PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

CAPACITOR

Capacitor

1. Two students A and B were taught that electric field near a uniformly charged large surface is normal to the surface and is equal to $\frac{\sigma}{2\in_0}$. They were also told that field near the surface of a conductor is $\frac{\sigma}{\in_0}$ normal to the conductor where s is charge density on the conductor surface. Now both of them were asked to write field between the plates of an ideal parallel plate capacitor having charge density σ and $-\sigma$ on its plates. Student A said that field can be seen as superposition of field due to two large charged surfaces. He wrote the answer as

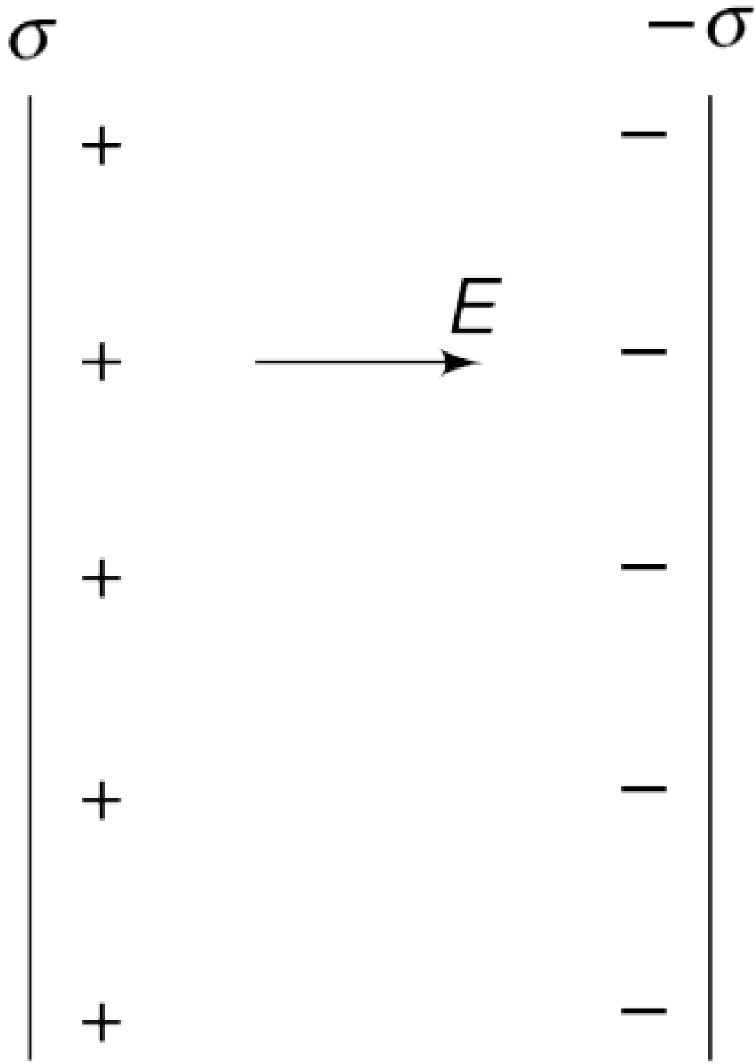
$$E = \frac{\sigma}{2 \in_0} + \frac{\sigma}{2 \in_0} = \frac{\sigma}{\in_0}$$

Student B thought that a capacitor has conducting plates and therefore field due to each plate

Must be $\frac{\sigma}{\in_0}$. He wrote his answer as

$$E = \frac{\sigma}{\in_0} + \frac{\sigma}{\in_0} = \frac{2\sigma}{\in_0}$$

Who is wrong and where is the flaw in thinking ?



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2. A large parallel plate capacitor has vertical plates with a potential difference of $2000V$ between them. Oil drops are sprayed between the plates. Few drops are observed to move with uniform velocities in directions inclined at $45^\circ, 33.7^\circ$ and 18.4° to the vertical. The space between the plates has air and mass of each drop is $m = 3.3 \times 10^{-15} kg$. Separation between the plates is 3 cm.

(a) Explain the observations.

(b) From the above observations estimate the magnitude of smallest charge in nature.

$\tan(33.7^\circ) = 0.67$ and $\tan(18.4^\circ) = 0.333$

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3. Electrical susceptibility (χ) of a dielectric material is defined as $\chi = \in_r - 1$ where $\in_r$ is its relative permittivity. An isolated parallel plate capacitor carries some charge and the field in the dielectric present between its plates is E. Express the electric field due to induced charge on dielectric surface in terms of χ and E.

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4. Imagin a parallel plate capacitor with a charge $+Q$ on one plate and $-Q$ on the other. Initially, the plates are almost, but not quite, touching. The plates are gradually pulled apart to make the separation d. The separation d is small compared to dimensions of the plates and we can maintain that field between the plates is uniform. Area of each plate is A.

(a) Write the energy stored in the electric field between the plates when separation between then is d.

(b) Assuming that the energy calculated in part (a) can be attributed to the work done by the external agent in pulling the plates apart, calculate the electrostatic attraction force between the plates.

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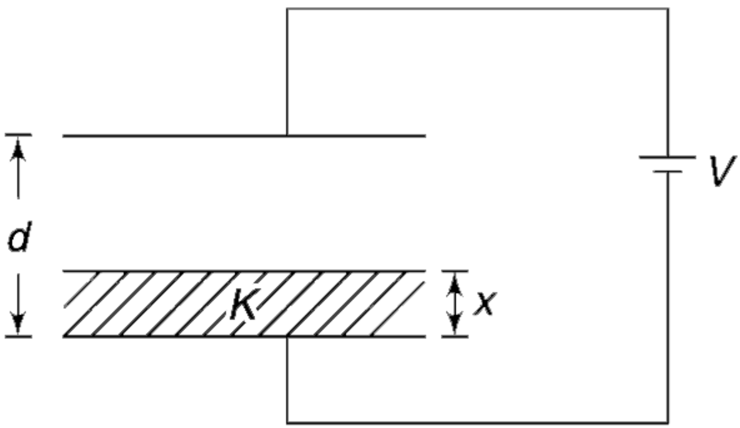
5. Two conducting plates each having area A are kept at a separation d parallel to each other. The two plates are con- nected to a battery of emf V. The space between the plates is filled with a liquid of dielectric constant K. The height (x) of the liquid between the plates increases at a uniform rate from zero to d in a time interval t_0.

(a) Write the capacitance of the system as a function of x as the liquid beings to fill the space between the plates.

(b) write the current through the cell at time t



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6. You have been given a parallel plate air capacitor having capacitance C, a battery of emf ε and three dielectric blocks having dielectric constants K_1, K_2 and K_3 such that $K_1 > K_2 > K_3$. Describe a sequence of steps such as connecting or disconnecting the capacitor to the battery, inserting or taking out of one of the dielectrics etc -so that the capacitor ends up having maximum possible energy stored in it. [Each dielectric block fills completely the space between the plates]. Write this maximum energy.

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7. A parallel plate capacitor has two plates of area A separated by a small distance d. The capacitor is charged to a potential difference of V and the battery is disconnected. A metal plate with area A and thickness $\frac{d}{2}$

is fully inserted between the plates, so that it always remains parallel to the plates.

(a) Calculate the work done on the metal slab while it was inserted.

(b) Does the two plates of the capacitor attract of repel the metal plate that is being inserted. Does the answer obtained in part (a) help you in answering this ?

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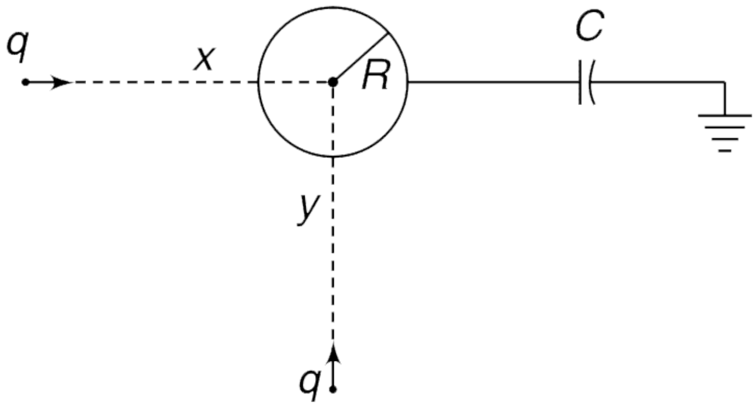
8. A neutral conducting ball of radius R is connected to one plate of a capacitor (Capacitance = C), the other plate of which is grounded. The capacitor is at a large distance from the ball. Two point charges, q each, begin to approach the ball from infinite distance. The two point charges move in mutually perpendicular directions. Calculate the charge on the capacitor when the two point charges are at distance x and y form the centre of the sphere.



