PHYSICS

BOOKS - NN GHOSH PHYSICS (HINGLISH)

CAPACITORS

Example

1. Eight globules of mercury, each with a diameter of 1 mm and a achange of $5 \times 10^9 C$

unite to from a large globule. What would be the potential energy the new globule?

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2. Show that if a dielectric of thickness t and with the same area as the plates of a parallel plate capacitor is introduce the capacitance of the capacitor is given by

$$C = \frac{\varepsilon_0 A}{\left(d - t + \frac{t}{\varepsilon_r}\right)}$$

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3. Two equal drops of water with the same and similar charge coalesce to from a large single drop. Show how the surface density, capacity, potential and energy change.

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4. Two spheres of radii 3 cm and 5 cm are changed to potnetials 3000 and 4500 V respectively. They are then connected bya thin metallic wire. Calculate the loss of electric

energy in this process. What happens to this energy?

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5. There are three conecentric hollow spheres of radii a, b and c and they are charged with charges q_1, q_2 and q_3 respectively. Calculate the potential of the spheres.

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6. A condenser is made of two thin plates with a glass slab of 2 mm thickness between them. The plates are $5cm \times 10cm$ and the relative premittivity of glass is 7.5 Find the capacitance of the capacitor.

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7. Show that the capacitance of a spherical capacitor is $\frac{4\pi\varepsilon_0 b^2}{(b-a)}$ when the outer sphere is charged and the inner earthed.

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8. Two parallel plate air capacitors, each of capacitance C=50 were connected is series ot emf $\varepsilon = 100V$. Then one of the capacitors was filled with a uniforme dielectirc of relative permittivity $\varepsilon = 5$ Compare the before and after the insertion of the dielectric? What amout of charge flows from the battery?

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9. Find the capacitance of an isolated spherical conductor of radius a surrounded by a concentric layer of dielectric of outer radius b and relative permittivity. ε

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10. A long staraight wire is located parallel to an infinite conducting plate at a distance b, The radius of the wire is a Find the

capacitance of this system per unit length of the wire under the condition $a << b$,

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Exercise

1. A charge of 15 nC (nanocoulomb) raises the potential of a spherical from 500 V to 1500 V Find the radius of the conductor.

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2. A hollow spherical conductor of radius 10 m cm is surrounded concentrically by another bigger shell of radius 12 cm and thickness 1 cm The inner one is charged with 39nC (nanocoulomb). Calculate the potntial of the inner sphere when (i) the outer one is not there, (ii) when the outer one is there, (iii) when the outer one is earthed,

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3. A brass spheres of radius 10 cm is electrified to a potential of 24 kV(kilo volts.) It is then made to share charge with another uncharged brass sphere and the potential is found to fall to 6 kV. What is the radius of the second sphere?

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4. 64 droplets of water of equal size unite from a large drop. If each dropet had equal

and similar charge, how would the potential energy and capacitance change?

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5. A charge sphere of radius a si put into conducting communication with an uncharged sphere of radius b. Show that the rationof the original distribution to that of the final distribution is (a+b):a

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6. A sphere of radius 10 cm conecentrically surrounded by a thin spherical shell of radius of 11 cm A charge of $100\mu C$ is imparted to the outer spheree and the inner one is earthed. Calculate the charge on the outer surface of the inner sphere and on the two surfaes of the outer sphere.

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7. Two spherical raindrops of radii 1 mm and 2 mm come in contact with a lighting conductor

at a potential of 500 volts and coalesce. Find the potnetial of the resulting drop and the electrical energy they acquired form the dconductor and gained or lost subsquently due to coalescence after getting detached from the conductor.

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8. Watert from a tap maintained at a potential of V is alllowed to fall by drops of radius r through a small hole into a hollow conducting

sphere of radius R standing on an insultating stand until it fills the entire sphere. Calculate the potential of the hollow conductor.

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9. An insulated sphere of radius 10 cm has a positive charge of 20 nC and another of radius 5 cm has a positive charge of 15 nC. If the two are connected find the

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10. Calculate the potenital energy of a nanocoulomb charge when placed at a distance of 10 cm from a microcoulomb charge.

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11. A parallel-plate capacitor is made up of 15 strips, each of 6 cm $\times$ 4 cm, separated by sheet of mica of dielectric coefficent 6 and constant thickness of 0.15 mm. Calculate its capacitance.

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12. A parallel-plate capacitor is made up of 11 metal plates each of area 15 cm^2 separated by sheets of mica of realative permittivity 6 and thickness 0.2 mm, the altemate plates being joined together. Calculate the capacitance of the capacitor in microfarad.

