PHYS120 Test 1 Recap

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Question 1

A calcium $2+$ ion (Ca^{2+}) has 20 protons, 20 neutrons and 18 electrons. What is the charge on this ion?

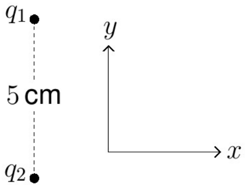
Objects are generally electrically neutral since they have the same number of protons and electrons (the same amount of positive charge as negative charge).
The ^{40}Ca atom has 20 protons and 20 neutrons, so it is electrically neutral.
The calcium $2+$ ion (Ca^{2+}) has 20 protons, 20 neutrons and 18 electrons. It has two more protons than electrons.
The charge on the calcium $2+$ ion is therefore

$$2 \times e = 3.20 \times 10^{-19}\,\text{C}$$

where $e = 1.60 \times 10^{-19}$ is the charge of a proton, the fundamental unit of charge.

Question 2

Two stationary point charges $q_1 = -3\,\mu C$ and $q_2 = -6\,\mu C$ are located in a vacuum a distance 5 cm apart as shown. What is the <u>force</u> on q_2, the $-6\,\mu C$ charge?



Since q_1 and q_2 are both negative, the force is repulsive and therefore points in the $-y$-direction.
The force $\mathbf{F}_{12}$ must point be given in terms of $-\hat{\mathbf{y}}$.

Question 2

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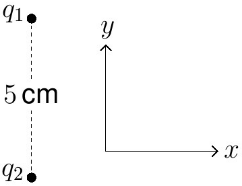
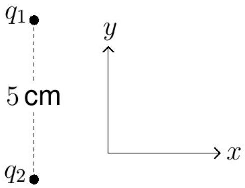


$$\mathbf{F}_{12} \neq k_e \frac{(-3\times 10^{-6})(-6\times 10^{-6})}{(0.05)^2}\,\hat{\mathbf{y}}\,\text{N}$$

$$\mathbf{F}_{21} = k_e \frac{(3\times 10^{-6})(6\times 10^{-6})}{(0.05)^2}\,\hat{\mathbf{y}}\,\text{N}$$

Question 2

Two stationary point charges $q_1 = -3\,\mu\text{C}$ and $q_2 = -6\,\mu\text{C}$ are located in a vacuum a distance 5 cm apart as shown. What is the force on q_2, the $-6\,\mu\text{C}$ charge?

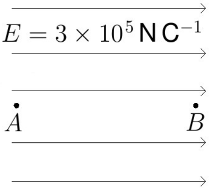


The correct answer is

$$\mathbf{F}_{12} = -k_e \frac{(3 \times 10^{-6})(6 \times 10^{-6})}{(0.05)^2} \, \hat{\mathbf{y}} \, \text{N}$$

Question 3

A point charge of $-3\,\mu C$ is placed midway between points A and B in a uniform electric field E as shown. Which of the following statements is correct?



A *positive* charge moves in the direction of the electric field, due to the electrostatic force it experiences because of the field.
A *negative* charge moves in the opposite direction to the field.

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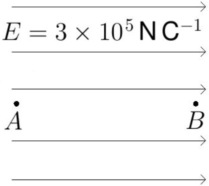

The *magnitude* of the force the negative charge experiences is

$$F = |q|E = (3 \times 10^{-6}) \times (3 \times 10^{5}) = 0.9\,\mathrm{N}$$

Question 3

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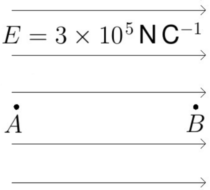
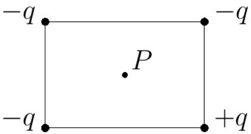


The correct statement from the available options was:
There is a force of 0.9 N acting on the charge in the direction of point A.

Question 4

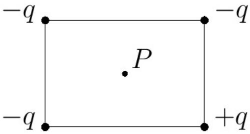
Point charges are located at the corners of a rectangle, as shown. What is the resultant electric field $\mathbf{E}_{\text{RES}}$ at the centre P of the rectangle?