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9. A parallel plate capacitor of capacitance C_0 is charged using a cell of emf V_0. Calculate the work done in reducing the separation between the plates to half its original value if

(a) The cell is disconnected before you start decreasing the plate separation

(b) The cell remains connected while you are reducing the separation

Assume that the plates are moved very slowly.

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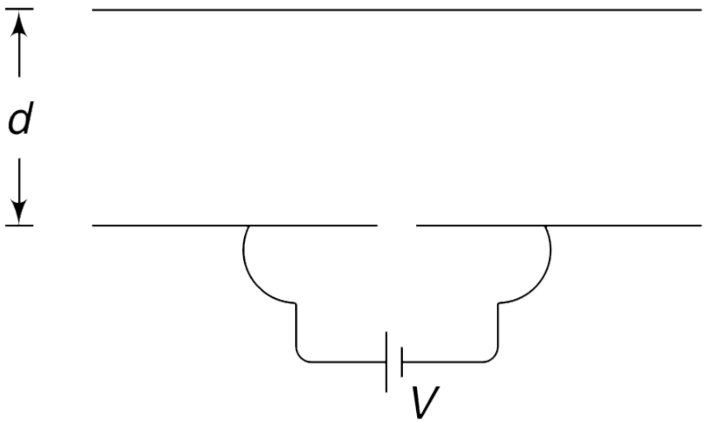
10. Two large conducting plates, identical in size, are placed parallel to each other at a separation d. Each plate has area A. One of the plates is cut into two equal parts and then a battery of emf V is connected across these two pieces. Find the work done by the battery in supplying charge to the plates.



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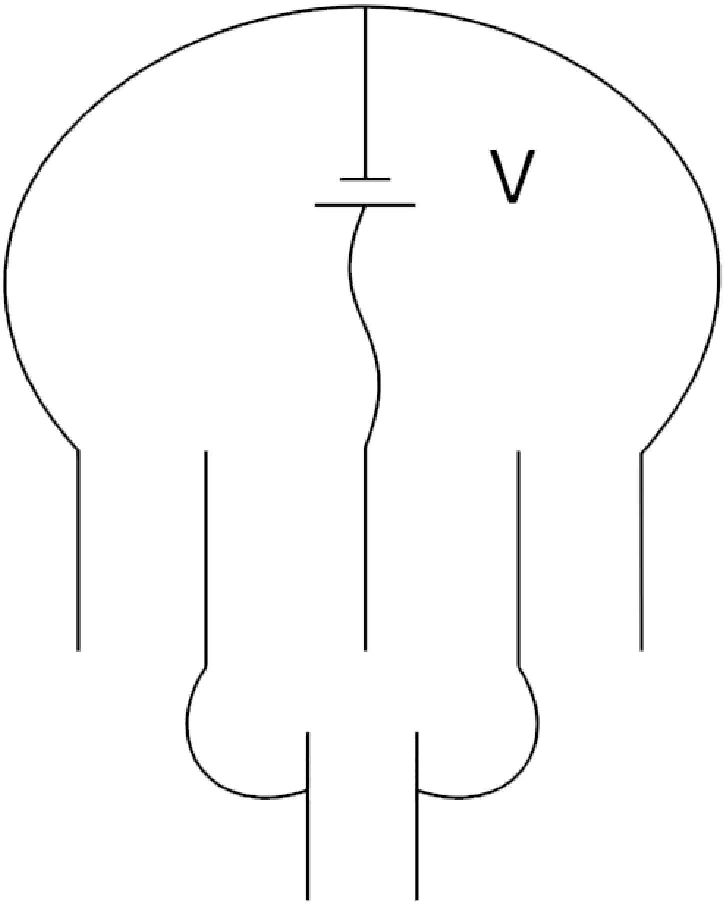
11. Seven identical plates, each of area A, are placed as shown. Any two adjacent plates are at separation d. Conducting wires have been used to connect the plates and a cell of emf V volt as shown in the figure. How much

charge does the cell supply?



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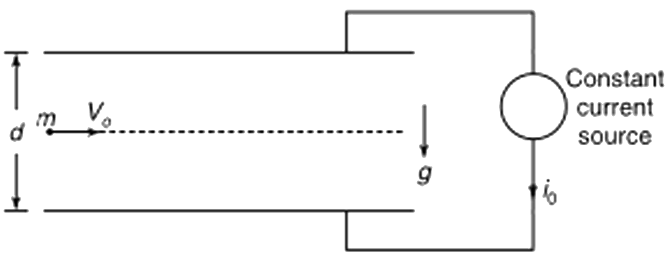
12. A diode is a device that conducts in one direction only. Figure (a) shows the symbol for a diode. When terminal A is at higher potential than B, the diode conducts, it means current flows from A to B. No current flows if B is kept at higher potential. Find the potential difference between terminals C and D after the switch (S) is closed in the circuit shown in Figure (b).



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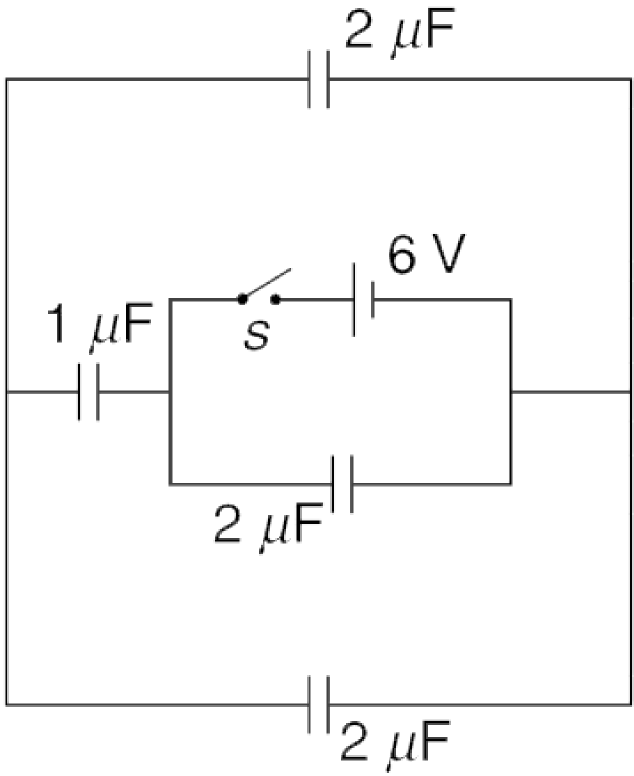
13. Find charge supplied by the cell after the switch is closed.



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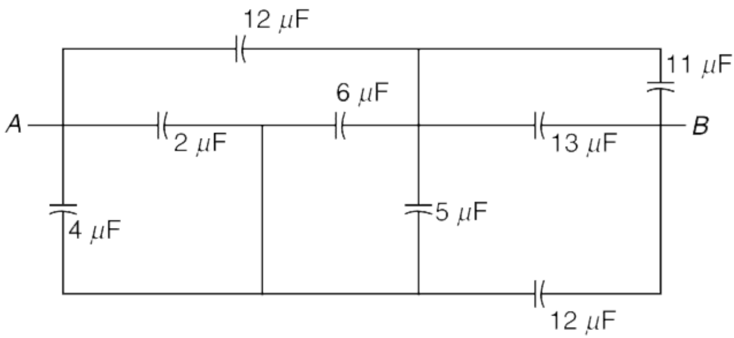
14. Find the equivalent capacitance across points A and B.



