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Where Minds Pollinate

Class 12
Physics

Chapter 19
Exercise Solution

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Short Questions

1) What is the relationship between electric potential and electric potential energy?

The relationship between electric potential and electric potential energy is $V = U/q$. Here V = electric potential, U = electric potential energy and q = charge. Electric potential is the potential energy per unit charge. Electric potential energy is the total energy a charge has due to its position in an electric field.

2) If you wish to store a large amount of energy in a capacitor bank, would you connect capacitors in series or parallel? Explain.

Formula for energy stored in capacitor is $E = 1/2\ CV^2$. As energy stored in capacitor (E) is directly propotional to capacitance (C), hence if capacitors will be connected in parallel ($C = C_1 + C_2 + C_3$) then the capacitance will increase and the energy stored will be large.

3) What are the units of electric potential difference, electric potential ~~difference~~ energy and capacitance?

Electric potential difference: volt (V) or joule per coulomb (J/C)

Electric potential energy: joule (J)

Capacitance: farad (F) = coloumb per volt (C/V)

4) What is the net amount of charge on a charged capacitor?

The net charge on a charged capacitor is zero. This because the capacitor has equal and opposite charges on its two plates. One plate holds $+Q$ and other plate holds $-Q$. So, total charge $Q_{net} = +Q + (-Q) = 0$

5) Write some applications of capacitors in real life.

Energy storage: stores and releases electrical energy in devices like camera flashes.

Power supply smoothing: filter out voltage fluctuations in DC power supplies.

Tuning circuits: used in radios, TVs etc.

Motor Starters: provide the phase shift needed to start single-phase induction motors.

Signal coupling/decoupling: allow AC signals to pass but block DC in amplifiers and audio systems.

Power factor correction: improve efficiency of AC power systems.

6) Would you place the plates of a parallel-plate capacitor closer together or farther apart to increase their capacitance.

The formula for capacitance is $C = \varepsilon_0 \varepsilon_r A/d$. This shows that capacitance C is inversely propotional to the distance d between the parallel plates of the capacitor. Hence the plates of parallel-plate capacitor should be closer to increase the capacitance.

7) What is meant by electroreception?

Electroreception is the biological ability of certain animals to detect electric fields in their environment. Many aquatic animals use electroreception to locate prey, navigate, communicate. It works because living organisms produce weak electric fields due to nerve and muscle activity, which these animals can sense.

8) If you were asked to design a capacitor in which small size and large capacitance were required, what would be the two most important factors in your design?

The formula for capacitance is $C = \varepsilon_0 \varepsilon_r A/d$. This shows that for a small size capacitor with large capacitance, the two most important design factors are:

Large plate area A, increases capacitance.

Small separation d between plates (with high-permittivity), increases capacitance.

9) If a capacitor is fully charged and then left for discharging. How much charge will be left on the plate of the capacitor after time equal to one time constant.

$q(t) = q_0 e^{-t/RC}$

At time = RC

$Q(t) = Q_0 e^{-RC/RC}$

$Q(t) = Q_0 e^{-}$

$Q(t) = Q_0 (2.71)^{-}$

$Q(t) = 0.37\ Q_0$

Hence after one time constant, about 37% of the initial charge remains on the plates.

Numericals

A heart defibrilator delivers 4×10^2 J of energy by discharging a capacitor initially at 1×10^4 V. What is its capacitance?

Data:

$E = 4 \times 10^2$ J

$V = 1 \times 10^4$ V

$C = ?$

Solution:

$E = 1/2\ CV^2$

$C = 2E/V^2$

$C = 2(4 \times 10^2)/(1 \times 10^4)^2$

$C = 8 \times 10^{-6}$ F

$C = 8\mu F$

Two capacitors of capacitance $C_1 = 6\mu F$ and $C_2 = 3\mu F$ are connected in series. Calculate the equivalent capacitance.

