# Electrodynamics and Optics: Problems

1. A point charge *1 μC* is fixed inside an insulator sphere at the bottom. The radius of the sphere is *10 cm* and the inner surface is smooth. On this surface a point charge can move whose charge is *0.048 μC* and its mass is *1.125g*. At the equilibrium what is the angle between the radius drawn to this point charge and the upward direction. (FFII/2)

2. Semicircle, thin, smooth insulator rod is fixed in a horizontal plane. At the end points *20 nC* and *10 nC* point charges are fixed. On the rod a small and positively charged pearl can move. Determine the equilibrium position of the pearl. Give the angle between the radius to the equilibrium and the radius to the *10 nC* charge. (FFII/10)

3. At the corners of a square there are four equal free point charges on a smooth horizontal plane. What is the charge of the fifth particle placing at the centre of the square, if the whole system is in equilibrium?

4. How much times is greater the Coulomb repulsive force between two protons then the attractive Newton's gravitational force. The charge of a proton is *1.6 ·10⁻¹⁹ C* the mass of the proton is *1.67· 10⁻²⁷ kg*. The Coulomb constant $k = 9 \cdot 10^9 \, \dfrac{Nm^2}{C^2}$ and the gravitational constant γ is $6,67 \cdot 10^{-11} \, \dfrac{m^3}{kgs^2}$. (FFII/1)

5. The base of an equilateral triangle is *10 cm* and its height is *12 cm*. At the end points of the base there are *0.5 μC* charges. What is the force acting on a charge of *0.1 μC* sitting at the third vertex? (FFII/7)

6. Two small similar conducting balls are hung at the same point from silk threads of length *l* and carry the same charges. At the equilibrium the distance between them is *d* << *l*. Neutralize one ball and determine the new equilibrium position. (FFII/3)

7. Two small similar conducting balls are hung from the same point with silk threads of length *l*, and carry the same charges. If the system is in the air the angle between the threads is *60ᵒ*. If the system is immersed into petroleum whose relative permittivity is *2* the angle between the threads is *54ᵒ*. What is the density of the ball if this density of the petroleum is *0.8 g/cm³*? (FFII/4)

8. A homogenous insulator sphere of radius *R* and relative permittivity ε_r is charged with constant volume charge density ρ. Find expression for the electric field and the potential as a function of the distance from the centre.

9. Determine the electric field and potential due to a uniformly charged ring whose radius is *R* and the linear charge density is λ, along the axis a distance *x* from the plane of the ring.

10. Consider an infinite line of charge with constant line charge density λ. Find expression for the electric field at a distance *r* from the line, suppose that it is placed in vacuum.

11. Determine the electric field and potential due to a charged conductor sphere of radius *R* if its chage is *Q* as a function of distance from center.

12. A *2 μF* capacitor is charged to *50 V* potential difference, the *3 μF* capacitor is charged to *100 V* potential difference. What is the final potential difference across the parallel combination? (FFII/13)

13. What is the maximum value of the applied potential difference between points A and B if the maximum charge is *1.2 μC* on any capacitor? (FFII/21)
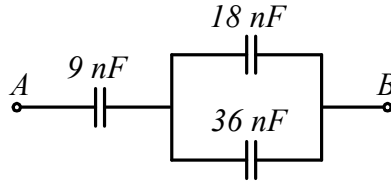

14. An unknown capacitor is charged to a potential difference of *80 V*. A *60 μF* capacitor is charged to a potential difference of *16 V*. Determine the capacitance of the unknown capacitor if they are connected parallel with their positive plates together and negative plates together and the potential difference on the parallel combination is *20 V*. (FFII/14)

15. The same as problem 14. but the two capacitors are connected parallel with terminals of opposite sign. (FFII/14)

16. A *5 μF* capacitor is capable of withstanding *200 V* without breakdown, the *20 μF* capacitor if capable of withstanding *100 V*. What is the maximum potential difference that can be applied on the series combination of the capacitors? (FFII/15)

17. Determine the capacitance of a cylindrical capacitor of radii a and b and length l. Assume that the capacitor is very long that is $l >> b$, so that we can ignore the fringing of the lines at the end. The permittivity of the medium between the plates is ε.

