Solution

ELECTROSTATIC POTENTIAL AND CAPACITANCE WS 1

Class 12 - Physics

1.

   (d) $\frac{1}{2}CV^2$

   Explanation: $U = \frac{1}{2}CV^2$

2.

   (b) 4

   Explanation: C' = KC (where K is the dielectric constant).

   V = $\frac{Q}{C}$

   V' = $\frac{Q}{C'}$

   V' = $\frac{V}{4} = \frac{Q}{C'} = \frac{Q}{kC} = \frac{V}{k}$

   $\therefore$ k = 4

3.

   (b) $9 \times 10^{-3} J$

   Explanation: Potential energy of a two charge system is given by

   U = $\frac{q_1 q_2}{4\pi\varepsilon_0 r}$

   $= \frac{9 \times 10^9 \times 1 \times 10^{-6} \times 1 \times 10^{-6}}{1}$

   $= 9 \times 10^{-3} J$

4.

   (d) $\frac{16C_1}{n_1 n_2}$

   Explanation: $\frac{1}{2}C_p V^2 = \frac{1}{2}C_s (4V)^2$

   or $\frac{1}{2}n_2 C_2 V^2 = \frac{1}{2}\frac{C_1}{n_1}(4V)^2$

   or $C_2 = \frac{16C_1}{n_1 n_2}$

5. **(a)** $\varepsilon_0 \frac{\mathrm{d}\phi_\mathrm{E}}{\mathrm{dt}}$

   Explanation: $\varepsilon_0 \frac{\mathrm{d}\phi_\mathrm{E}}{\mathrm{dt}}$

6.

   (c) E = 0, but V is same as on the surface and non-zero

   Explanation: The electric field on the surface of a hollow conductor is maximum and it drops to zero abruptly inside the conductor.

   Since $E = -\frac{dV}{dr}$, the potential difference between any two points inside the hollow conductor is zero.

   This means that the potential at all points inside the hollow charged conductor is same and it is equal to the value of the potential at its surface.

7. **(a)** They are concentric spheres for uniform electric fields.

   Explanation: Key Idea: There is no potential gradient along any direction parallel to the surface. Any surface over which the electric potential is the same everywhere is called an equipotential surface. The electric field and hence, lines of force everywhere are at right angles to the equipotential surface. This is so because there is no potential gradient along any direction parallel to the surface and, so no electric field parallel to the surface. This means the electric field and hence, lines of force are always at right angles to the equipotential surface. Hence, they are not concentric spheres for a uniform electric field. They are concentric spheres for an isolated point charge.

8.

   (b) electric polarization

   Explanation: When a dielectric is placed between the plates of a capacitor, electric polarization results in a reverse electric field inside the dielectric. The net electric field reduces and therefore the potential reduces.

   Since, $C = \frac{Q}{V}$

   Thus, the capacitance increases.

9.

(c) 0.2%

Explanation: The initial energy stored in the capacitor at potential difference V is $E=\frac{1}{2}CV^2$

When the p.d is increased by ΔV, the energy stored is $E+\Delta E=\frac{1}{2}C(V+\Delta V)^2$

Solving,

$\frac{E+\Delta E}{E}=\frac{\frac{1}{2}C(V+\Delta V)^2}{\frac{1}{2}CV^2}$

$1+\frac{\Delta E}{E}=\left(\frac{V+\Delta V}{V}\right)^2$

$=\left(1+\frac{\Delta V}{V}\right)^2=1+2\frac{\Delta V}{V}+\left(\frac{\Delta V}{V}\right)^2$

$\because\left(\frac{\Delta V}{V}\right)^2=\left(\frac{0.1}{100}\right)^2=0.000001\approx 0$

$1+\frac{\Delta E}{E}=1+2\frac{\Delta V}{V}$

$\frac{\Delta E}{E}=2\frac{\Delta V}{V}=2\times 0.1\%=0.2\%$

10. **(a)** $12\pi\varepsilon_0\frac{V}{A}$

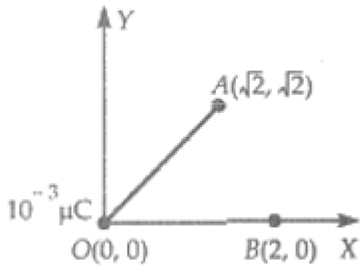
Explanation: $V=\frac{4}{3}\pi R^3$ and A = $4\pi R^2$

$\therefore\frac{V}{A}=\frac{R}{3}\Rightarrow R=\frac{3V}{A}$

$C=4\pi\varepsilon_0 R=4\pi\varepsilon_0\left(\frac{3V}{A}\right)=\frac{12\pi\varepsilon_0 V}{A}$

11. **(a)** zero

Explanation:



OA = $\sqrt{(\sqrt{2}-0)^2+(\sqrt{2}-0)^2}$ = 2

OB = $\sqrt{(2-0)^2+(0-0)^2}$ = 2

$\therefore$ OA = OB

12.

