PHYSICS

BOOKS - IE IRODOV PHYSICS (HINGLISH)

ELECTRODYNAMICS

Constanct Electric Field In Vaccum

1. Calculate the ratio of the electrostatic of gravitational inteaction forces between two electrons, between two protons. At what values of the specific cahreg q/m of a praticle would these forces become equal (in their absoule values) in the case of interaction of indentical) particles ?

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2. What would be the interaction force between two copperspheres, each of mass $1g$, separated by the distance $1m$, if the total electrons charge in them differted from the total charge of the nuclei by one of part cent?

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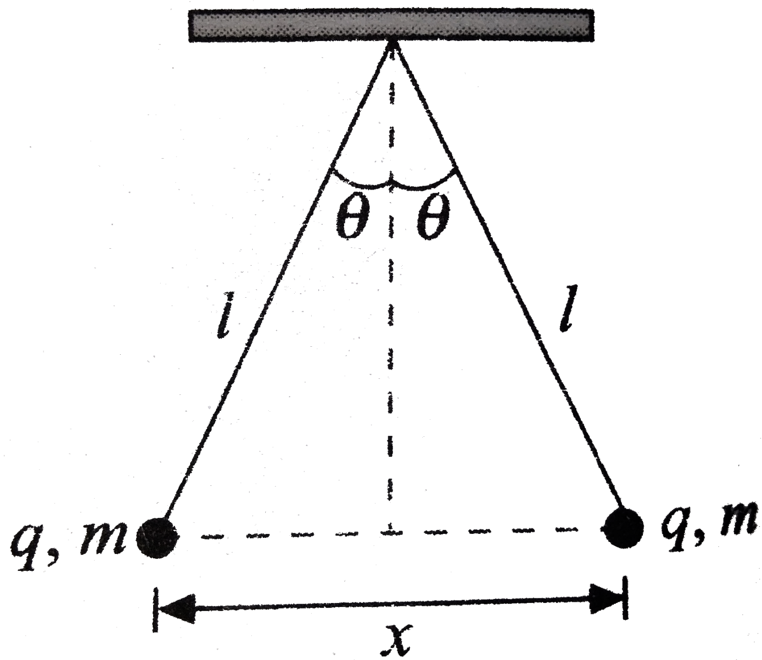
3. Two similar balls, each of mass m and charge q, are hung from a common point by two silk threads, each of length l. Prove that separation between the ball is

$x = \left[\frac{q^2 l}{2\pi\varepsilon_0 mg}\right]^{1/3}$, if θ is small

Find the rate $\frac{dq}{dt}$ with which the charge should leak off each sphere if the velocity of approach varies as $v = a/\sqrt{x}$, where a is a constant.



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4. Two positive charges q_1 and q_2 are located at the points with redius vectors r_1 and r_2. Find a negative charge q_3 and a radius vector r_3 of the point at which it has to be placed for the force acting on each of the three charges to be equal to zero.

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5. A thin wire ring of radius r has an electric charge q. What will be the increment of the force stretching the wire if a point charge q_0 is placed at the ring's centrre ?

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6. A positive point charge $50\mu C$ is located in the plane xy at the point with radius vector $r_0 = 2i + 3j$, where I and j are the unit vectors of the x and y axes. Find the vector of the electric field strength E and its magnitude ath the point with radius vector $r = 8i - 5j$. Here r_0 and r are expressed in metres.

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7. Point charge q and $-q$ are located at the vertices of a square with diagonals $2l$ as shown in Fig. Find the magnitude of the electric field strength at a point located symmetrically with respect to the vertices of the square at a distnace x from its centre.

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8. A thin half ring of radius $R = 20cm$ is uniformly charged with a total charge $q = 0.70nC$.Find the magnitude of the electric field strength at the curvaite centre of this half-ring.

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9. A whin wire ring of radius r carries charge q. Find the magnitude of the electric field strength on the axis of the ring as a function of distance l from its centre. Investigate the obtained function at $l > > r$. Find the maximum strength magnitude and the corresponding distance l. Draw the appoximate polt of the function. $E(l)$.

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10. A point charge q is located at the centre fo a thin ring of radius R with uniformly distributed charge $-q$, find the magnitude of the electric field strength vectro at the point lying on the axis of the ring at a distance x from its centre, if $x > > R$.