18. Determine the energy of an isolated conducting sphere of radius R in vacuum if its charge is Q. Use the energy density expression at an arbitrary point is space.

19. Consider an isolated conducting sphere of radius R in vacuum charged to Q. Determine the outer radius of the shell around the sphere so that half of the total electrostatic energy is stored in the spherical shell.

20. Consider the next circuit shown on figure. $U = 25\ V$, $C_1 = 5\ μF$, $C_2 = 10\ μF$ and $C_3 = 20\ μF$. First C_3 and C_2 are uncharged and C_1 is connected to the seat of emf as the switch is thrown to the left. After that the switch is thrown to the right and the seat of emf is removed from the circuit. Find the final charges on the different capacitors.
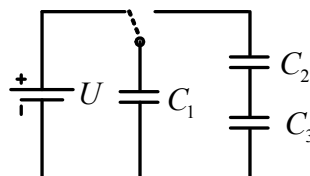

21. The figure shows a hemispherical ideal conductor as a ground connection. The current thought this connection is *10 kA*. The conductivity of the earth is $\gamma = 0.01\dfrac{1}{\Omega m}$, $a = 10$ cm, $r_o = 10\ m$ and $l = 75\ cm$.
a) What is the potential of the ground connection?

b) What is the electric resistance of the system?

c) What is the potential difference between points A and B? (It is called step potential difference.) (FFII/126)
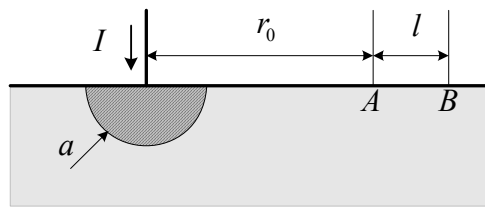
22. The voltmeter with an internal resistance of $20\ k\Omega$ intended for measuring a potential difference up to $50\ mV$. What resistance should be selected and how should it be connected to measure a potential difference up to $100\ V$? What is the actual potential difference if the pointer shows $30\ mV$? (We broaden the range of potential difference can be measured.) (FFII/78)

23. An ammeter with an internal resistance of $0.01\ \Omega$ is intended to measure currents up to $10\ mA$. What resistance should be selected and connected (shunt) to measure a current up to $2A$? What is the actual current if the pointer shows $3\ mA$? (FFII/79)

24. A seat of emf has internal resistance of $4\ \Omega$. Connect first to the terminals of the seat of emf an external resistance of $8\ \Omega$ and change it to a resistor R. In both cases the power on the consumer are the same. Find the resistance R?

25. Two consumers having resistances R_1 and R_2 respectively are connected first in series a second in parallel and connected to a battery. The power dissipated on the series or parallel connection is the same in both cases. What is the internal resistance of the battery?

26. Two identical cells are connected first in parallel and second in series and are connected across an external resistor of $20\ \Omega$. In the second case the terminal potential difference of a cell is $75\ \%$ as in the first care.

a) Determine the internal resistance of the cell.

b) How many times the electric power on the resistor in the second case as in the first one? (FFII/103)

27. Three wires are made of the same metallic conductor. Their length is the same but their cross-sectional area is A, $2A$ and $3A$ receptively. They are connected series and $110\ V$ potential differences are applied across the system. Determine the potential differences across the three wives. (FFII/112)