Data:

$C_1 = 6\mu F = 6 \times 10^{-6} F$

$C_2 = 3\mu F = 3 \times 10^{-6} F$

$Ce = ?$

Solution:

For series combination of capacitors:

$1/Ce = 1/C_1 + 1/C_2$

$1/Ce = 1/6\times10^{-6} + 1/3\times10^{-6}$

$1/Ce = (1/6 + 1/3)\, 1/10^{-6}$

$1/Ce = (3/6)\, 1/10^{-6}$

$1/Ce = 1/2\times10^{-6}$

$Ce = 2\times10^{-6}$

$Ce = 2\mu F$

A $2200\mu F$ capacitor is charged up with a 1.5V cell. Calculate the charge and energy stored in the capacitor.

Data:

$C = 2200\mu F = 2200\times10^{-6}F$

$V = 1.5V$

$Q = ?$

$E = ?$

Solution:

$Q = CV$

$Q = (2200\times10^{-6})(1.5)$

$Q = 3300\times10^{-6}$

$Q = 3.3\times10^{-3}C$

$Q = 3.3mC$

$E = 1/2\, CV^2$

$E = 1/2(2200\times10^{-6})(1.5)^2$

$E = (1100\times10^{-6})(2.25)$

$E = 0.002475\, J$

$E = 0.00248\, J$

Find the equivalent capacitance for the following circuit if $C_1 = 1pF$, $C_2 = 0.5pF$, $C_3 = 1pF$

The circuit diagram indicates that C_1 and C_3 are in parallel with each other and combination is in series with C_2

Solution:

The equivalent capacitance of C_1 and C_3 in parallel is:

$C_{1-3} = C_1 + C_3 = 1 + 1 = 2pF$

The equivalent capacitance with C_2 in series is:

$1/Ce = 1/C_{1-3} + 1/C_2$

$1/Ce = 1/2 + 1/0.5$

$1/Ce = 0.4pF$

The calculated equivalent capacitance is 0.4pF. However, the provided answer is 1/3pF, suggesting a possible misinterpretation of the circuit configuration or an error in the problem statement.

Suppose electrons in a TV tube are accelerated through a potential difference of $2.0\times10^4 V$ from the heated cathode (where they are produced) toward the screen (which also serves as the anode), 25.0 cm away.

a) At what speed would the electrons impact the phosphors on the screen? Assume they accelerate from rest and ignore relativistic effects.

b) What's the magnitude of the electric field, if it is assumed constant?

Data:

$V = 2\times10^4 V$

$e = 1.6\times10^{-19}C$

$m = 9.1\times10^{-31}kg$

$d = 25cm = 0.25m$

$v = ?$

$E = ?$

Solution:

$v = \sqrt{2eV/m}$

$v = \sqrt{\dfrac{2(1.6\times10^{-19})(2\times10^4)}{9.1\times10^{-31}}}$

$v = \sqrt{\dfrac{6.4\times10^{-15}}{9.1\times10^{-31}}}$

$v = \sqrt{0.7\times10^{16}}$

$v = 0.837\times10^8$

$v = 8.37\times10^7\, ms^{-1}$

$E = V/d$

$E = 2\times10^4/0.25$

$E = 8\times10^4\, Vm^{-1}$

A network of five capacitors C is connected to a 100V supply, as shown in below figure. Determin the equivalent capacitance of the network

Data:

$V = 100V$

$Ce = ?$

Solution:

As three capacitors are in series,

$1/C_3 = 1/C + 1/C + 1/C$

$1/C_3 = 3/C$

$C_3 = C/3$

As two capacitors are in series,

$1/C_2 = 1/C + 1/C$

$1/C_2 = 2/C$

$C_2 = C/2$

Now $C_2 + C_3$ are in parallel,

$Ce = C_2 + C_3$

$Ce = C/2 + C/3$

$Ce = 3C + 2C/6$

$Ce = 5C/6$

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