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11. A system consits fo a thin charged wire ring of radius R and a very long uniformly charged thread oriented along the axis of the ring, with one of its ends coinciding with the centre of the ring. The total charge of the ring, with one of the ring so equal to q. The charge of the thread (per unit length) is equal to λ. Find the interaction froce between the ring and the thread.

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12. A thin nonconducting ring of radius R has a linear charge density $\lambda = \lambda_0 \cos \varphi$, where λ_0 is a constant , ϕ is the azimutahl angle. Find the magnitude of the electric field strength

(a) at the centre of the ring ,

(b) on the axis of the ring as a function of the distance x from its centre. Investegation the obtained function at $x > \; > R$.

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13. A thin straight rod of length $2a$ carrying a uniformly distributed charge q is located in vacumm. Find the magnitude of the electric field strength as a function of the distatance r from the rod's centre along the streaight line

(a) perpendicular to the rod and passing through its centre ,

(b) coinciding with the rod's direction (at the point lying outside the rod).

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14. A very long straight uniformly charged thread carries a charge λ per unit length. Find the magnitude and direaction of the electric field strength at point which is at a distance y from the thread and lies on the perpendicular passing through one of the thread's ends.

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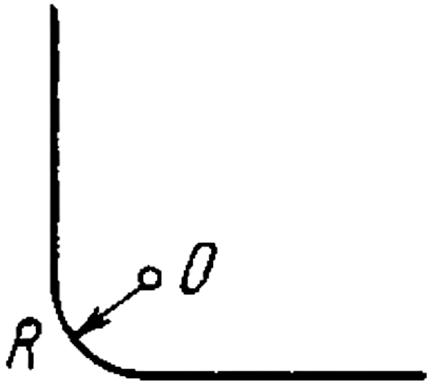
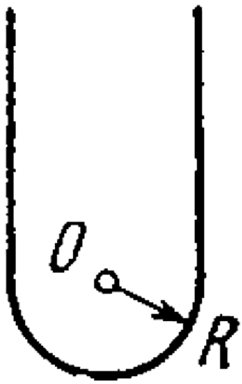
15. A thread carrying a unifrom charge λ per unit length has the configuration shown in fig, Assuming a curvature radius R to be considerably less than the length of the thread, find the magnitude fo the electric field strength at the point O.



(a)

,



(b)

16. A shpere of radius r carries a surface charge a density $\sigma = ar$, where a is a constant, vector and r is radius vector of a point of the sphere ralative to its centre. Find the electric field strength vector at the centre relative at the centrre of the sphere.

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17. Suposse the surface charge density over a sphere of radius R dendends on a polar angle θ as $\sigma = \sigma_0 \cos \theta$, where σ_0 is a positive constant. Show that such a charge distribution can be represented as a result of a small relative shift of two uniformly charge balls of radius R whose charges are equal in magnitude and opposite in sign. Restoring to this representation, find teh electric field strength vector inside the given spehre.

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18. Find the electric field strength vector at the centre of a ball of raiduius R with volume charge density $\rho \Rightarrow ar$, where a is a constant vector, and r is a radius vector drawn from the ball's centre.

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19. A very long uniformly thread oriented along the axis of a a circle of raius R rests on its centre with one of the ends. The charge of the thread per unit length is equla to λ. Find the flux of the vector E across the circle area.

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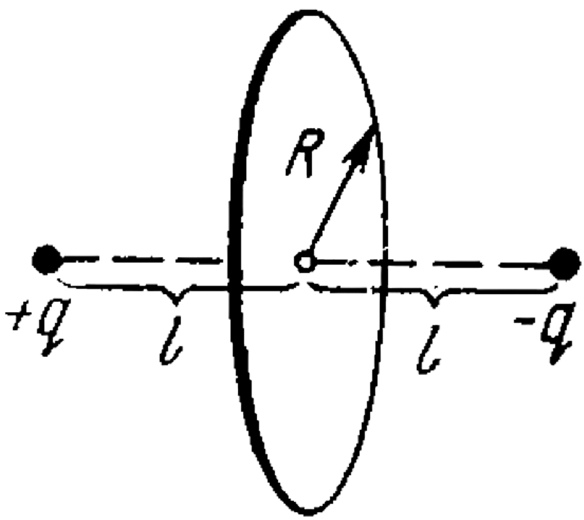
20. Two point charges q and $-q$ are separated by the distance $2l$. Find the flux of the electric field strength vector across a circle of radius R.



