Name ______________________ Date ______________

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# PH 102 Quiz 3: A Mixed Bag

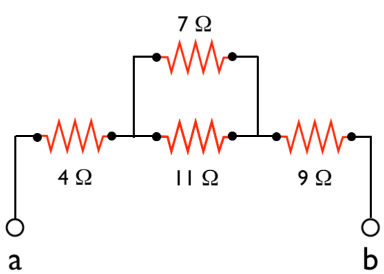
1. A light bulb has a resistance of $230\,\Omega$ when operated at a voltage of $120\,\mathrm{V}$. What is the current in the bulb? Recall $1\,\mathrm{mA} = 10^{-3}\,\mathrm{A}$.

- ◯ 1.92 A
- ⊗ 522 mA
- ◯ 256 mA
- ◯ 1.04 A

We know the resistance $R = 230\,\Omega$, and the voltage $V = 230\,\mathrm{Volts}$. We can get the current from Ohm's law:

$$R = \frac{V}{I} \qquad \Rightarrow \qquad I = \frac{V}{R}$$

$$I = \frac{120\,\mathrm{Volts}}{230\,\Omega} = 0.522\,\frac{\mathrm{Volts}}{\Omega} = 0.522\,\mathrm{Amps} = 522\,\mathrm{mA}$$




2. What is the equivalent resistance between points $a$ and $b$?

- ◯ 31.1 Ω
- ◯ 12.5 Ω
- ⊗ 17.3 Ω
- ◯ 20.8 Ω

First, note that you can combine the middle two resistors ($7\,\Omega$ and $11\,\Omega$ which are just in a simple parallel combination. The equivalent resistance for these two is:

$$\frac{1}{R_{\mathrm{eq},7-11}} = \frac{1}{7} + \frac{1}{11} = 0.234$$

$$\Rightarrow \quad R_{\mathrm{eq},7-11} = 4.28\,\Omega$$

Now we have three resistors in *series* - $4\,\Omega$, $4.28\,\Omega$, and $9\,\Omega$. Resistors in series just add together, so the total equivalent resistance is:

$$R_{\mathrm{eq,total}} = 4 + 4.28 + 9 = 17.28 \approx 17.3\,\Omega$$

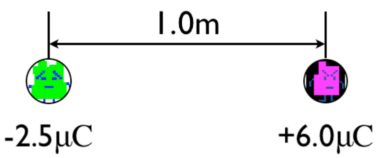
3. A capacitor with air between its plates is charged to $120\,\mathrm{V}$ and then disconnected from the battery. When a piece of glass is placed between the plates, the voltage across the capacitor drops to $30\,\mathrm{V}$. What is the dielectric constant of the glass? (Assume the glass completely fills the space between the plates.)

- ⊗ 4
- ◯ 2
- ◯ 1/4
- ◯ 1/2

Without the piece of glass, our capacitor has a value we'll call $C$. The charge stored on the capacitor is $Q = CV = 120C$ when the initial voltage is $V_{\text{initial}} = 120\,\text{V}$. The piece of glass acts as a dielectric, which increases the capacitance to $\kappa C$ ($\kappa$ is always greater than 1).

Since the battery was disconnected, after inserting the piece of glass the total amount of charge $Q$ stays the same - there is no source for additional charge to enter the capacitor. Now, however, the voltage $V_{\text{final}}$ is less and the capacitance is more. We can set the initial amount of charge before inserting the glass equal to the final charge after inserting the glass, and solve for $\kappa$:

$$\begin{aligned} Q &= CV_{\text{initial}} = \kappa C V_{\text{final}} \\ &= \cancel{C}V_{\text{initial}} = \kappa \cancel{C} V_{\text{final}} \\ V_{\text{initial}} &= \kappa V_{\text{final}} \\ \kappa &= \frac{V_{\text{initial}}}{V_{\text{final}}} = \frac{120}{30} = 4 \end{aligned}$$




4. Determine the point (other than infinity) at which the total electric field is zero. This point is not between the two charges.