[Hint: There will be (n-1) similar parallel plate capactions of capacitance $\frac{\varepsilon_0 \varepsilon_r A}{d}$

$\therefore C = (n-1)\frac{\varepsilon_0 \varepsilon_r A}{d}$]

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13. A slab of copper of thckness t is thrust into a parallel plate capacitor of area A and plate separation d. What is the capacitance before and after the slab is introduced?

[Hint:There is no electric field inside a copper slab, or we may say that metals are isulators of $\varepsilon_r = \infty$]

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14. A parallel - plate capacitor of plate area A and plate separation d is charged to a potential difference V and then the battery is disconnected . A slab of dielectric constant K is then inserted between the plate of the capacitor so as to fill the space between the plate .Find the work done on the system in the process of inserting the slab.

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15. Assuming that the energy of a charged parallel plate capacitor is $CV^2/2$ and this energy is stored in the medium between the plates, show that energy density in the medium is $\mu_\varepsilon = \frac{1}{2}\varepsilon E^2$.

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16. A spherical capacitor is made of two spherical conductors of radi 4 cm and 6 cm respectivley. A spherical sheel of permittivity 4

and thickness 1 cm surrounds the inner sphere, the remainder of the space between the spheres being filled with an insulator of permittivity 6, Calculate the capacitance of the capacitor.

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17. Calculate the capacitance per metre of a capacitor formed by two long coaxial cylinders of radii 5 and 5.2 cm filled with dielectric of permittivity 1.2.

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18. A submarine cable consisting of a wire 3 mm in diameter and insulated with 3 mm of guttapercha (permittivity=4.26) is placed in water. Calculate the capacitance of 1 km of the cable in micro farads.

[Hint: Consider the submarine cable as a cylindral capacitor of inner radius 1.55 mm and outer radius of 4.5 mm.]

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19. Find the capacitance of unit length of a cylindrical capacitor which has conductor of radii 2.5 mm and 4.5 mm, respectively and the dielectric consists of two layers whose cylinder of contact is 3.5 cm in radius, the inner layer having a dielectric coefficinet 4 and the outer layer 6.

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20. A parallel-plate capacitor is charged to a certain potential difference. A slab of 3 mm

thickness is inserted between the plates, and it becomes necessary to increase the distance between them by 2.3 mm to maintain the same p.d. Find the dielectric coefficient of the slab.

[Hint: See examples 3]

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21. A parallel-plate condenser of area 100 cm^2, plate separation 5 mm is charged to a p.d. of 100 V when air is used between the plates. If

now air is replaced by glass $(\varepsilon_r = 6)$ calculate (a) the new capacity, (b) the new p.d. and (c) the loss of energy. Account for the loss of energy.

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22. Two equal metal spheres of radius 10 cm are joined together by a long fine wire. They are insulated and electrified by a battery of e.m.f. 10 V. Connection with the battery is not disturbed. If now one of the spheres contract

to one-fourth its original surface, will the system consisting of the two spheres draw or give charge to the battery? by how much? What amount of charge was taken by the system in the beginning?

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23. Calculate the self potential energy of charge q distributed over the surface of a hollow sphere of radius R. What happens to

this self energy when R=0, or when the charge is an ideal point charge?

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24. A charge q is distributed uniformly throughout a non-conducting spherical volume of radius R.(a) Show that the potential at a distance x from the centre when x lt R is given by $V = \frac{q\left(3R^2 - x^2\right)}{8\pi\varepsilon R^3}$ and the self potential energy of the charge distributed is $U = \frac{3q^2}{20\pi\varepsilon R}$. [Hint: Calculate the potentials

due to the charge inside the concentric sphere through the point and due to the charge in the outer portion and add. The calculate self potential energy first calculate the elementary work done in building the charge in shell of thckness dz over a sphere of radius z and then integrate from z=0 to z=R.]

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25. Calculate the capacitance of a sherial capacitor consisting of two concentric

spherical conductros of radii a and b(bgta), when the outer one is charged and the inner is earthed. The space between the spheres is filled by insulating material of relative permittivity ε_r.

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26. A parallel-plate capacitor is filled half-and half with two dielectrics of dielectric constants ε_1 and ε_2, respectively. In the first case, one dielectric is placed over the other. In the

second case, one dielectric fills half the space and the other the second half. Calculate their capacitances in the two cases. The distance between the plates is d and area of each plate is A.