(b) 100 V

Explanation: By conservation of charge, 0.2 $\times$ 600 = (0.2 + 1) V

$\therefore V=\frac{0.2\times 600}{1.2}$ = 100 V

13. **(a)** $\sqrt{1.5}v$

Explanation: At infinity, $V_\infty=0$

At the surface of the sphere, $V_s=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R}$

At the centre of the sphere, $V_c=\frac{1}{4\pi\varepsilon_0}\cdot\frac{3Q}{2R}$

Let m be the mass and -q be the charge of the small particle.

Let V_0 be speed of the particle at the centre of the sphere.

$\frac{1}{2}mv^2=-q\left[V_\infty-V_s\right]=\frac{1}{4\pi\varepsilon_0}\cdot\frac{qQ}{R}$ ...(i)

$\frac{1}{2}mv_0^2=-q\left[V_\infty-V_c\right]=\frac{1}{4\pi\varepsilon_0}\cdot\frac{3qQ}{2R}$ ...(ii)

Dividing (ii) by (i), we get

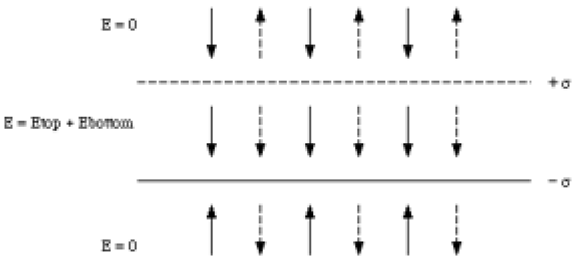
$\frac{v_0^2}{v^2}=\frac{3}{2}$ = 1.5

$\therefore v_0=\sqrt{1.5}v$

14.

(b) outside the plates will be zero

Explanation: The electric field outside two large plates with opposite charge densities will be zero.



The electric field between the plates , having area=2 m^2 of the capacitor is given by :-

$E=\frac{\sigma}{\varepsilon_0}=\frac{\frac{Q}{A}}{\varepsilon_0}$

$=\frac{Q}{A\varepsilon_0}=\frac{8.85\times10^{-10}}{2\times8.85\times10^{-12}}$

= 50 N/C

and it is a constant electric field.

15.

(b) varies as $\frac{1}{r}$ where r is the distance from the axis

Explanation: The electric field at point distance r from the axis of the capacitor and located in the annular region (the region between the two cylinders) of a cylindrical capacitor with linear charge density λ is given by $E=\frac{\lambda}{2\pi\varepsilon_0 r}$

Thus, $E\propto\frac{1}{r}$

This field is higher near the inner cylinder.

16. **(a)** 200 V

Explanation: The break down potential of the capacitor is 220 V. In order to prevent damage to a capacitor, it should be always used in a circuit where the p.d is less than its break down potential. The p.d difference can be 200 V.

17.

(d) A potential difference appears between the two cylinders when inner cylinder is charged.

Explanation: When the charge is given to inner cylinder, then an electric field is produced between cylinders which is given by $E=\frac{\lambda}{2\pi\varepsilon_0 r}$ and due to this a potential difference is developed between two cylinders.

18.

(c) It must cross S at some time

Explanation: A positive charge tends to move from a region of higher potential to that of lower potential. So the positive charge will cross the circle S at some time.

19.

(b) $1\cdot1\times10^{-10}$

Explanation: Here, r = 1 m

Now, C = $4\,\pi\,\varepsilon_0\,r$

= $\frac{1}{9\times10^9}\times1=1\cdot11\times10^{-10}F$

20. **(a)** $\frac{V}{2}$

Explanation: $\frac{V}{2}$

21. **(a)** not be able to reach the plate P_2

Explanation: not be able to reach the plate P_2

22.