28. Two voltmeters of resistances $R_1 = 5\ k\Omega$ and $R_2 = 3\ k\Omega$ respectively and a consumer $R = 4\ k\Omega$ are connected as shown in the next figure. The applied battery is resistanceless and the emf is $200\ V$. Determine the voltmeters readings. (FFII/90)
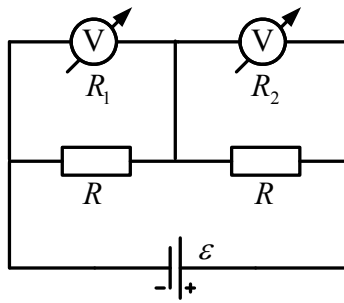
29. What is the reading of the ammeter is the next circuit shown in figure if $\varepsilon = 10\ V$ and $R = 100\ \Omega$. The ammeters and the emf is resistanceless. (FFII/91)
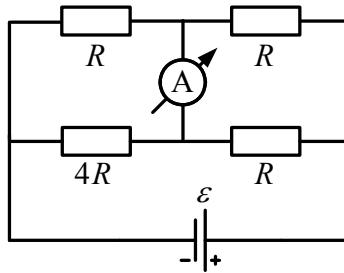

30. Find the power dissipated on the resistor $4R$, if $\varepsilon_1 = 4.5\ V$, $\varepsilon_2 = 16\ V$ and $R = 1\ \Omega$. Suppose that the cells are resistanceless. See figure. (FFII/106)
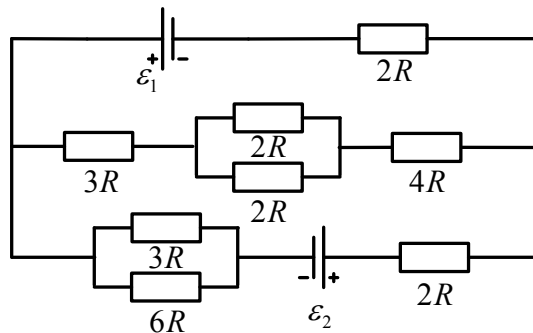

31. The two ideal (resistanceless) batteries of emf $\varepsilon_1 = 45\ V$ and $\varepsilon_2 = 30\ V$, the resistors $R_1 = 10\ \Omega$, $R_2 = 22\ \Omega$, $R = 40\ \Omega$ and the capacitance of $C = 70\ \mu F$ are connected in circuit as shown in figure. Determine the stationary current through the battery in the right side and the charge on the capacitor. (E/8)
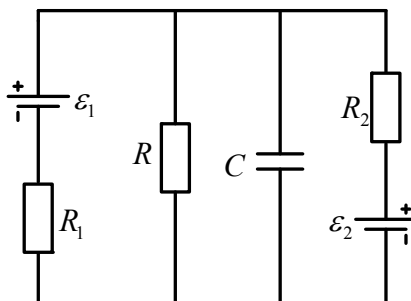

32. Determine the equivalent resistance of the infinite number of resistors connected in a circuit as it is shown on the figure.
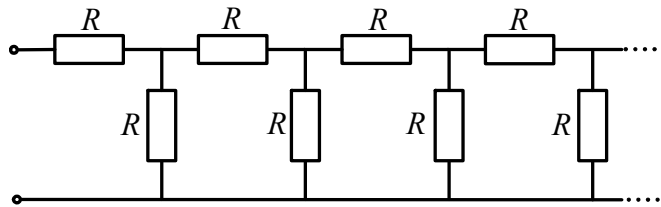
33. Consider the circuit shown in the figure. $R = 400\ \Omega$, $C = 40\ \mu F$ and $\varepsilon = 360\ V$, the internal resistance of the seat of emf is negligible. Determine the charge flows through the wire at poit Y if we disconnect the circuit at poit X. (FFII/97)
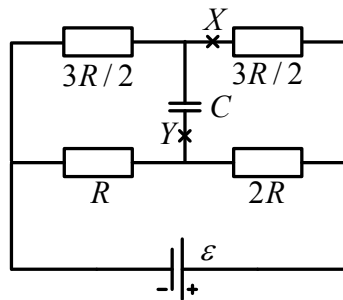
34. Determine the equivalent resistance of the system shown in the figure. What is the magnitude and direction of the current through the branch AB? The emf of the source is $U_o = 70\ V$, and $R = 20\ \Omega$. The source is resistanceless. (FFII/108)
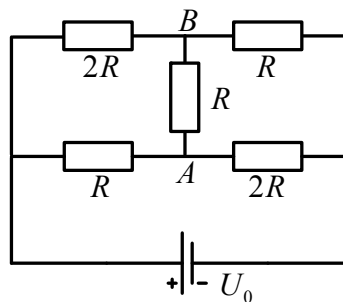