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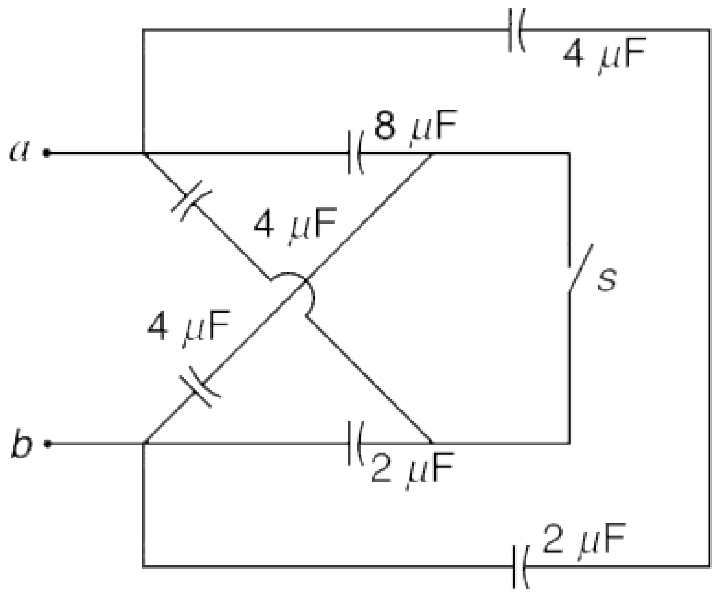
15. In the circuit shown in the Figure find the equivalent capacitance between points a and b when–

(a) Switch S is open.

(b) Switch S is closed.



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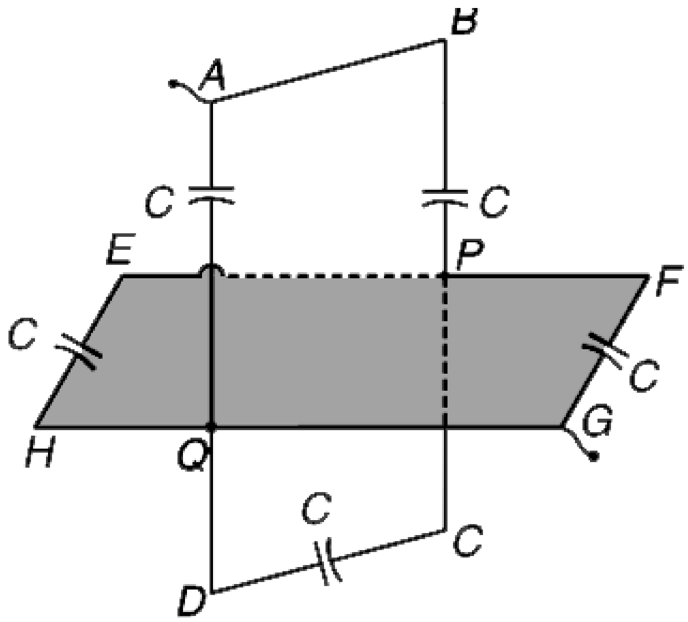
16. In the circuit shown in the Figure ABCD is a rectangular and vertical frame of conducting wires having three capacitors. EFGH is in horizontal plane having two capacitors. The two rectangular frames are connected at P and Q only.Find equivalent capacitance between A and G if each capacitor has capacitance C.



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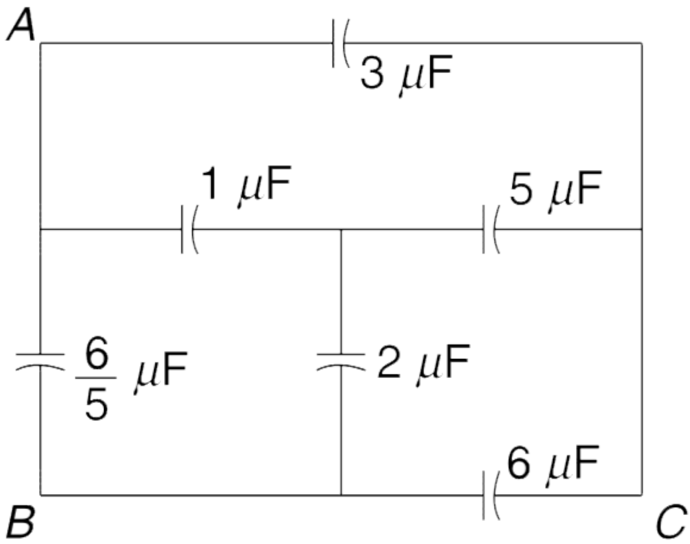
17. In the circuit shown in the Figure find the ratio of equivalent capacitance between A and B to that between

A and C.



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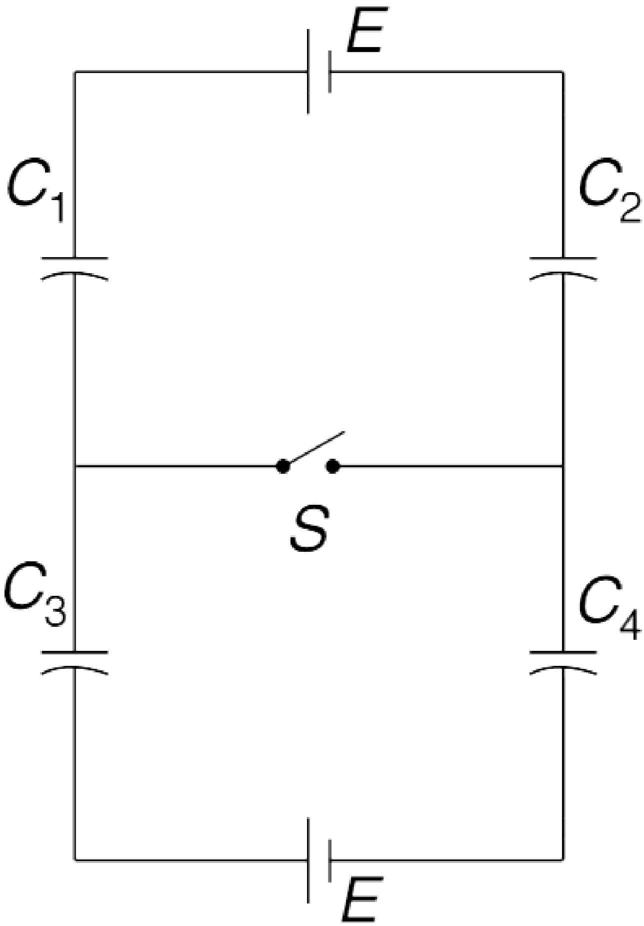
18. In the circuit shown in Figure $E = 12V, C_1 = 4\mu F, C_2 = 2\mu F, C_3 = 6\mu F$ and $C_4 = 3\mu F$

Find the heat produced in the circuit after switch S is shorted.



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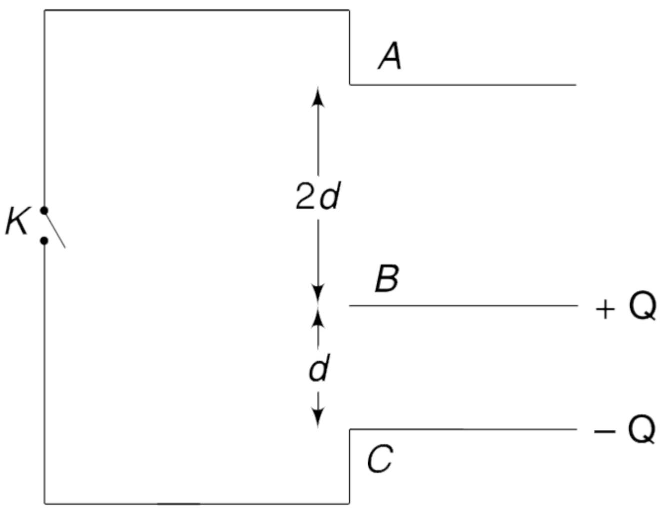
19. Three identical large metal plates each of area S are at distance d and $2d$ from each other as shown. Metal plate A is uncharged, while metal plates B and C have charges $+Q$ and $-Q$ respectively. Metal plates A and C are connected by a conducting wire through a switch K. How much electrostatic energy is lost when the switch is closed ?