(d) -10^{-9}

Explanation: Surface charge density of the earth = -10^{-9} Cm^{-2}

23.

(d) Potential difference

Explanation: As the battery remains connected with the capacitor, the potential difference remains constant.

24.

(d) cylindrical capacitor with outer cylinder earthed

Explanation: A submarine cable consists of an inner conductor which carries power. This conductor is covered by an insulator, which acts as a dielectric. The dielectric material is covered by a metal coating called shield, which is connected to ground. The cable acts as a cylindrical capacitor, with the conductor acting as the inner cylinder, and the metal shield as the outer cylinder which is connected to earth.

25.

(d) 2C

Explanation: The capacitance C of a parallel plate capacitor is given by $C=\frac{\varepsilon_0 A}{d}$

A metal plate of thickness $\frac{d}{2}$ when introduced between the plates reduces the distance between the plates to $\frac{d}{2}$. The effective capacitance becomes

$C_m=\frac{\varepsilon_0 A}{\frac{d}{2}}=\frac{2\varepsilon_0 A}{d}=2C$

26. **(a)** infinite

Explanation: Capacitor does not allow DC to pass through it. The effective capacitance or the capacitive reactance,

$X_C=\frac{1}{C\omega}$

where ω is the frequency of voltage source.

Since DC current is a constant current, its frequency is zero.

The capacitive reactance is therefore infinity.

27. **(a)** $ML^{-1}T^{-2}$

Explanation: $\left[\frac{1}{2}\varepsilon_0 E^2\right]$ = energy density

$=\frac{ML^2\,T^{-2}}{L^3}=\left[ML^{-1}\mathbf{T}^{-2}\right]$

28.

(b) 4

Explanation: Dielectric constant of air is 1. All dielectrics generally have a value of the dielectric constant greater than 1.

$K=\frac{F}{F_m}$

where Fm is the force between two charged particles in a medium of dielectric constant K and F is the force between the two charges when placed in air.The force between two charges is greatest in air or vacuum and it decreases when any medium is placed between the charges. K cannot have negative, fractional or zero values.

29. **(a)** $\frac{CV^2}{2d}$

Explanation: 

Electric field due to plate 1 near plate 2

Is E = $\frac{Q}{2Al_{i_0}}$

Force, F = -Q × $\left(\frac{Q}{2\ A\bar{\sigma}_0}\right)$

= $-\frac{-Q^2}{2A\varepsilon_0}$ = $\frac{-(CV)^2}{2A\varepsilon_0}$

C = $\frac{A\varepsilon_0}{d}$ or A ε_0 = Cd

F = $\frac{-\left(C^2V^2\right)}{2\times Cd}-\frac{-CV^2}{2d}$

|F| = $\frac{CV^2}{2d}$

Negative sign indicates force is attractive in nature.

30. **(a)** d = 10^{-5} m, A = 10^{-2} m^2

Explanation: The capacitance of a parallel plate capacitor of area A, and separation between the plates is d with a dielectric of dielectric constant K is given by $C=\frac{\varepsilon_0 KA}{d}$.

The ratio $\frac{A}{d}=\frac{C}{\varepsilon_0 K}=\frac{1.77\times10^{-6}}{8.85\times10^{-12}\times200}=10^3$.

The minimum plate separation d’ for which the capacitor will not breakdown is found using $E=\frac{V}{d'}$

where E is the breakdown strength and V is the maximum potential the capacitor can withstand .Thus,

$d' = \frac{V}{E} = \frac{20}{3 \times 10^6} = 6.67 \times 10^{-6} m$.

The plate separation has to be greater than $6.67 \times 10^{-6} m$

Thus, if d = 10^{-5} m, A = 10^{-2} m^2, it will satisfies the condition, $\frac{A}{d} = \frac{10^{-2}}{10^{-5}} = 10^3$

31.

(c) 100

Explanation: At the top of the stratosphere, E = 100 Vm^{-1}

32.

(b) decreasing the distance between the plates.

Explanation: C = $\frac{\varepsilon_0 A}{d}$

So, by decreasing the distance between the plates, capacitance increases.

33. **(a)** 24 V

Explanation: Here, in Fig,

$C_p = C_1 + C_2 = C + C = 2C$

$\therefore q_1 = q_2 = C_p V = 2CV$

When combined in series, $C_s = \frac{C}{2}$

$\therefore V = \frac{q}{C_s} = \frac{2CV}{\frac{C}{2}} = 4V$

= 4 × 6 = 24 volt

34.