35. Two long parallel wires carry currents of $I = 10\ A$ in opposite directions. The distance of the current carrying wires is $d = 20\ cm$. Determine the magnetic field strength at the points P_1, P_2, P_3 and P_4. (FFII/135)
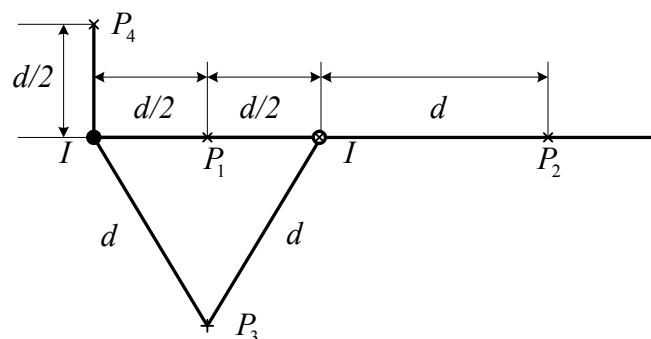

36. Consider a coaxial cable, the inner cylindrical conductor has a radius r_o and the outer shell has an r_1 inner and r_2 outer radii. The central conductor carries a current I, and the outer conductor providing the return path. Suppose that the current is distributed uniformly in both sections. Find and plot the magnetic field strength as a function of the distance r measured from the axis. (FFII/136)

37. The cross section of the iron core shown in figure is square. The length of the air-gap is *1 mm*. The number of the turns of the first and second coils are *1000* and *600* respectively.
a) Determine the current in the first coil if there is no current in the second coil and the magnetic induction in the air-gap is *1.3 T*.
b) How much is the current in the second coil if the current in the first coil is the same as part a) but the magnetic induction is only *0.8 T* at the gap. $\mu_o = 4\pi \cdot 10^{-7}$ *Vs/Am*. The measured magnetisation curve of the iron core is shown on the figure. (FFII/139)
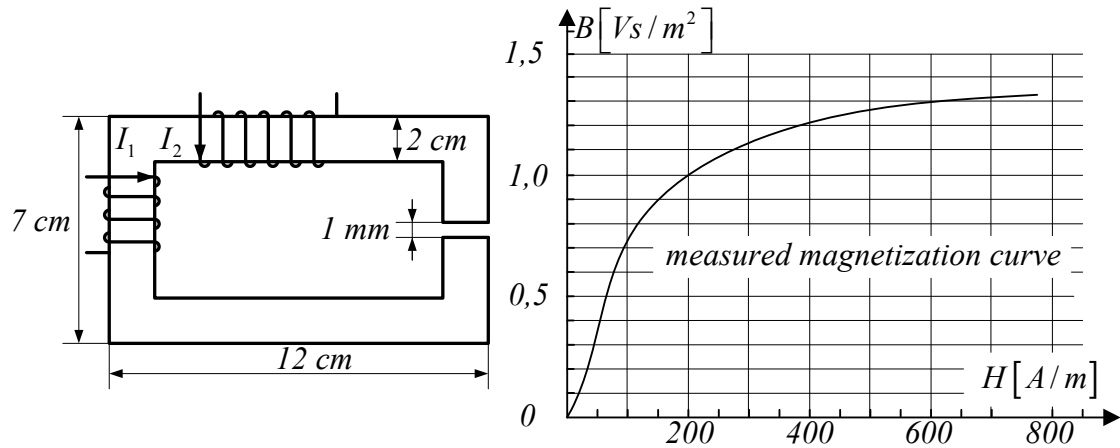

38. The next figure shows an infinitely long straight wire carrying a current of *30 A*. The square loop lies in the some plane and carries a current of *10 A* in the shown direction. Calculate the magnitude and direction of the resultant force acting on the loop. Assume that *a = 2 cm* and *b = 1 cm*. (FFII/162)
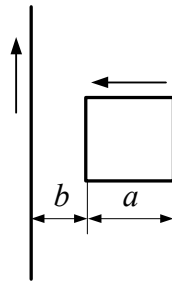