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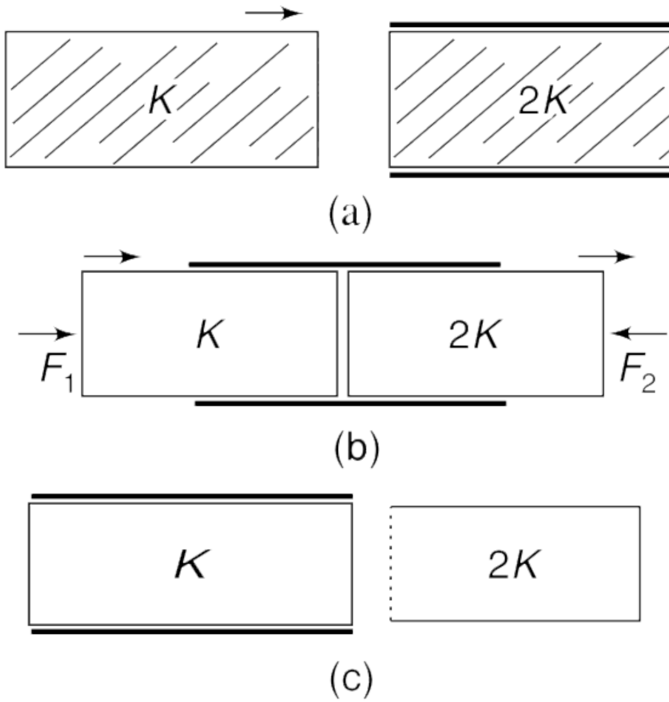
20. An air core parallel plate capacitor has capacitance C. It is completely filled with a dielectric slab having dielectric constant 2 K. The capacitor is now connected to a battery of emf V. It was planned to replace the dielectric slab of the capacitor while it remains connected to the battery. Another dielectric slab (which fits exactly between the plates) is inserted slowly so as to push out the earlier slab. The new slab has a dielectric constant K [see Figure (a) to (c)]

(a) By energy considerations calculate the mechanical work that must be done against the electric forces in order to complete the process.

(b) Looking at the expression of mechanical work obtained in (a), tell what was the direction of force applied by the external agent - from left to right (as indicated by F_1 in Figure) or from right to left (as indicated by F_2).

(c) Which dielectric slab experienced higher force of attraction from the capacitor plates during the process ?



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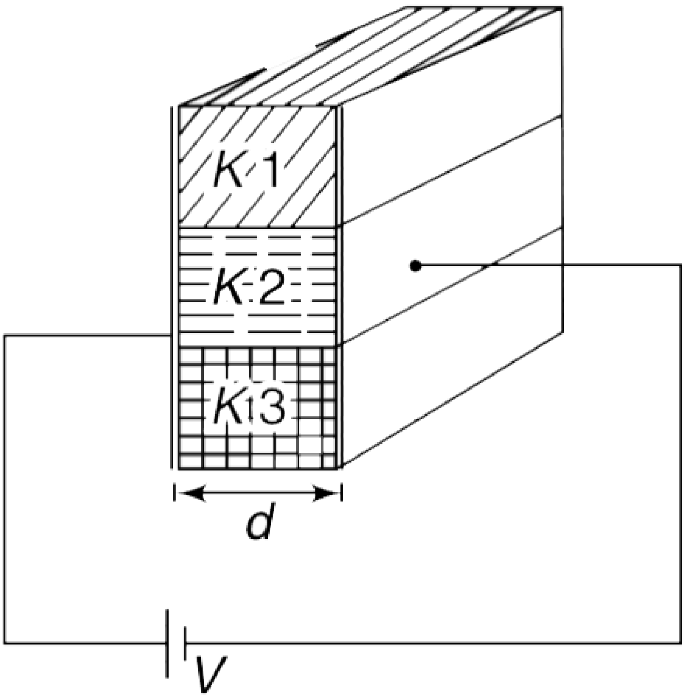
21. A parallel plate capacitor of plate area A and spac- ing between the plates d is filled with three dielectrics as shown in the Figure. The dielectric constants of the three dielectrics are $K_1 = K, K_2 = 2K, K_3 = 3K.$ The capacitor is connected to a cell of emf V.

(a) Write the ratio of maximum to minimum charge density on the surface of the capacitor plate.

(b) Calculate the surface charge density of bound (induced) charge on the middle dielectric.

(c) If the three dielectrics occupy equal volume between the plates, calculate the capacitance of the capacitor.



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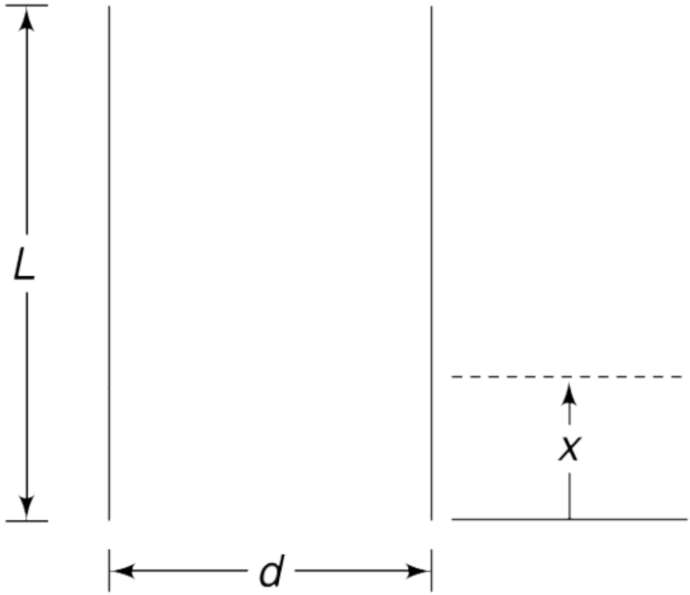
22. A parallel plate capacitor has square plates of side length L. Plates are kept vertical at separation d between them. The space between the plates is filled with a

dielectric whose dielectric constant (K) changes with height (x) from the lower edge of the plates as $K = e^{\beta x}$ where b is a positive constant. A potential difference of V is applied across the capacitor plates.

(i) Plot the variation of surface charge density (s) on the positive plate of the capacitor versus x.

(ii) Plot the variation of electric field between the plates as a function of x.

(iii) Calculate the capacitance of the capacitor.



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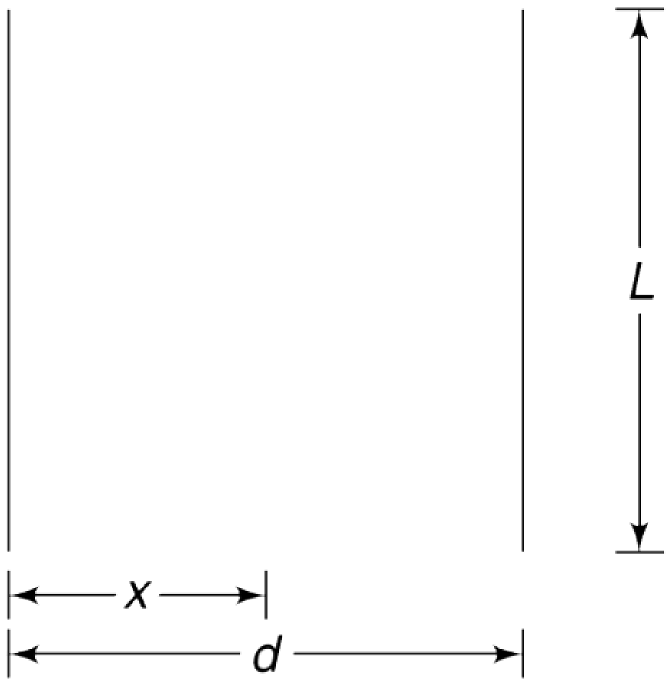
23. A parallel plate capacitor has square plates of side length L kept at a separation d. The space between them is filled with a dielectric whose dielectric constant changes as $K = e^{\beta x}$ where x is distance measured from the left plate towards the right plate, and b is a positive constant.

A poten- tial difference of V volt is applied with left plate positive.

(i) What happens to capacitance of the capacitor if d is increased ? What is the smallest possible capacitance that can be obtained by changing d ?

(ii) Write the expression of electric field between the plates as a function of x.