(c) $\frac{t}{d+t}$

Explanation: Without dielectric, $C_0 = \frac{\varepsilon_0 A}{d}$

With dielectric, $C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}} = \frac{C_0}{2} = \frac{1}{2} \frac{\varepsilon_0 A}{d}$

$\therefore 2d = d - t + \frac{t}{\mathbf{x}}$

or $d + t = \frac{t}{\kappa}$ or $\kappa = \frac{t}{d+t}$

35.

(d) $(\frac{6}{5})C$

Explanation: $(\frac{6}{5})C$

36.

(b) $\frac{F}{2}$

Explanation: $\frac{F}{2}$

37.

(c) 70 V

Explanation: The potential at any point inside the charged hollow metallic sphere is the same as that on its surface.

38.

(d) $\pm 5 \times 10^{-3}\ C$

Explanation: In parallel combination, potential across each capacitor will be same thus charge

Hence, charge on each capacitor is given by :-Q =± CV

$Q = \pm 25 \times 10^{-6} \times 200$

$Q = \pm 5 \times 10^{-3} C$

39.

(c) it would be pulled inside and would come to rest occupying the space in between the plates

Explanation: it would be pulled inside and would come to rest occupying the space in between the plates

40.

(c) $\frac{2}{\ln(2)} \mathrm{M\Omega}$

Explanation: $U = \frac{q_0^2}{2C}$

At t = 1 s, energy reduces to half, so

$q = \frac{q_0}{\sqrt{2}}$

Now $q = q_0 e^{-\frac{t}{\tau}}$
$\therefore \frac{q_0}{\sqrt{2}} = q_0 e^{-1}$
$\Rightarrow e^{\frac{1}{t}} = \sqrt{2} \Rightarrow \frac{1}{\tau} = \ln(\sqrt{2})$
$\Rightarrow \tau = \frac{2}{\ln(2)}$
$\Rightarrow RC = \frac{2}{\ln(2)}$
$R = \frac{2}{C\ln(2)} = \frac{2}{10^{-6}\ln(2)}\Omega = \frac{2}{\ln(2)}\mathrm{M\Omega}$

41. **(a)** 500 μF
Explanation: Given that , voltage = 200V and Specific Heat is =250J/Kg-K and mass= 100g = 0.1 kg
Energy stored in the capacitor, $U = \frac{1}{2}CV^2 = \frac{1}{2}(200)^2C \ = 2 \times 10^4 C$ J
This is released as heat when the capacitor discharges through the metal block.
The quantity of heat = mass × sp.heat × rise in temperature.
$Q = m \times s \times \Delta\theta = 0.1 \times 2.5 \times 10^2 \times 0.4 = 10J$
$U = Q \Rightarrow 2 \times 10^4 C = 10$
or $C = 5 \times 10^{-4} F = 500\mu F$

42.
(c) $\frac{C_1 V}{C_1 + C_2}$
Explanation: The common potential difference across the parallel combination of two capacitors,
$V' = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$
But V_1 = V, V_2 = 0
$\therefore V' = \frac{C_1 V}{C_1 + C_2}$

43.
(b) 4 V
Explanation: Charges on the two capacitors are 36 μC and 72 μC. When they are connected in opposition, the total charge on the system = (72 - 36) μC = 36 μC. This is shared between the capacitors so that they acquire the same potential difference. Let this be V. (3 μF)V + (6 μF)V = 36 μC or V = 4 V

44. **(a)** Decreasing the battery potential
Explanation: An electroscope is a device which measures the potential difference. If it is connected in parallel to the capacitor, the potential across it will be equal to the potential across the capacitor, which is equal to the potential across the battery. On decreasing the battery potential, the potential difference across the electroscope reduces and hence the reading reduces.

45.
(d) all of these
Explanation: A positively charged body can have +ve, -ve, or zero potential.

46.
(b) 12, 4
Explanation: $C_P = C_1 + C_2 = 16\ \mu F$
$C_s = \frac{C_1 C_2}{C_1 + C_2} = 3\mu F$
or $C_1C_2 = 3(C_1 + C_2) = 3 \times 16 = 48\ \mu F$
$C_1(16 - C_1) = 48$
On solving, $C_1 = 12\ \mu$ F, $C_2 = 4\ \mu F$

47.
(d) 2ε0 A/D
Explanation: The capacitance due to single capacitor is given as
$C = \varepsilon_0 \frac{A}{d}$
here 2 capacitors formed are in parallel
so total capacitance = $C_1 + C_2 \ = \in_0 \frac{A}{d} + \in_0 \frac{A}{d} = 2 \in_0 \frac{A}{d}$

48.