39. The electron beam is produced by an electron gun and the electrons are accelerated by a potential difference of *1 kV*. The electron beam is directed into the direction of the *f* straight line. The target point *C* is *5 cm* away from point *A* and at an angle of *60°* with respect two *f*. Find the magnitude of the applied magnetic induction if the electrons hit the target,
a) the direction of the applied magnetic field perpendicular to the plane of the straight line *f* and the point *C*,
b) the direction of the applied magnetic field is parallel with the *AC* direction. The mass of the electron is *9,1·10⁻³¹ kg* and it change is *1,6·10⁻¹⁹ C*. (FFII/173)
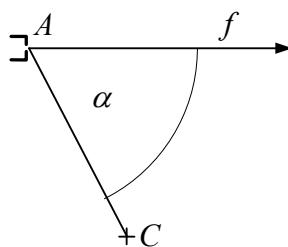
40. The figure shows an infinitely long straight wire carrying a current I. The rectangular loop lies in the same plane and moves away from the straight wire with constant velocity c. The resistivity of the homogeneous wire of the loop is ρ, and its cross-recessional area is A. At the initial moment the P_1P_2 side is a distance d form the long wire. Determine the currant in the loop as a function of the time. (The magnetic field due to the induced current is negligible.) (FFII/184)
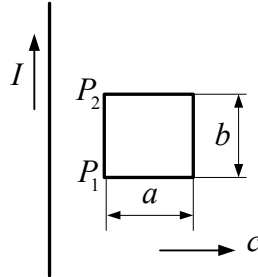
41. Determine the root-mean-square value of the two periodical currents shown in the figure. The curves on the figure are sinusoidal functions. (FFII/214)
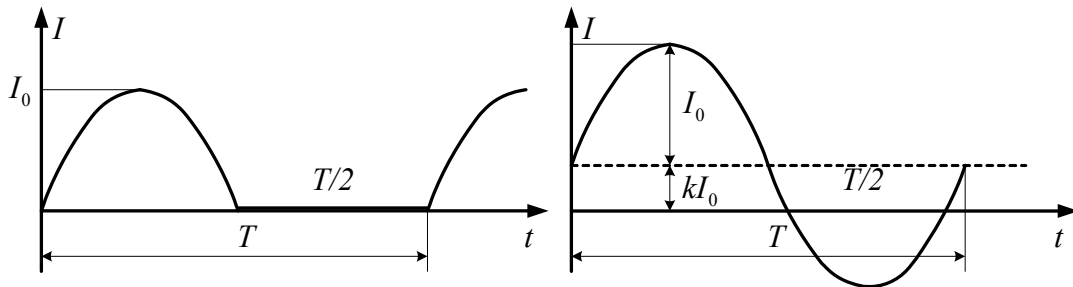
42. A single-loop circuit containing a resistor and an ideal inductor and connected to an ac. generator. The terminal potential difference leads the current by $\pi/3$. How many times will be the power delivered by the generator if we double the frequency of the generator but the effective value of the emf is the same? (FFII/217)

43. *A 50 Ω resistor* and an ideal inductor in a single-loop circuit is connected to an alternating current generator with $\varepsilon_{rms} = 220\ V$ and $f = 50\ Hz$. The effective value of the current is *2A*. If an additional capacitor is connected to this series connection the current remains the same *2A*.
a) find the inductance,
b) find the capacitance,
c) determine the average power without capacitor and with capacitor. (FFII/219)

44. In an RLC serial circuit the generator serves *108 V* effective voltage. The frequency of the generator is variable. At *25 Hz* frequency the rms current is *8 A*. If we increase the frequency at *55 Hz* the rms current has a maximum value just *24A*. Determine the resistance, the capacitance and the inductance of the circuit. What is the power factor at *25 Hz*? (FFII/220)