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24. A parallel plate capacitor is to be constructed which can store $q = 10\mu C$ charge at $V = 1000$ volt. The minimum plate area of the capacitor is required to be A_1 when space between the plates has air. If a dielectric of constant $K = 3$ is used between the plates, the minimum plate area required to make such a capacitor is A_2. The breakdown field for the dielectric is 8 times that of air. Find $\frac{A_1}{A_2}$

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25. The electric field between the plates of a parallel plate capacitor is E_0. The space between the plates is filled completely with a dielectric. There are n molecules in unit volume of the dielectric and each molecules is like a dumb - bell of length L with its ends carrying charge $+q$ and $-q$. Assume that all molecular dipoles get aligned along the field between the plates. Find the electric field between the plates after insertion of the dielectric.

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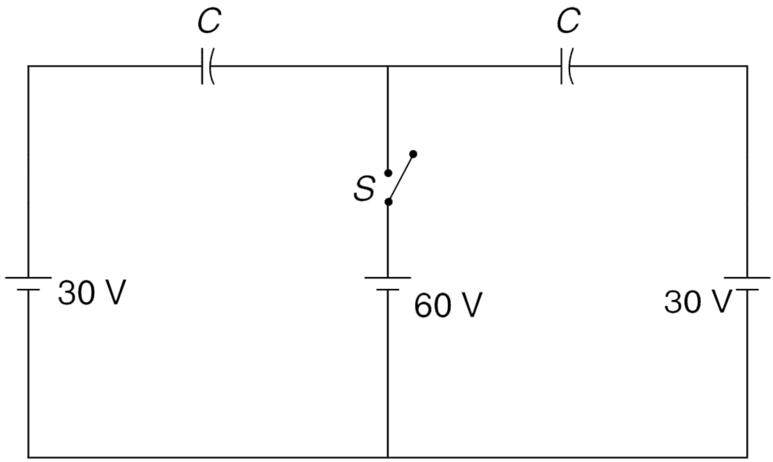
26. Find heat dissipated in the circuit after switch S in closed. $C = 2\mu F$.



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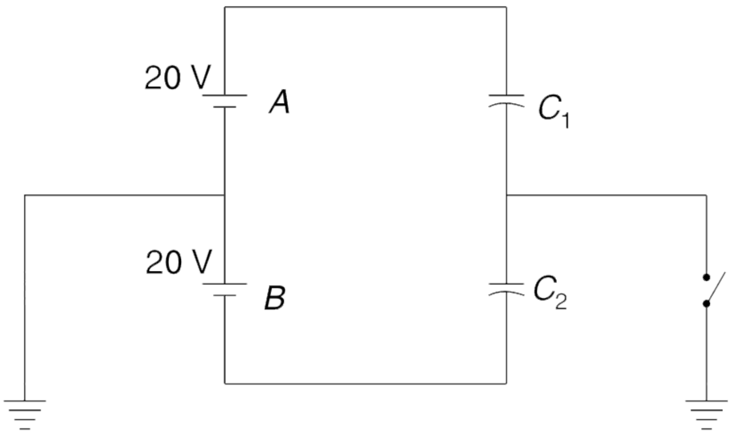
27. In the circuit shown in the Figure calculate the quantity of charge that flows through the switch after it is closed. Give your answer for following two cases-

(a) $C_1 = C_2 = 2\mu F$

(b) $C_1 = 2\mu F, C_2 = 1\mu F$



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28. In a parallel plate capacitor the separation between the two plates is maintained by a dielectric of dielectric constant K and thickness d. The dielectric material is not rigid and has a young's modulus of Y. Capacitance of the capacitor is C_0 if applied potential difference is nearly zero. At higher potentials the attractive force between the plates compresses the dielectric (by a small amount) and reduces the gap between the plates. Change in K can be neglected due to compression in the dielectric. Find the change in capacitance when a battery of V volt is connected across it.

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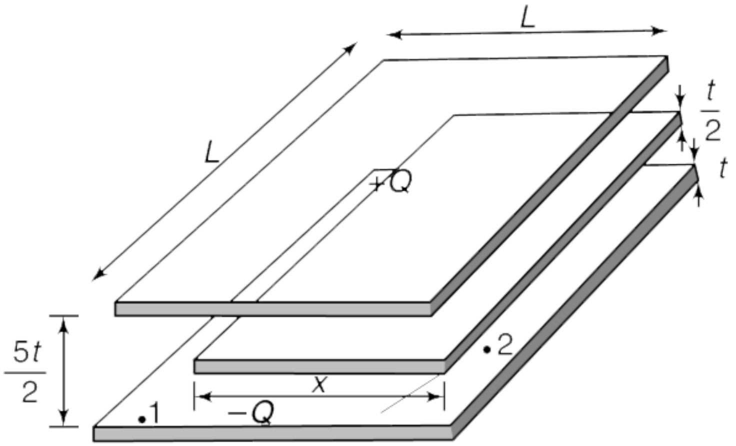
29. Two square metal plates have sides of length L and thickness $t(< < < L)$. They are arranged parallel to each other with their inner faces at a separation of $\frac{5}{2}$t. One of the plates is given a charge $-Q$ and the other one is given a charge $+Q$. A third rectangular metal plate of sides L and x, having thickness $\frac{t}{2}$ is inserted between the plates as shown. The third plate is equidistant from the two plates and parallel to them. Neglect edge effects.



(a) Find the charge density on lower plate at points 1 and 2 shown in Figure.

(b) Find potential difference between the upper plate and the middle plate.

(c) Find electric field between the two outer plates in space where the third plate is not present (i.e., at a point above point 1.)

(d) Find the capacitance of the system across two outer plates.

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30. A hollow spherical conductor of radius R has a charge Q on it. A small dent on the surface decreases the volume of the spherical conductor by 2%. Assume that the charge density on the surface does not change due to the dent and the electric field in the dent region remains same as other points on the surface.

(a) ΔE is the electrostatic energy stored in the electric field in the shallow dent region and E is the total electrostatic energy of the spherical shell. Find the ratio $\frac{\Delta E}{E}$

(b) Using the ratio obtained in part (a) calculate the percentage change in capacitance of the sphere due to the dent.

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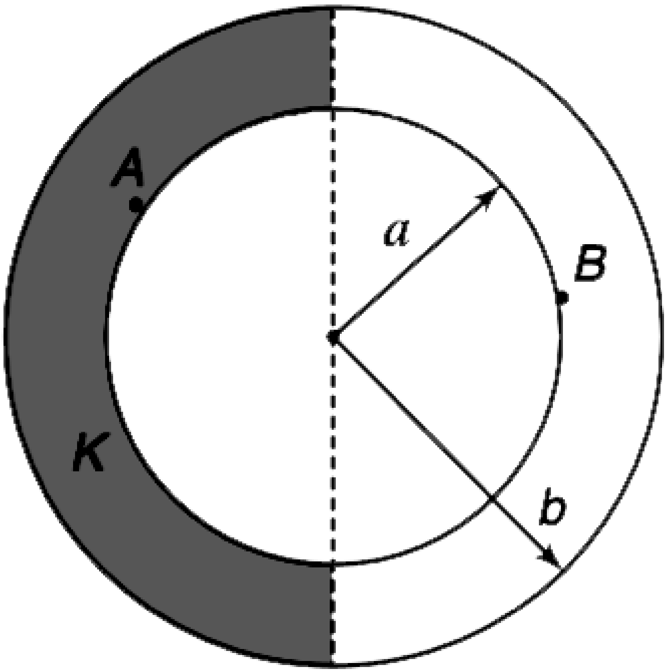
31. The space between the conductors of a spherical capacitor is half filled with a dielectric as shown is Figure. The dielectric constant is K.

(a) If a charge is given to the capacitor write the ratio of free charge density on the inner sphere at point A and B.

(b) Write the ratio of capacitance with dielectric and without dielectric.



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32. Two concentric spherical shells have radii a and $b(> a)$. Write the capacitance of the system in following cases.

(a) Positive terminal of the battery is connected to the outer shell and its other terminal and the inner shell are grounded.

(b) Positive terminal of the battery is connected to the inner shell and its negative terminal is grounded.

(c) A terminal of the battery is connected to the inner shell and the other terminal along with the outer shell is grounded.

(d) A terminal of the battery is connected to the outer shell and the other terminal is grounded.

