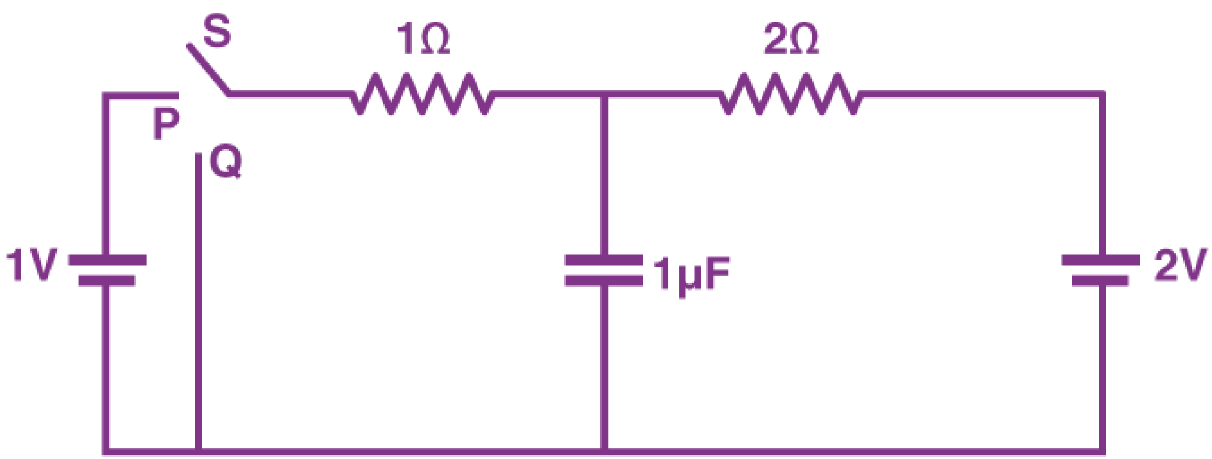
Question 1) In the circuit shown below, the switch S is connected to position P for a long time so that the charge on the capacitor becomes q_1 µC. Then S is switched to position Q. After a long time, the charge on the capacitor is q_2 µC.



The magnitude of q_1 is

Answer : 01.33

Solution:

With switch S at position P after long time potential difference across capacitor branch

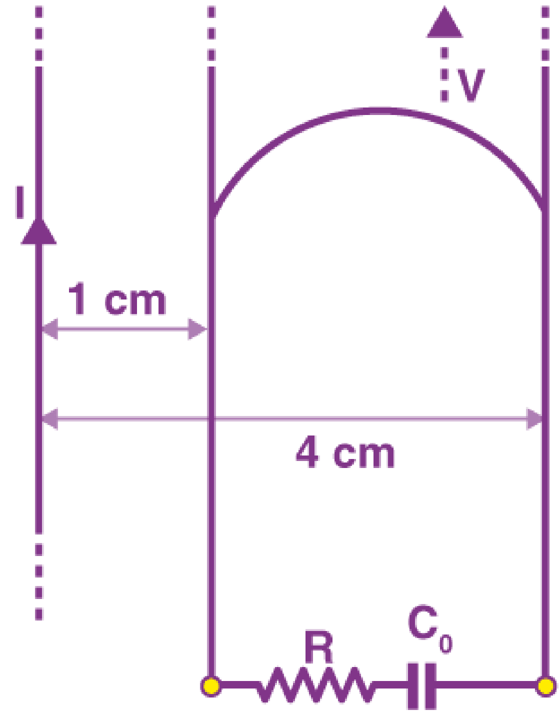
$$\frac{\frac{2}{2}+\frac{1}{1}}{\frac{1}{2}+\frac{1}{1}} = \frac{2\times 1}{3} = (4/3)v$$

Charge on capacitor q_1µC = (4/3) µC

$\Rightarrow q_1 = 4/3 = 1.33$

Question 2) A long straight wire carries a current, I = 2 ampere. A semi-circular conducting rod is placed beside it on two conducting parallel rails of negligible resistance. Both the rails are parallel to the wire. The wire, the rod and the rails lie in the same horizontal plane, as shown in the figure. Two ends of the semicircular rod are at distances 1 cm and 4 cm from the wire. At time t = 0, the rod starts moving on the rails with a speed v = 3.0 m/s (see the figure).