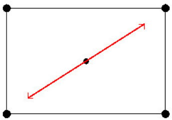


Use symmetry first.

Question 4

Point charges are located at the corners of a rectangle, as shown. What is the resultant electric field $\mathbf{E}_{\mathrm{RES}}$ at the centre P of the rectangle?





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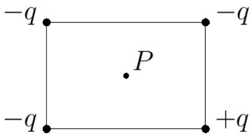
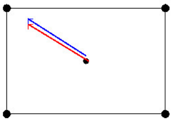
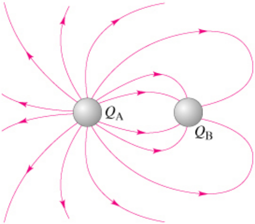




Question 5

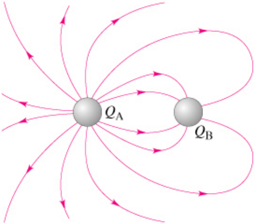
The diagram above shows the electric field pattern in the region around two charges Q_A and Q_B. Which of the following statements is true?



Field lines start at positive charges and end at negative charges. Clearly Q_A is a positive charge, while Q_B is a negative charge.

Question 5

The diagram above shows the electric field pattern in the region around two charges Q_A and Q_B. Which of the following statements is true?



The number of field lines is related to the strength of the field - more field lines means the field is stronger.
The field close to Q_A is stronger than the field close to Q_B, therefore its magnitude $|Q_A|$ is greater than the magnitude $|Q_B|$ of Q_B.

Question 5

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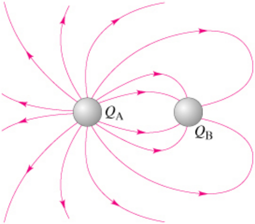


The correct statement from the available options was:
Q_A is a positive charge and Q_B is a negative charge and $|Q_A| > |Q_B|$.

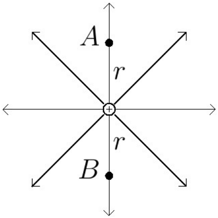
Question 6

Which of the following is the definition of the electric potential?

The electric potential (and the potential difference) is a work per unit charge.
The work done on the charge must be done *slowly* over some distance.
The correct statement from the available options was:
The electric potential at a point P is the work done per unit charge on any charge to move it slowly from a reference position to the point P.

Question 7

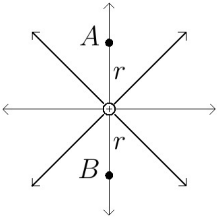
With reference to the diagram alongside, showing the electric field around a point charge, which of the following statements is true?



The electric field at A points in a different direction to the electric field at B, therefore $\mathbf{E}_A \neq \mathbf{B}_B$.
The electric potential (and the field) depends on the positive charge in the centre. The electric potential is the same at every point that is the same distance from the charge.
The potential V_A at A has to equal the potential V_B at B, since both points are a distance r away from the charge.

Question 7

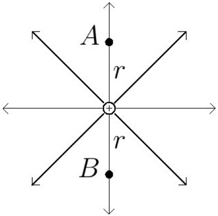
With reference to the diagram alongside, showing the electric field around a point charge, which of the following statements is true?



Since the electric field at a point depends on the charge that creates it as well as the distance from that point to the charge, the *magnitude* of the electric field at A and B has to be equal.
Therefore $E_A = E_B$ (which is not the same as $\mathbf{E}_A = \mathbf{B}_B$).

Question 7

With reference to the diagram alongside, showing the electric field around a point charge, which of the following statements is true?

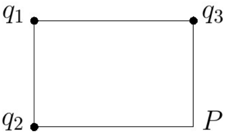


The correct statement from the available options was:

$$E_A = E_B \text{ and } V_A = V_B$$

Question 8

Three point charges q_1, q_2 and q_3 are arranged on three corners of a rectangle of length 4.00 m and width 3.00 m, as shown. If the value of the charges are $q_1 = -8.00$ nC, $q_2 = 3.00$ nC and $q_3 = -10.0$ nC, what is the electric potential V at the fourth corner, point P?