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33. Two conducting sphere of radii a and b are placed at separation d. It is given that $d > > a$ and $d > > b$ so that charge distribution on both the sphere remains spherically symmetric. Assume that a charge $+q$ is given to the sphere of radius a and $-q$ is given to the sphere of radius b.

(i) Write the electrostatic energy (U) of the system and calculate the capacitance of the system using the expression of U.

(ii) Prove that the capacitance of the system is given by

$$\frac{1}{C} = \left(\frac{1}{4\pi \in_0 a} + \frac{1}{4\pi \in_0 b}\right) \text{if} d \rightarrow \infty$$

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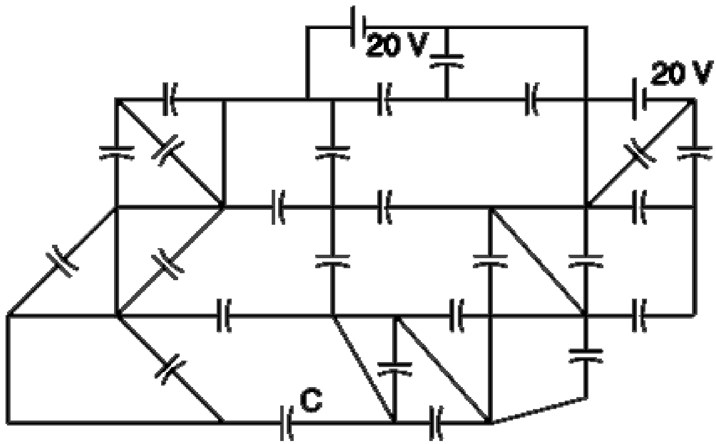
34. All capacitors in the network given below are identical with capacitance of each being $1\mu F$. Find the charge on the capacitor marked as C.



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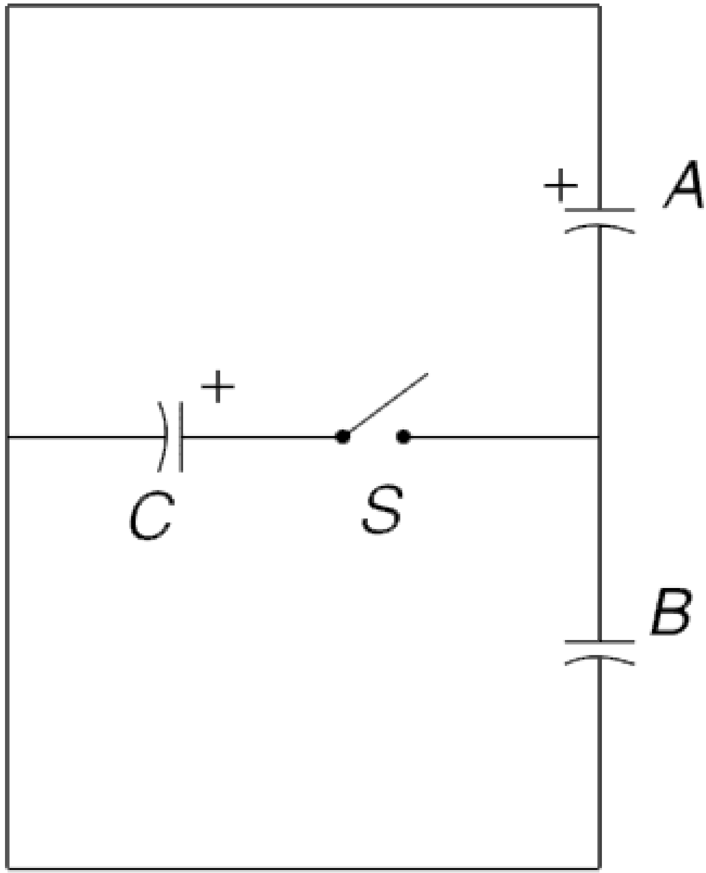
35. In the given circuit it is known that the capacitor A has a capacitance of $2\mu F$ and carries a charge of $40\mu C$. Capacitor C has a capacitance of $6\mu F$ and carries a charge of $180\mu C$. The positive plate of both capacitors has been indicated in the Figure. Capacitance of capacitor B is $3\mu F$.

Calculate charge on B after the switch S is closed.



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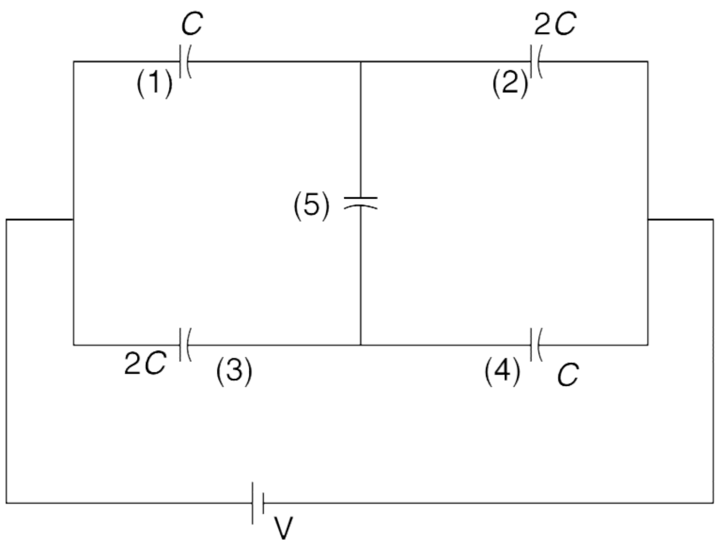
36. In the circuit shown in the Figure, find the ratio of potential difference across capacitor 1 and 2. The capacitance values are as indicated in the Figure.



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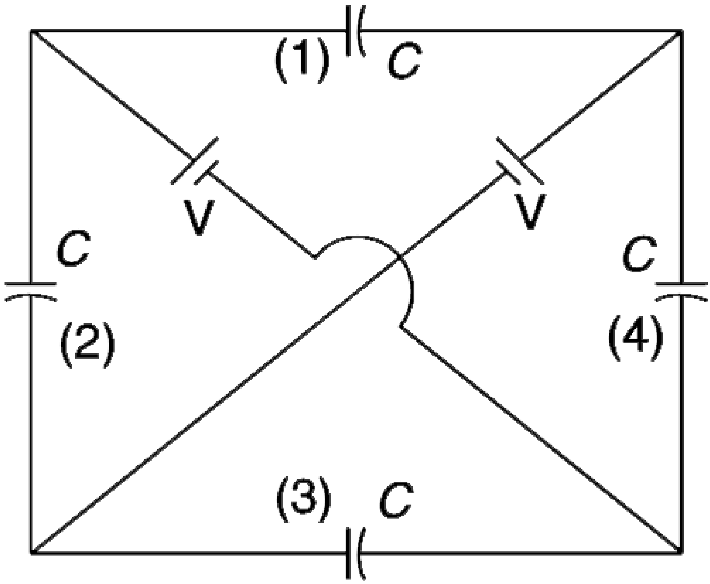
37. In the circuit shown in the figure, find charge on each capacitor.



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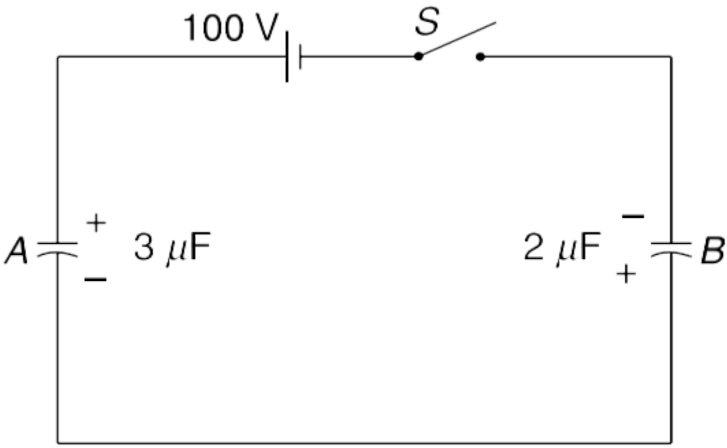
38. Two capacitors A and B with capacitors $3\mu F$ and $2\mu F$ are charged to a potential difference of 100 V and 180 V respectively. One plate of two capacitors are connected as shown. Now switch S is closed so as to connect a cell of 100 V to the free plates of two capacitors.