A resistor R = 1.4 and a capacitor C_0 = 5.0 F are connected in series between the rails. At time t = 0, C_0 is uncharged. Which of the following statement(s) is(are) correct? [$\mu_0 = 4 \times 10^{-7}$ SI units. Take ln 2 = 0.7]



(A) Maximum current through R is 1.2×10^{-6} ampere

(B) Maximum current through R is 3.8×10^{-6} ampere

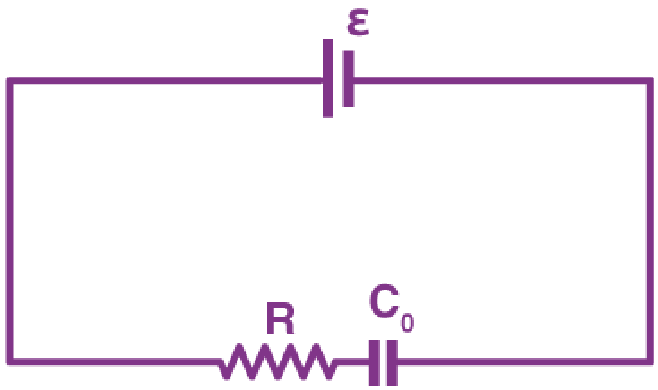
(C) Maximum charge on capacitor C_0 is 8.4×10^{-12} coulomb

(D) Maximum charge on capacitor C_0 is 2.4×10^{-12} coulomb

Answer (A, C)

Solution:

Equivalent circuit of the given arrangement is



$$\epsilon = \frac{\mu_0 I v}{2\pi} In \frac{b}{a}$$

$= 1.68 \times 10^{-6}$ V

At t = 0, $i_{max} = \varepsilon/R = 1.68 \times 10^{-6}/1.4$

$= 1.2 \times 10^{-6}$ A

At $t = \infty$, $q_{max} = C_0\varepsilon = 8.4 \times 10^{-12}$ C

Question 3) A small object is placed at the center of a large evacuated hollow spherical container. Assume that the container is maintained at 0 K. At time t = 0, the temperature of the object is 200 K. The temperature of the object becomes 100 K at $t = t_1$ and 50 K at $t = t_2$. Assume the object and the container to be ideal black bodies. The heat capacity of the object does not depend on temperature. The ratio (t_1/t_2) is ______.

Answer: 9

Solution:

Heat radiated = $e\sigma AT^4$

$= KT^4$

$-mS(dT/dt) = KT^4$

$$-mS\int_{200}^{100}\frac{dT}{T^4} = Kt_1$$

$$t_1 = \frac{1}{K_1}\left[\frac{1}{100^3}-\frac{1}{200^3}\right] = \frac{1}{K_1}\left[\frac{7}{200^3}\right]$$

$$t_2 = \frac{1}{K_1}\left[\frac{1}{50^3}-\frac{1}{200^3}\right] = \frac{1}{K_1}\left[\frac{63}{200^3}\right]$$

$$\frac{t_2}{t_1} = 9$$

Question 4) In a circuit, a metal filament lamp is connected in series with a capacitor of capacitance C μF across a 200 V, 50 Hz supply. The power consumed by the lamp is 500 W while the voltage drop across it is 100 V. Assume that there is no inductive load in the circuit. Take rms values of the voltages. The magnitude of the phase-angle (in degrees) between the current and the supply voltage is ϕ. Assume, π√3 = 5 .

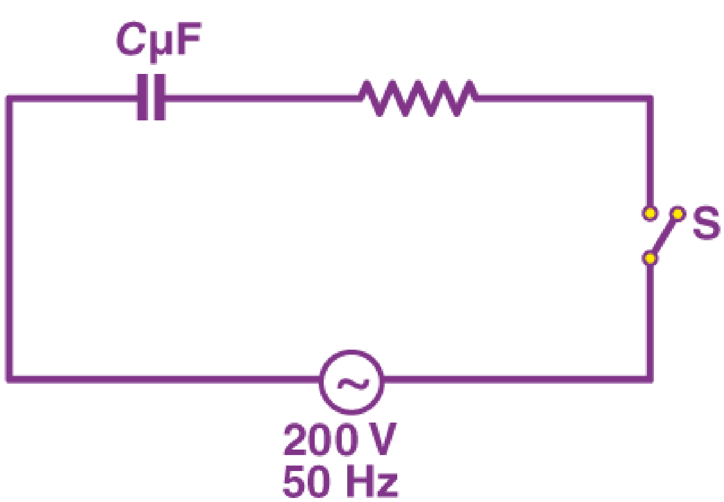
a. The value of C is ___.