(c) $\frac{C}{3}$, 3v

Explanation: V_{eff} = V + V + V = 3V

$\frac{1}{C_{\text{eff}}}=\frac{1}{C}+\frac{1}{C}+\frac{1}{C} \Rightarrow C_{\text{eff}}=\frac{C}{3}$

49.

(b) decreases

Explanation: With temperature rise, the dielectric constant of liquid decreases.

50.

(b) 711 μF

Explanation: The capacitance of a spherical conductor of radius R is

$C=4\pi\varepsilon_0 R=4\times 3.14\times 8.85\times 10^{-12}\times\frac{128\times 10^5}{2}$

$=7.11\times 10^{-4}F=711\mu F$

51.

(d) inverse ratio of capacitors

Explanation: When capacitors are connected in series, they have equal charge but the potential difference across them is given by $V_1=\frac{Q}{C_1}; V_2=\frac{Q}{C_2}\ldots$ and so on.

Therefore, $V\propto\frac{1}{C}$

52.

(b) 20

Explanation: The initial energy of the capacitor of capacitance C and charge Q_1 is $U_1=\frac{Q_1^2}{2C}$

When the charge increases to Q_2, the energy of the capacitor $\frac{U_2-U_1}{U_1}=\frac{Q_2^2-Q_1^2}{Q_1^2}$

Given percentage increase of energy $\frac{U_2-U_1}{U_1}=0.21$

$\therefore\ \frac{Q_2^2-Q_1^2}{Q_1^2}=\frac{Q_2^2}{Q_1^2}-1$

$\Rightarrow 0.21=\frac{Q_2^2}{Q_1^2}-1$

$\Rightarrow 1.21=\frac{Q_2^2}{Q_1^2}$

$\Rightarrow\frac{Q_2}{Q_1}=1.1$

But $Q_2-Q_1=2; Q_2=1.1Q_1$

On solving, we get initial charge on capacitor is, Q_1 = 20C

53.

(d) zero

Explanation: The potential at every point of the circle will be same.

$\therefore W=q\Delta V=q\times 0=0$

54. **(a)** a current flows in the circuit for sometime and then decreases to zero

Explanation: When an uncharged capacitor is connected to a battery, charges flow from the poles of the battery to the plates of the capacitor and this process continues till the potential across the capacitor attains the potential difference of the battery. The current flows in the circuit till the time the capacitor is charged and then it ceases.

55. **(a)** capacitance

Explanation: By definition of capacitance, $C=\frac{Q}{V}$

56.

(d) $\frac{3}{2}$

Explanation: Given $\frac{C_p}{C_s}=\frac{25}{6}$

Let C_p = 25k; C_s = 6k where k is a constant.

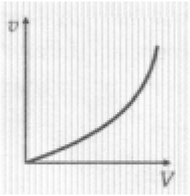
$C_p = C_1 + C_2 = 25k$

$C_s=\frac{C_1C_2}{C_1+C_2}=6k$

$\frac{C_1C_2}{25k} = 6k$

$C_1C_2 = 150k^2$

On Solving, We get $C_2 = 15k$; $C_1 = 10k$ and their ratio is $\frac{C_2}{C_1} = \frac{3}{2}$

57. **(a)** 

Explanation: K.E. gained by the electron $\frac{1}{2}mv^2 = eV$

$\therefore v^2 \propto V$

58.

(d) 90°

Explanation: An electric line of force is perpendicular to the equipotential surface at every point.

59.

(b) one on which aluminium oxide film is formed

Explanation: Aluminium electrolytic capacitors have the Aluminium foil anode (positive terminal) which is etched and covered with a layer of Aluminium Oxide which acts as a dielectric. The whole assembly is covered using a paper separator soaked in electrolyte such as, Borax or Glycol and covered by Aluminium foil which acts as cathode (negative electrode)

60. **(a)** $\frac{1}{2}\varepsilon_0\frac{V^2}{d^2}$

Explanation: Energy stored per unit volume in a capacitor,

$u = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2 = \frac{1}{2}\varepsilon_0 \cdot \frac{V^2}{d^2}$

61.