○ 3.5 m to the left of the negative charge
○ 2.1 m to the right of the positive charge
○ 1.3 m to the right of the positive charge
⊗ 1.8 m to the left of the negative charge

By symmetry, we can figure out on which side the field should be zero. In between the two charges, the field from the positive and negative charges *add together*. The force on a fictitious positive test charge placed in between the two would experience a force to the left due to the positive charge, and another force to the left due to the negative charge. There is no way the fields can cancel here.

If we place a positive charge to the *right of the positive charge*, it will feel a force to the right from the positive charge, and a force to the left from the negative charge. The directions are opposite, but the fields still cannot cancel because the test charge is closest to the larger charge.

This leaves us with points to the left of the negative charge. The forces on a positive test charge will be in opposite directions here, and we are closer to the smaller charge. What position gives zero field? First, we will call the position of the negative charge $x = 0$, which means the positive charge is at $x = 1\,\text{m}$. We will call the position where electric field is zero $x$. The distance from this point to the negative charge is just $x$, and the distance to the positive charge is $1 + x$. Now write down the electric field due to each charge:

$$\begin{aligned} E_{\text{neg}} &= \frac{k_e(-2.5\,\mu\text{C})}{x^2} \\ E_{\text{pos}} &= \frac{k_e(6\,\mu\text{C})}{(1+x)^2} \end{aligned}$$

The field will be zero when $E_{\text{neg}} + E_{\text{pos}} = 0$

$$\begin{aligned}
E_{\text{neg}} + E_{\text{pos}} &= 0 \\
\frac{k_e(-2.5\,\mu\text{C})}{x^2} + \frac{k_e(6\,\mu\text{C})}{(1+x)^2} &= 0 \\
\frac{\cancel{k_e}(-2.5\,\cancel{\mu\text{C}})}{x^2} + \frac{\cancel{k_e}(6\,\cancel{\mu\text{C}})}{(1+x)^2} &= 0 \\
\frac{-2.5}{x^2} + \frac{6}{(1+x)^2} &= 0 \\
\Rightarrow \qquad \frac{2.5}{x^2} &= \frac{6}{(1+x)^2}
\end{aligned}$$

Cross multiply, apply the quadratic formula.

$$\begin{aligned}
2.5(1+x)^2 &= 6x^2 \\
2.5 + 5x + 2.5x^2 &= 6x^2 \\
3.5x^2 - 5x - 2.5 &= 0 \\
\Rightarrow \qquad x &= \frac{-(-5) \pm \sqrt{5^2 - 4(-2.5)(3.5)}}{2(3.5)} \\
x &= \frac{5 \pm \sqrt{25+35}}{7} \\
x &= \frac{5 \pm 7.75}{7} = 1.82, -0.39
\end{aligned}$$

Which root do we want? We wrote down the distance $x$ the distance to the *left* of the negative charge. A negative value of $x$ is then in the wrong direction, in between the two charges, which we already ruled out. The positive root, $x = 1.82$, means a distance 1.82 m to the *left* of the negative charge. This is what we want.

5. A flat surface having an area of $3.2\,\text{m}^2$ is rotated in a uniform electric field of magnitude $E = 5.7 \times 10^5\,\text{N/C}$. What is the electric flux when the electric field is parallel to the surface?

- ◯ $1.82 \times 10^6\,\text{N} \cdot \text{m}^2/\text{C}$
- ⊗ $0\,\text{N} \cdot \text{m}^2/\text{C}$
- ◯ $3.64\,\text{N} \cdot \text{m}^2/\text{C}$
- ◯ $0.91\,\text{N} \cdot \text{m}^2/\text{C}$

Remember that electric flux is $\Phi_E = EA\cos\theta$, where $\theta$ is the angle between a line perpendicular to the surface and the electric field. If $E$ is *parallel* to the surface, then $\theta = 90$ and $\Phi_E = 0$.

Put more simply, there is only an electric flux if field lines penetrate the surface. If the field is parallel to the surface, no field lines penetrate, and there is no flux.