Answer (100)

b. The value of ϕ is ___.

Answer (60)

Solution for (a) and (b)



$P = V^2/2$

$\Rightarrow 500 = 100^2/R$

$\Rightarrow R = 20\ \Omega$

Now across resistance $500 = I \times 100$

$\Rightarrow I_{rms} = 5$ A

$V_{rms} = 200$ V,

$V_{rms/real} = 100$ V

$\cos \varphi = 100/200 = ½ \Rightarrow \Phi = 60^0$

$\tan \Phi = X_C / R = 1/\omega RC$

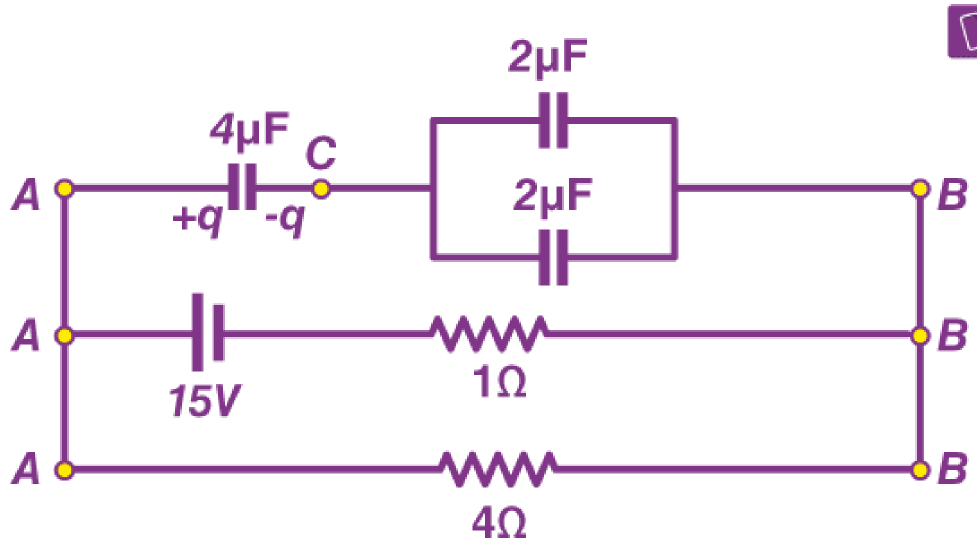
$\sqrt{3} = 1/100\pi(20)C$

$C = 1/(20\pi\sqrt{3} \times 100)$

$= 10^{-4}$ F

$= 100$ μF

Question 5) Find q on 4 μf capacity at t = ∞



(A) 8 μC

(B) 12 μC

(C) 20 μC

(D) 24 μC

Answer: (D)

Solution:

Using i = 15/(4+1) = 3 A

Therefore, $V_{AB} = i \times 4 = 12$ V

$V_{AC} = V_{CB} = 6$ Volt

Therefore, q on 4 μF = CV_{AC} = 24 μC

Question 6) A parallel plate capacitor whose capacitance C is 14pF is charged by a battery to a potential difference V = 12 V between its plates. The charging battery is now disconnected and a porcelain plate with k = 7 is inserted between the plates, then the plate would oscillate back and forth between the plates, with a constant mechanical energy of ____ pJ.(Assume no friction)

Answer. (864)

Solution:

Initial energy stored in capacitor is,

$U_i = (½)\ cv^2$

$= (½) \times 14 \times (12)^2$ pJ

= 1008 pJ

Final energy stored in capacitor is,

$U_f = Q^2/2kC$

$$= \frac{(14\times12)^2}{2\times7\times14}$$

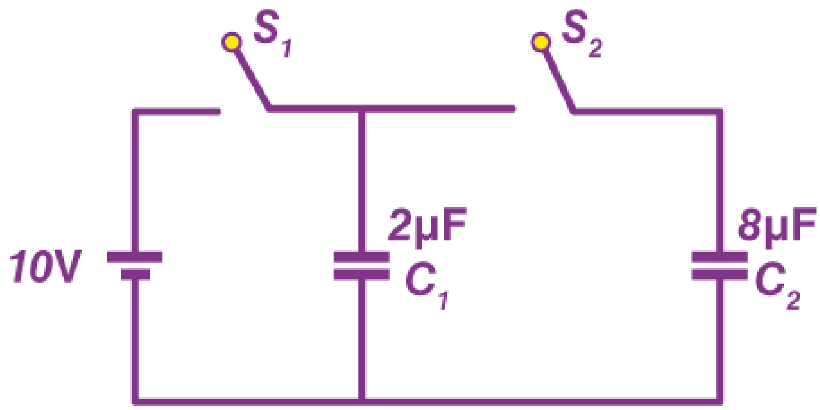
= 144 pJ

oscillating energy = $U_i - U_f$

= 1008 – 144

= 864 pJ

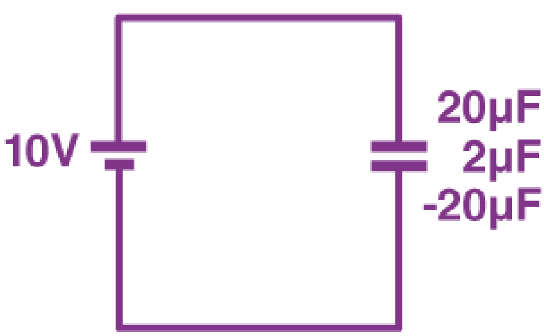
Question 7) A 2μF capacitor C_1 is first charged to a potential difference of 10V using a battery. Then the battery is removed and the capacitor is connected to an uncharged capacitor C_2 of 8 μF. The charge in C_2 on equilibrium condition is ________ μC. (Round off to the Nearest Integer)

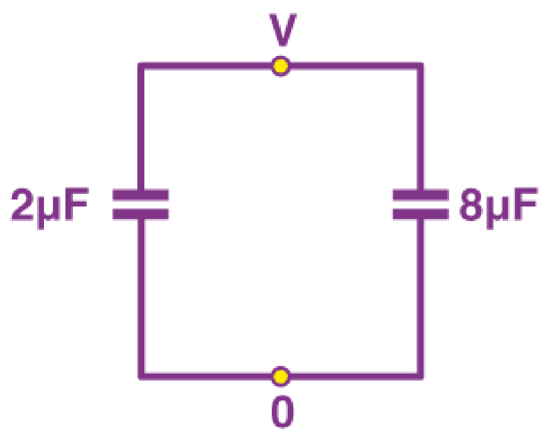


Answer (16)

Solution:

After capacitor C_1 is fully charged,





When battery is removed & the capacitor is connected

At equilibrium condition, let voltage across each capacitor be V.

Then, using conservation of charge

$2V + 8V = 20$

$10V = 20$

$V = 2$ volt

$Q = CV$

$Q = 8 \times 2 = 16\mu c$

Question 8) A parallel plate capacitor whose capacitance C is 14pF is charged by a battery to a potential difference V = 12 V between its plates. The charging battery is now disconnected and a porcelain plate with k = 7 is inserted between the plates, then the plate would oscillate back and forth between the plates, with a constant mechanical energy of ____ pJ.(Assume no friction)

Answer. (864)

Solution:

Initial energy stored in capacitor is,

$U_i = (½)\ cv^2$

$= (½) \times 14 \times (12)^2$ pJ

$= 1008$ pJ

Final energy stored in capacitor is,

$U_f = Q^2/2kC$

$$= \frac{(14\times12)^2}{2\times7\times14}$$

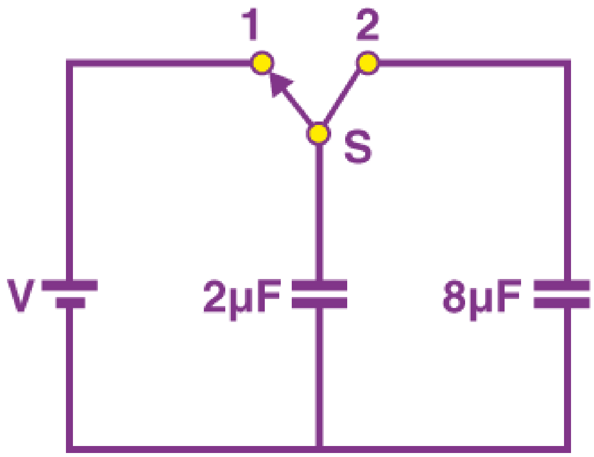
$= 144$ pJ

oscillating energy $= U_i - U_f$

$= 1008 - 144$

$= 864$ pJ

Question 9) A 2μF capacitor is charged as shown in figure. The percentage of its stored energy dissipated after the switch S is turned to position 2 is



(A) 0%

(B) 20%

(C) 75%

(D) 80%

Answer: (D) 80%

Solution:

Initially, the energy stored in a 2μF capacitor is

U_i = (½)CV^2 = (½) (2 x 10^{-6}) V^2 = V^2 x 10^{-6} J

Initially, the charge stored in a 2 μF capacitor is Q_i = C_v = (2 x 10^{-6}) v = 2v x 10^{-6} coulomb. When switch S is turned to position 2,the charge flows and both the capacitors share charges till a common potential V_c is reached.

V_c = total charge/total capacitance

= (2v x 10^{-6})/(2 + 8) x 10^{-6}

= V/5 volt

Finally, the energy stored in both the capacitors

$$U_f = \frac{1}{2}[(2+8)\times 10^{-6}](\frac{V}{5})^2 = \frac{V^2}{5}\times 10^{-6} J$$

Percentage loss of energy, ΔU = [(U_i - U_f)/U_i] x 100 %

$$= \frac{(V^2 - V^2/5) \times 10^{-6}}{V^2 \times 10^{-6}} \times 100\% = 80\%$$

= 80%

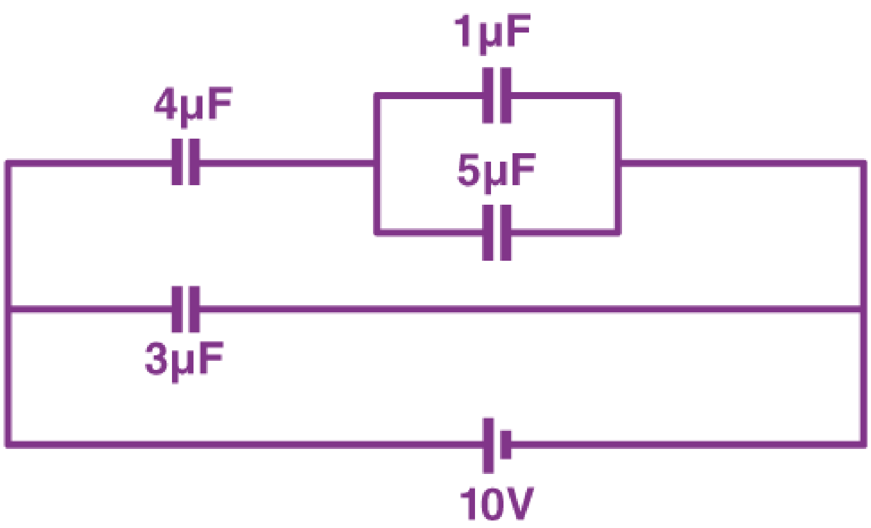
Question 10) In the given circuit, the charge on 4 μF capacitor will be

(A) 5.4 μF

(B) 9.6 μF

(C) 13.4 μF

(D) 24 μF



Answers: (D) 24 μF

Solution:

$V_1 + V_2 = 10$ ------(1)

$4V_1 = 6V_2$ ----------(2)

On solving equation (1) and (2) we get

$V_1 + (4V_1/6) = 10$

$V_1 + (2V_1/3) = 10$

$3V_1 + 2V_1 = 30$

$5V_1 = 30$

$\Rightarrow V_1 = 6$ V

Charge on 4μf,

$q = CV_1 = 4 \times 6 = 24$ μF