(d) charge on each is different but non-zero

Explanation: Charge on each capacitor becomes zero when two capacitors of equal capacitances are charged and then connected to opposite terminals. But capacitances of the two capacitors are given to be different.

62.

(d) $\frac{U}{2}$

Explanation: Initial energy stored in the capacitor, $U = \frac{1}{2}CV^2 = \frac{q^2}{2C}$

When the battery is disconnected, charge q = constant. Another capacitor connected across the first capacitor is in parallel with it. So,

$C_{eq} = C + C = 2C$

Final energy stored by the system of two capacitors,

$U = \frac{q^2}{2C_{eq}} = \frac{q^2}{2\times 2C} = \frac{1}{2}u$

63.

(b) Two of them connected in series and the combination in parallel to the third.

Explanation: Two of them connected in series and the combination in parallel to the third.

64.

(c) 

Explanation: P.E. of a dipole is maximum when $\vec{p}$ is antiparallel to $\vec{E}$.

U = -pE cos 180° = +pE = maximum +ve value.

65.

(c) 0.32 J

Explanation: Heat produced in the 2 kΩ resistor

= Energy stored in the charged capacitor

$= \frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (400)^2$ J = 0.32 J

66. **(a)** 7.2 $\times$ 10^4 V

Explanation: $V=\frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r}=\frac{9\times10^9\times50e}{10^{-12}}$

$=\frac{9\times10^9\times50\times1.6\times10^{-19}}{10^{-12}}$ = 7.2 $\times$ 10^4 V

67. **(a)** 80 V

Explanation: A hollow metal sphere is a conductor in which charge always reside on the surface. Thus electric field inside the sphere will be zero and potential at the center is the same as that on its surface, hence potential will be constant and equal to as that on the surface i.e. V = 80 Volt

68.

(b) infinite

Explanation: The permittivity of metals is very high compared to the permittivity of free space. So dielectric constant for metal is infinite.

69.

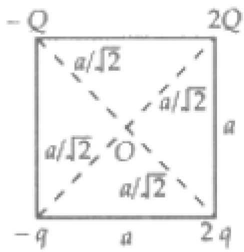
(c) Q = -q

Explanation:

Potential at the centre O is

$V=k\left[\frac{-Q}{a/\sqrt{2}}+\frac{-q}{a/\sqrt{2}}+\frac{2q}{a/\sqrt{2}}+\frac{2Q}{a/\sqrt{2}}\right]=0$

$\Rightarrow$ Q - q + 2q + 2Q = 0



$\Rightarrow$ Q + q = 0

$\Rightarrow$ Q = -q

70. **(a)** always zero

Explanation: Since that circular path behaves as equipotential surface, so work done is always zero.

71.

(c) relative permittivity

Explanation: As we know that,

k = $\varepsilon_r=\frac{\varepsilon}{\varepsilon_0}$ = Relative permittivity

72.

(c) 4W

Explanation: $W=\frac{Q^2}{2C}$

$W'=\frac{(2Q)^2}{2C}=4\cdot\frac{Q^2}{2C}=4W$

73. **(a)** 12 $\times$ 10^{-4} J

Explanation: $\Delta U=U_2-U_1=\frac{1}{2}C\left(V_2^2-V_1^2\right)$

$=\frac{1}{2}\times8\times10^{-6}\left(20^2-10^2\right)$

= 4 $\times$ 10^{-6} $\times$ 300 J = 12 $\times$ 10^{-4} J

74. **(a)** no work is done

Explanation: On the equipotential surface, the electric field is normal to the charged surface (where the potential exists) So that no work will be done.

75. **(a)** 8μC

Explanation: At steady state, the capacitor is open-circuited so no current flows through the 10-ohm resistor. So current will flow across 2 ohm resistor is

$I=\frac{V}{R+r}=\frac{2.5}{2+0.5}=\frac{2.5}{2.5}=1Amp$

So P.D. across 2Ω resistance V = RI = 2×1 = 2 Volt.
As a battery, capacitor and 2Ω branches are in parallel. So P.D. will remain the same across all three branches.
As current does not flow through the capacitor branch so no potential drop will be across 10Ω
So P.D. across 4μF capacitor = 2 Volt
charge on the capacitor plate is given by:
$[q = CV] = 4\mu F \times 2 = 8\mu C$