(a) Find charge on the two capacitors after the switch is closed.

(b) Calculate heat generated in the circuit



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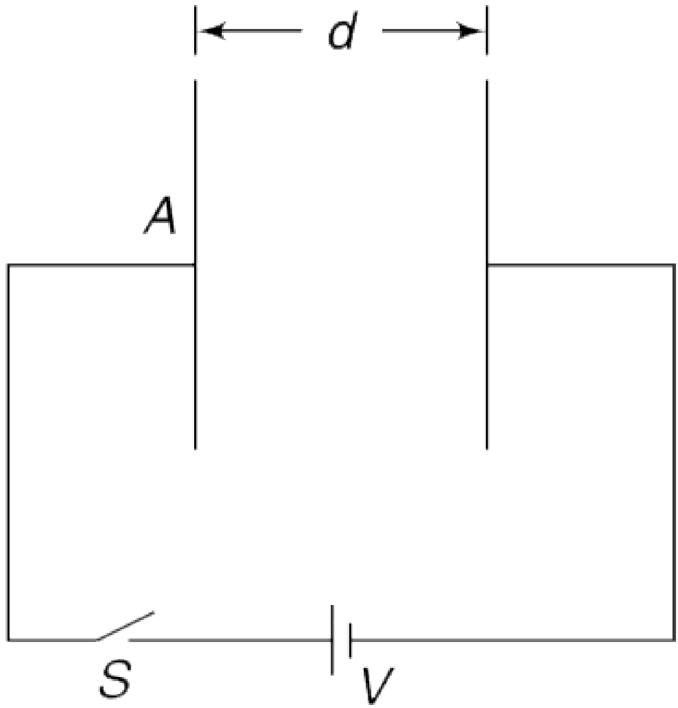
39. A parallel plate air capacitor has plate area A and separation between the plates d. Switch S is closed to connect the capacitors to a cell of emf V.

(a) Calculate the amount of heat generated in the circuit as the capacitor gets charged.

(b) Calculate the force (F) that one capacitor plate exerts on the other. (c) The distance between the plates is slowly reduced to $\frac{d}{2}$. Calculate the work done by the external agent in the process. For your calculation use the basic definition of work as work = force $\times$ displacement.

(d) How much energy is dissipated in the circuit as the distance between the plates is reduced from d to $\frac{d}{2}$? Try to give answer without any calculations. Give reasons. Now use work energy theorem to show that your answer is right.



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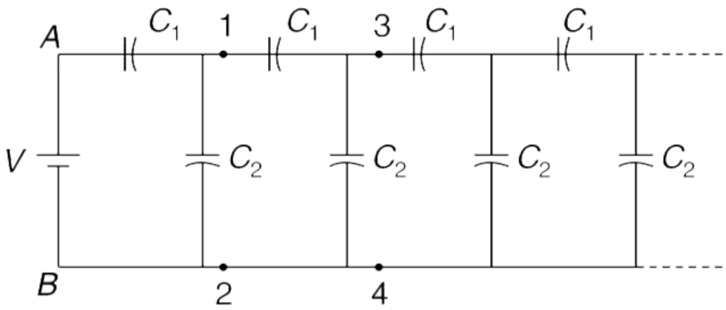
40. The circuit shown in the figure continues to infinity. The potential difference between points 1 and 2 is $\frac{V}{2}$, that between points 3 & 4 is $\frac{V}{4}$ and so on , i.e., the potential difference becomes $\frac{1}{2}$ after every step of the ladder. Find the ratio $\frac{C_1}{C_2}$



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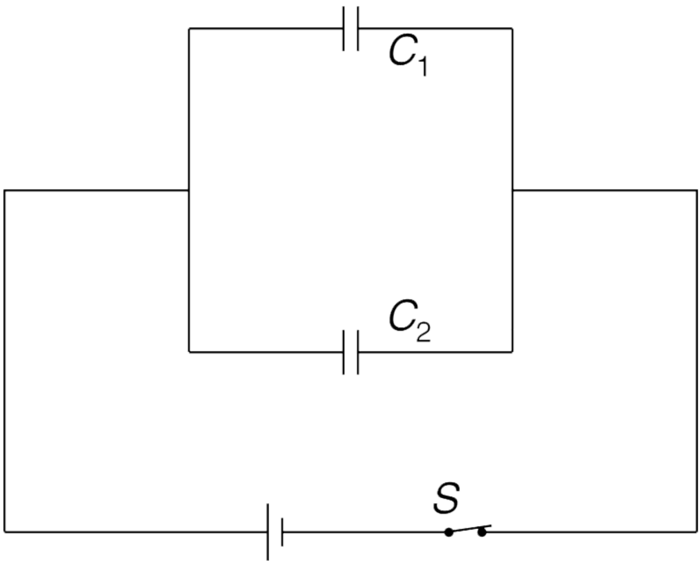
41. The parallel plate capacitors shown in the Figure have capacitance $C_1 = C$ and $C_2 = 2C$. The switch S is opened. Energy stored in the capacitor system is U_1. Now the separation between the plates of C_1 is slowly reduced to half its original value. Energy stored in the capacitor system now changes to U_2.

(a) Which will be larger $- U_1$ or U_2 ? Why ?

(b) Calculate work done by the external agent in slowly reducing the distance between the plates of C_1.

(c) If the plate separation of C_1 is reduced to half and simultaneously the separation between plates of C_2 is doubled, will the energy stored in the capacitor system increase or decrease? Quantify the change in energy.



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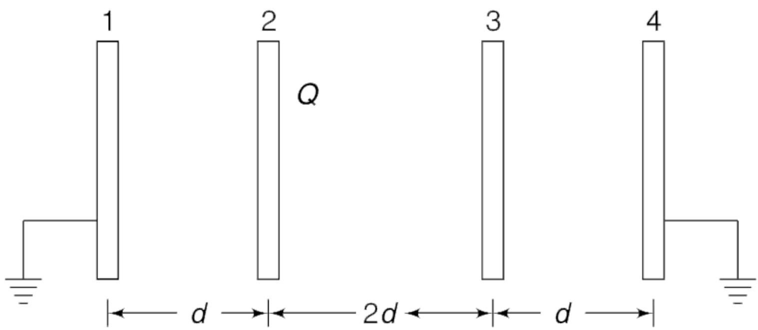
42. Four large identical metallic plates are placed as shown in the Figure. Plate 2 is given a charge Q. All other plates are neutral. Now plates 1 and 4 are earthed. Area of each plate is A.

(a) Find charge appearing on right side of plate 3.

(b) Find potential difference between plates 1 and 2.



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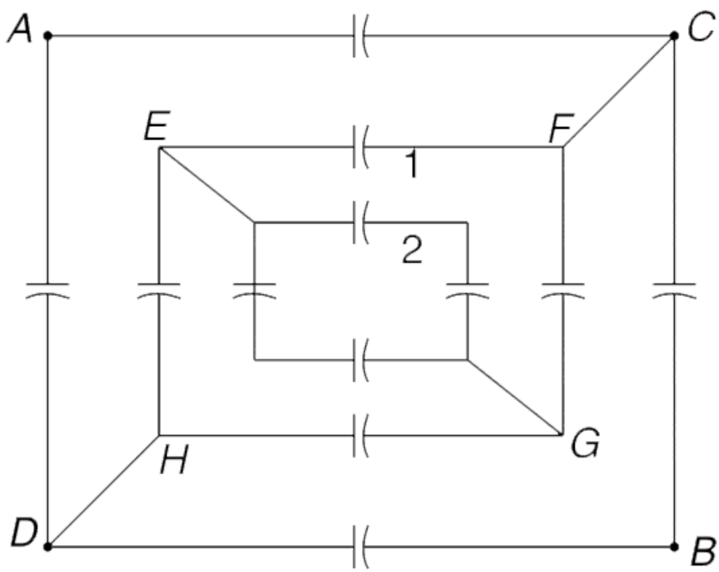
43. In the circuit shown in the figure all the capacitors have capacitance C.