Charges q_1, q_2 and q_3 are at distances of 5.00 m, 4.00 m and 3.00 m, respectively, from the point P.
The electric potential at P depends only on the charge and its distance from P, and not on direction.

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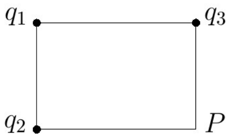
Three point charges q_1, q_2 and q_3 are arranged on three corners of a rectangle of length 4.00 m and width 3.00 m, as shown. If the value of the charges are $q_1 = -8.00$ nC, $q_2 = 3.00$ nC and $q_3 = -10.0$ nC, what is the electric potential V at the fourth corner, point P?



The principle of superposition applies to the electric potential (as it does to the electrostatic force and the electric field), so the potential at P is the sum of the potentials due to all of the charges present.

$$V = k_e \left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} \right]$$

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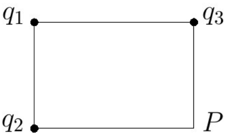

The values of the charges should have been $q_1 = -8.00$ nC, $q_2 = -10.0$ nC and $q_3 = 3.00$ nC.

$$
\begin{aligned}
V &= (9.00 \times 10^9) \left[-\frac{8.00}{5.00} - \frac{10.0}{4.00} + \frac{3.00}{3.00} \right] (\times 10^{-9}) \\
&= (9.00) [-1.60 - 2.50 + 1.00] = -27.9 \text{ V}
\end{aligned}
$$

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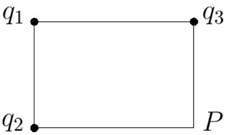


$$
\begin{aligned}
V &= (9.00 \times 10^9)\left[-\frac{8.00}{5.00} + \frac{3.00}{4.00} - \frac{10.0}{3.00}\right](\times 10^{-9}) \\
&= (9.00)\left[-1.60 + 0.75 - 3.33\right] = -37.6\,\text{V}
\end{aligned}
$$

Question 9

A charge of 2.0×10^{-7} C is between two parallel metal plates, separated by 50 mm. The charge experiences a force of 4.0×10^{-2} N in the electric field. The potential difference between the plates is:

Using the relationship between the electric field **E** and the electric potential V

$$\Delta V_{AB} = -\int_A^B E\,dx$$
$$\Rightarrow \frac{\Delta V}{\Delta x} = -E$$

The electric field between two parallel plates is then given by

$$E = \frac{V_0}{d}$$

where V_0 is the potential difference maintained across the plates and d is the plate separation.

Question 9

A charge of 2.0×10^{-7} C is between two parallel metal plates, separated by 50 mm. The charge experiences a force of 4.0×10^{-2} N in the electric field. The potential difference between the plates is:

The charge experiences a force due to the electric field given by

$$F = qE$$

The potential difference V_0 between the plates is then

$$\begin{aligned} \frac{V_0}{d} &= \frac{F}{q} \\ \therefore\ V_0 &= \frac{Fd}{q} \\ &= \frac{(4.0 \times 10^{-2}) \times (50 \times 10^{-3})}{2.0 \times 10^{-7}} \\ &= 10000\,\text{V} = 10\,\text{kV} \end{aligned}$$

Question 10

The potential difference between Q and P (ie V_{QP}) is 90.0 V. Determine the work done in moving an electron from P to Q.

Which point is at a higher potential, Q or P?

$$V_{QP} = V_P - V_Q = 90.0\,\text{V}$$

Therefore V_P is at a higher potential, since the difference is positive. An electron, being a negative charge wants to move from Q to P. Work must therefore be done, to move the electron to move it from P to Q.

Question 10

The potential difference between Q and P (ie V_{QP}) is 90.0 V. Determine the work done in moving an electron from P to Q.

The work done is

$$
\begin{aligned}
W &= qV = (-e)V_{PQ} \\
&= (-e)(-V_{QP}) \\
&= (1.60 \times 10^{-19}) \times (90.0) = 1.44 \times 10^{-17}\,\text{J}
\end{aligned}
$$

Question 11

A 1.10×10^{-4} F capacitor contains 1.20 kJ of stored energy. Determine the voltage needed to store that amount of energy.

