_L \) \( (2^{nd} \text{ situation}) \)

c) \( X_C = X_L \) \( (1^{st} \text{ situation}) \)
A dish antenna having a diameter of 22.0 m receives (at normal incidence) a radio signal from a distant source, as shown in Figure P34.51. The radio signal is a continuous sinusoidal wave with amplitude $E_{\text{max}} = 0.500 \, \mu\text{V/m}$. Assume the antenna absorbs all the radiation that falls on the dish.

**Figure P34.51**

(a) What is the amplitude of the magnetic field in this wave?

\[ B = \frac{E}{c} = \frac{0.500 \, \mu\text{V/m}}{3 \times 10^8 \, \text{m/s}} = 1.67 \times 10^{-15} \, \text{T} \]

(b) What is the intensity of the radiation received by this antenna?

\[ S_{\text{av}} = \frac{E_{\text{max}}^2}{2\mu_0 c} = \frac{(0.500 \, \mu\text{V/m})^2}{2 \times 10^{-7} \, \text{V/m} \cdot \text{m}^2/\text{W}} = 3.32 \times 10^{-16} \, \text{W/m}^2 \]

(c) What is the power received by the antenna?

\[ P_{\text{av}} = S_{\text{av}} A = (3.32 \times 10^{-16} \, \text{W/m}^2)(\pi (11 \, \text{m})^2) = 1.26 \times 10^{-13} \, \text{W} \]

(d) What force is exerted by the radio waves on the antenna?

\[ F = \frac{P_{\text{av}}}{c} = \frac{1.26 \times 10^{-13} \, \text{W}}{3 \times 10^8 \, \text{m/s}} = 4.21 \times 10^{-22} \, \text{N} \]
16. PSEB 34.QQ.001, [328164] What is the phase difference between the sinusoidal oscillations of the electric and magnetic fields in Figure 34.3?

- $180^\circ$
- $0$
- $90^\circ$
- impossible to determine

From the graphs, $E$ and $B$ are changing in the same manner with change in time.

17. PSEB 35.QQ.008, [328592] A beam of white light is incident on a crown glass-air interface as shown in Figure 35.26a. The incoming beam is rotated clockwise, so that the incident angle $\theta$ increases. Because of dispersion in the glass, some colors of light experience total internal reflection (ray 5 in Figure 35.26a) before other colors, so that the beam refracting out of the glass is no longer white. The last color to refract out of the upper surface is which of the following?

- red
- violet
- blue
- green
- impossible to determine
- yellow

Check the 2 extremes: violet and red. $n = \frac{c}{v}$ and $v = \lambda f \Rightarrow n = \frac{c}{\lambda f}$

$\lambda_{\text{red}}$ is longest $\Rightarrow$ $n_{\text{red}}$ is smallest

$\lambda_{\text{violet}}$ is shortest $\Rightarrow$ $n_{\text{violet}}$ is greatest

red: $\theta_{\text{red}} = \sin^{-1} \left( \frac{1}{n_{\text{red}}} \right)$

violet: $\theta_{\text{violet}} = \sin^{-1} \left( \frac{1}{n_{\text{violet}}} \right)$

b/c $n_{\text{red}} < n_{\text{violet}}$, $\theta_{\text{red}} > \theta_{\text{violet}}$

red is last color to undergo internal reflection.
19. PSE6 35 QQk 005. [340739] You shine a beam of light from glass into air at an angle that is exactly at the critical angle, so that the refracted ray is along the glass-air interface (bottom left). You repeat the experiment but place a thin sheet of a different type of glass, with a lower index of refraction, on top of the original piece (bottom right). If you now shine the beam at exactly the same angle as in the first experiment, which of the following will occur?

- The ray will not make it out of the original glass, but will be totally internally reflected.
- A ray will travel along the glass/new glass interface.
- A ray of light will emerge from the top piece of glass into the air at some refracted angle less than 90°.
- A ray will travel into the new glass but then become totally internally reflected at the air interface.
- A ray will travel along the air/new glass interface.

\[
\sin \theta_c = \frac{n_i}{n_f} \Rightarrow \theta_c = \sin^{-1} \left( \frac{1}{n_i} \right)
\]

1st interface: \( n_1 \sin \theta_c = n_3 \sin \theta_2 \)

\[
n_1 \sin \left( \sin^{-1} \left( \frac{1}{n_i} \right) \right) = n_3 \sin \theta_2
\]

\[
\frac{n_1}{n_1} = \frac{n_3 \sin \theta_2}{1}
\]

\[
\Rightarrow \sin \theta_2 = \frac{1}{n_3}
\]

2nd interface:

\[
\theta_3 = \theta_2
\]

and \( \sin \theta_2 = \frac{1}{n_3} \Rightarrow \sin \theta_3 = \frac{1}{n_3} \)

This is the critical angle condition: \( \sin \theta_c = \frac{1}{n_i} \)

so \( \theta_3 = \theta_c \)

\[ \therefore \] The ray will travel along the air/new glass interface.
20. Plane-polarized light is incident on a single polarizing disk with the direction of $E_0$ parallel to the direction of the transmission axis. Through what angle should the disk be rotated so that the intensity in the transmitted beam is reduced by a factor of each of the following?

(a) 3.40
(b) 5.20
(c) 12.4

Use $S = S_0 \cos^2 \theta$

a) $S = 3.40S_0 \cos^2 \theta$

\[
\frac{1}{3.4} = \cos^2 \theta \quad \Rightarrow \quad \cos \theta = \sqrt{\frac{1}{3.4}} \quad \theta = \cos^{-1}\left(\sqrt{\frac{1}{3.4}}\right) \quad \theta = 57.2^\circ
\]

b) $S = 5.20S_0$

\[
\frac{1}{5.2} = \cos^2 \theta \quad \Rightarrow \quad \theta = \cos^{-1}\left(\sqrt{\frac{1}{5.2}}\right) \quad \theta = 64^\circ
\]

c) $S = 12.4S_0$

\[
\frac{1}{12.4} = \cos^2 \theta \quad \Rightarrow \quad \theta = \cos^{-1}\left(\sqrt{\frac{1}{12.4}}\right) \quad \theta = 73.5^\circ
\]

21. Suppose the slit width in Figure 38.6 is made twice as wide. The central bright fringe does which of the following?

- becomes wider
- remains the same
- becomes narrower

\[\phi = \frac{2\pi}{\lambda} \sin \theta\] and \[S_\theta = \frac{S_o \sin^2(\phi/2)}{(\phi/2)^2}\]

If $a$ is doubled, $\phi$ increases. When $\phi$ increases, the argument of $\sin^2(\phi/2)$ increases. This increase in the argument makes the $\sin^2$ function more narrow.