[Hint:(i) In fact there are two capacitors, each of area equal to the area of a plate and thickness equal to half the plate separation. The are in series. (ii) There are two capacitors, each of thickness equal to the plate separation and area equal to half of the area of a plate. They in parallel.]

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27. A solid silver sphere of radius 1 cm is charged to a potential of 10 KV. Calculate the fraction η of the aloms ionized assuming that one atom contributes only one free electron. Density of silver $= 10.5 \times 10^3 kgm^{-3}$ and its atomic weight is 107.9 (Avogadro's number $= 6 \times 10^{26} kgmol^{-1}$ and charge of an electron $= 1.6 \times 10^{-19}$C.

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28. Find the capacitance of a system consisting of a metal sphere of radius a placed at a large distance from an identical metallic sphere.

[Hint: When the distance is large the charges on the spheres may be assumed to be distributed practically uniformly over the surfaces of the spheres. Consider their potential difference and apply $C = Q/V$.

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29. Two long straight wires with equal cross-sectional radii a area located parallel to each other in air at large distance b from each other. Find the capacitance per unit length of the wires.

[Hint: Take charge to be uniformly distributed. Consider the field at any point and hence find the p.d. between the wires.]

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30. A parallel-plate capacitor contains a mica sheet (thickness 10^{-3}m) and a sheet of fibre (thickness 0.5×10^{-3}m). The dielectric constant of mica is 8 and that of the fibre is 2.5. Assuming that the fibre breaks down when subjected to an electric field of $6.4 \times 10^{6} Vm^{-1}$, find the maximum safe voltage that can be applied to the capacitor.

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31. A parallel-plate capacitor consists of two square plates of effective area A, length L and plate separation d. If one of the plates is turned through a small angle θ, what is the change in the capacitance of the capacitor?

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32. A double-layer cylindrical capacitor consists of conductors of radii R_1 and R_3 and two layers of dielectrics of relative permittivtties ε_1

and $es\pi on_2$. The radius of the common surface of the dielectrics. Is R_2 . The breakdown field strengths of the dielectrics are E_1 and E_2 respectively. What is the breakdown voltage of this capacitor if (a) $\varepsilon_1 R_1 E_1 < \varepsilon_2 R_2 E_2$ (b)$\varepsilon_2 R_2 E_2 > \varepsilon_1 E_1 R_1$?

[Hint: If $E_1 = E_{1\max}$ and $E_2 >$, $E_{2\max}$ dielectric 1 will break first and if $E_2 = E_{2\max}$, $E_1 > E_{1\max}$ dielectric 2 will break first.]

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33. A charge q is distributed over the volume of a sphere of radius R. Assuming the permittivty to be equal to unity, compare the energy stored inside the sphere with the energy pervading the surrounding space.

[Hint: $u = \frac{1}{2}\varepsilon_0 E^2$.]

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34. A spherical shell of radius R_1 with uniformly distributed charge q has a point charge q_0 at its centre. Find the work

performed by the electric forces during the expansion of the shell from R_1 to R_2.

[Hint: W=W_1(decrease in self potential energy) $+W_2$(work done by electrical force of q_0 on q)]

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35. A point charge Q is placed at the centre of an uncharged spherical shell of inner radius a and outer radius b. There is a small tunnel in the body of the shell. Calculate the work done to transfer the charge through the tunnel to

infinity.

[Hint: Remove the charge bit by bit and calculate the total work done.]

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36. Calculate the capacitance of a parallel-plate capacitor of area S, separation d and dielectric constant varying linearly from ε_1 to $\varepsilon_2 (\varepsilon_2 > \varepsilon_1)$ in the direction of the applied field.

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37. Two small equal balls of radius r carry chrges q_1 and q_2 they are joined by a thin wire while being kept at a fixed distacne l/ Calaulate the heat produced in the connecting wire. Why is the wire fine?

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38. Two metal balls with radii $r_1 = 1cm$ and $r_2 = 2cm$ at a large distance R=100 cm from each other, are connected to a battery of emf

$\varepsilon = 3000V$ Find the of interactio betwenn the balls. What is the signification of the ward large?

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39. Find the capacitance of a system consisting of a metal ball of radius $a = 0.9$ cm and an infinite conducting plane separatedform the centre of the ball by a distance l=1m.

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40. A system consists of two thin concentric metal shells of radii a=5 cm and b=7 cm with charges $q_1 = 6\mu C$ and $q_2 9\mu C$ What is the interaction energy and the total electric energy of the system.

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