The energy stored in a capacitor is the work done W in charging it, given by

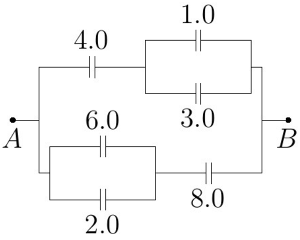
$$W = \frac{1}{2}qV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{q^2}{C}$$

where C is the capacitance, q is the charge on the capacitor and V is the final voltage across the capacitor.
Given W, C, the voltage V needed to store that energy is

$$\begin{aligned} W &= \frac{1}{2}CV^2 \\ \therefore\ V^2 &= \frac{2W}{C} \\ &= \frac{2 \times 1.20 \times 10^3}{1.10 \times 10^{-4}} \\ V &= 4.67 \times 10^3 \text{ V} \end{aligned}$$

Question 12

For the combination of capacitors alongside, what is the equivalent capacitance (where all capacitances are in µF) between A and B?



For the top branch, the equivalent capacitance is

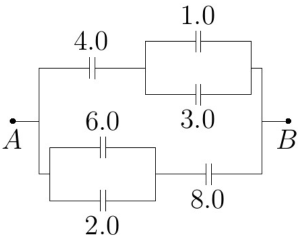
$$C_{\text{eq}}^{\text{top}} = \frac{4 \times 4}{4 + 4} = 2\,\mu\text{F}$$

For the bottom branch, the equivalent capacitance is

$$C_{\text{eq}}^{\text{bottom}} = \frac{8 \times 8}{8 + 8} = 4\,\mu\text{F}$$

Question 12

For the combination of capacitors alongside, what is the equivalent capacitance (where all capacitances are in µF) between A and B?



The equivalent capacitance is therefore

$$C_{\text{eq}}^{\text{AB}} = 2 + 4 = 6\,\mu\text{F}$$

Question 13

A 3.0 µF, 4.0 µF and 12 µF capacitor are connected in series with each other and in series with a 24 V battery. What is the voltage drop across the 12 µF capacitor?

The equivalent capacitance is

$$\frac{1}{C_{\text{eq}}} = \frac{1}{3.0} + \frac{1}{4.0} + \frac{1}{12} = \frac{4+3+1}{12} = \frac{8}{12}$$

The total charge q is the same charge on each capacitor since they are connected in series.

$$q = C_{\text{eq}}V = (1.5 \times 10^{-6}) \times (24) = 36\,\mu\text{C}$$

The voltage across the 12 µF capacitor is then

$$V = \frac{q}{C} = \frac{36 \times 10^{-6}}{12 \times 10^{-6}} = 3.0\,\text{V}$$

Question 14

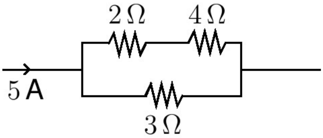
A copper wire, of length 10.0 m and cross-sectional area 6.88×10^{-8} m^2, has a resistivity of $1.72 \times 10^{-8}\,\Omega\,$m. What is the resistance of this length of wire?

The resistance of a conductor depends on its length, cross-sectional area and the resistivity of the material.

$$
\begin{aligned}
R &= \rho \frac{l}{A} \\
&= (1.72 \times 10^{-8}) \times \frac{10.0}{6.88 \times 10^{-8}} \\
&= 2.50\,\Omega
\end{aligned}
$$

Question 15

For the combination of resistors shown below, what is the potential difference across the $3\,\Omega$ resistor?



The equivalent resistance is

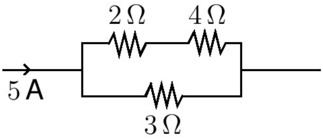
$$R_{\text{eq}} = \frac{3 \times (4+2)}{3 + (4+2)} = 2\,\Omega$$

For a current of 5 A, the potential difference across each branch is

$$V = IR_{\text{eq}} = 5 \times 2 = 10\,\text{V}$$

Question 15

For the combination of resistors shown below, what is the potential difference across the 3 Ω resistor?



Since the potential difference across each branch is 10 V, the potential difference across the 3 Ω resistor is 10 V.