(a) Find the charge on capacitors marked as 1 and 2 when a battery of emf V is connected across points A and B.

(b) Find the equivalent capacitance across points C and D marked in the Figure.

(c) Find the equivalent capacitance across points E and G.



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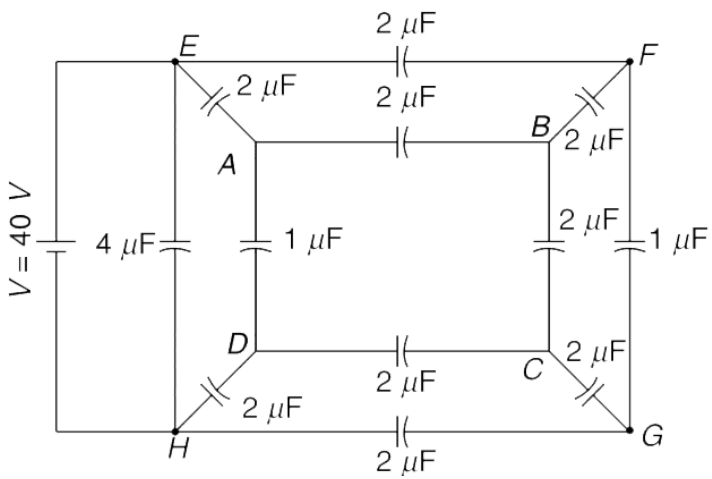
44. There are nine $2\mu F$ capacitors, two $1\mu F$ capacitors and one $4\mu F$ capacitor in the circuit shown in the Figure.

(a) Identify a point in the circuit where potential is same as that of point A.

(b) Identify another pair of points which are having equal potential.

(c) Calculate the charge supplied by the cell to the network of capacitors



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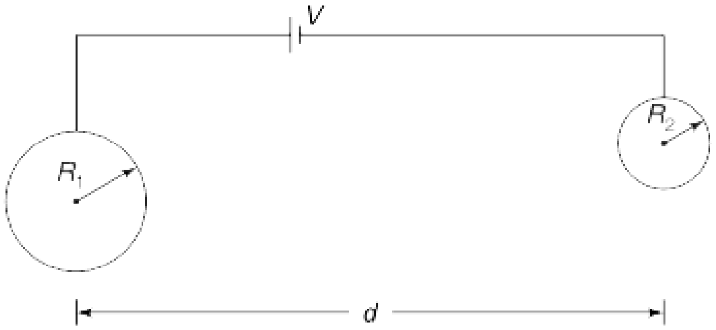
45. Two solid conducting spheres of radii R_1 and R_2 are kept at a distance $d(>>R_1 \text{ and } R_2)$ apart. The two spheres are connected by thin conducting wires to the positive and negative terminals of a battery of emf V. Find the electrostatic force between the two spheres



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46. Two identical long metal wires having radius a are held parallel to each other at a separation $d(>>a)$. Calculate the capacitance of the system per unit length.

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47. A particle of mass m and charge $+q$ enters horizontally with speed V_0 midway between the horizontal plates of a parallel plate capacitor at time $t=0$. Separation between the capacitor plates is 'd' and it starts getting charged, by a constant current source, at time t = 0. Plate area of the capacitor is A. It was found that the particle just misses (to hit) the lower plate. Assume that the plates are quite long and acceleration due to gravity is g.

(a) Give a rough sketch of the path of the particle.

(b) Find the constant current (i_0) supplied by the source to the capacitor.

Consider no magnetic force on the charge

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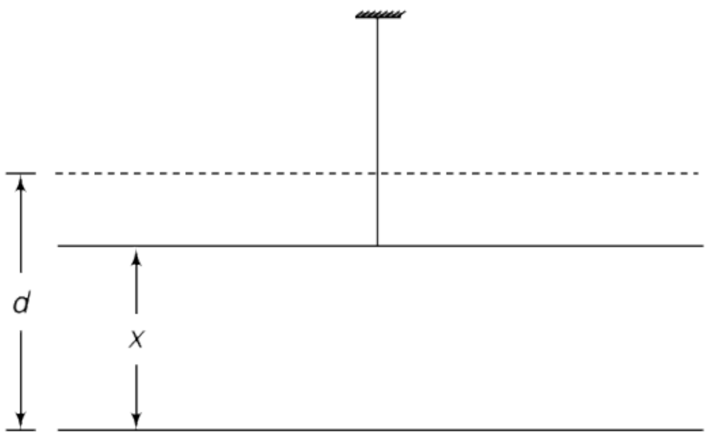
48. Lower plate of a parallel plate capacitor is fixed on a horizontal insulating surface. The upper plate is suspended above it using on elastic cord of force constant K. The upper plate has negligible mass and area of each plate is A. When there is no charge on the plates the equilibrium separation between them is d. When a potential difference = V is applied between the plates the equilibrium separation changes to x.

(a) Calculate V as a function of x.

(b) Find the value of x for which V is maximum. Calculate the maximum value of $V(=V_{\max})$

(c) What will happen if $V > V_{\max}$?

(d) Plot a rough graph showing variation of equilibrium separation (x) with V



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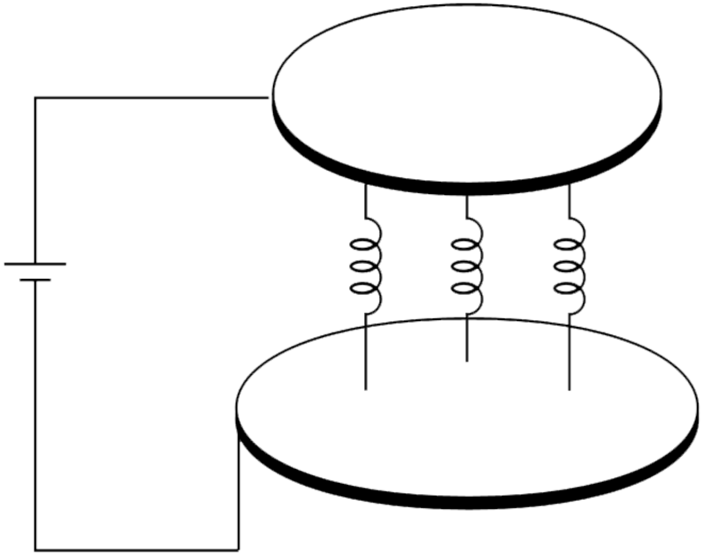
49. Two identical metal plates with area A and mass m are kept separated by help of three insulating springs as shown in the Figure. The equilibrium separation between the plates is $d_0(> > \sqrt{A})$ and force constant of each spring is K. When a constant voltage source having emf V is connected to the plates, the equilibrium separation changes to d. Assume that the lower plate is fixed and the upper plate is free to move.

(a) Find V in terms of given parameters.

(b) If the upper disc is slightly displaced from its equilibrium position and released, calculate the time period of its oscillation.



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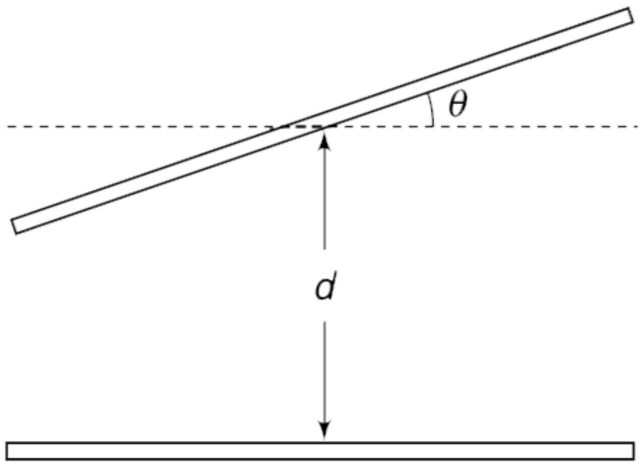
50. One plate of a parallel plate capacitor is tilted by a small angle about its central line as shown in the Figure. The tilt angle θ is small. Both the plates are square in shape with side length a and separation between their centers is d. Find the capacitance of the capacitor.

Given : $ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} + ...$

$$ln(1-x) = -\left(x + \frac{x^2}{2} + \frac{x^3}{3} + ...\right)$$



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