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21. A ball of radius R is uniformly charged with the volume density ρ. Find the flux if the electric field strength vector across the balls section formed by the plane located at a distance $r_0 < R$ from the centre of the ball.

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22. Each of the two long parallel threads carries a uniform charge λ per unit length. The threads are separated by a distance l. Find the maximum magnitude of the electric firld strength in the symmetry plane of theis system located between the threads.

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23. An infineltly long cylindrical surface density $\sigma = \sigma_0 \cos \varphi$. Where φ is the polar angle of the cylindrical coordinate system whose z axis coincides with the axis of the given surface. Find the magnitude and direction of the electric fiels strength vector on the z axis.

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24. The electric field strength depends only on the x and y coordinates according to the law $E = a\frac{xi + yj}{x^2 + y^2}$, where a is a constant , i and j are the unit vectors of the

x and y axes. Find the flux of the vector E through a sphere of raidus R with its centre at the origin of coordinates.

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25. A ball of radius R carries a positive charge whose volume density depends according only on a separation r from the ball's centre as $\rho = \rho_0(1 - r/R)$, where ρ_0 is a constant. Asumming the permittivites of the ball and the enviroment to be equal to unity find :

(a) the magnitude of the electric field strength as a function of the distance r both inside and outside the ball :

(b) the maximum intensity $E_{\max}$ and the corresponding distance r_m.

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26. A system consits of a ball of radus R carrying spherically symmetric charge and the surrounding space filled with a charge of volume density $\rho = \alpha / r$, wehre α is a constant, r is the distance from the centre of the ball. Find the ball's the charge at whcih the magnitude of the electric field strength vector is independent of r outside the ball. How high is this strength ? The permittives of the ball and the surrounding space are assumed to be equal to unity.

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27. A space is filled up with a charge with volume desnsity $\rho = \rho_0 e^{-\alpha r^3}$, where ρ_0 and α are positive constansts, r is the distance from the centre of this system. Find the magnitude of the electric field strength vector as a function of r. Investigate the obtained expresssion for the small and large values of $r, i.e.,$ at $\alpha r^3 < < 1$ and $\alpha r^3 > > 1$.

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28. Inside a ball charged uniformly with volume density ρ there is a spherical cavity. The centre of the ball by a distance a. Find the field strength E inside the cavity, assuming the permittively equal to unity.

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29. Inside a indinitely long circular cylinder cavity. The distance between the axes of the cylinder and the cavity is equal to a. Find the electric field strength E inside the cavity. The permittivity is assumed to eb equal to unity.

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30. Two thin wire rings each having radius R are placed at distance d apart with their axes coinciding. The charges on the two are $+Q$ and $-Q$. The potential difference between the centre so the two rings is

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31. There is an infinitely long straight thread carrying a charge with linear density $\lambda = 0.40 \mu C / m$. Calculate the potentail difference between points I and 2 is removed $\eta = 2.0$ times farhter from the thread than point 1.

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32. Find the electric field potentail and strength at the centre of a hemisphere fo raidus R ahcged uniformly with the the surface density σ.

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33. A very thin round plate of radius R carrying a uniform surface charge density σ is located in vacumm. Find the electric field potentail and strength along the plate's axis as a function of a distance l from its centre. Investigation the obtained expression of $l \rightarrow 0$ and $l > \; > R$.

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34. Find the potential φ at the edge of a thin disc of radius R carrying the uniformly distributed charge with surface density σ.

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35. Find the electric field strength vector if the potentail of this field has the form $\varphi = ar$, where is a constatn vector, and r is the radius vector of point of the field.

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36. Determine the electric field strength vector if the potential of this field depends on x, coordinates as

(a) $V = a\left(x^2 — y^2\right)$ (b) $V = axy$

where, a is a constant.

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37. The potential of a certain electrostaitc field has the form $\varphi = a(x^2 + y^2) + bz^2$, where a and b are constants. Find the magnitude and direction fo the electric field strength vector. What shape have the equipotentail surfaces in the fololowing cases:

(a) $a > 0, b > 0$, (b) $a > 0, b < 0$?

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38. A charge q is uniformly distributed over the volume of a shpere of radius R. Assuming the permittively to be equal to unity throughout, find the potential

(a) at the centre of the sphere,

(b) inside the sphere as a function of the distance r from its centre.

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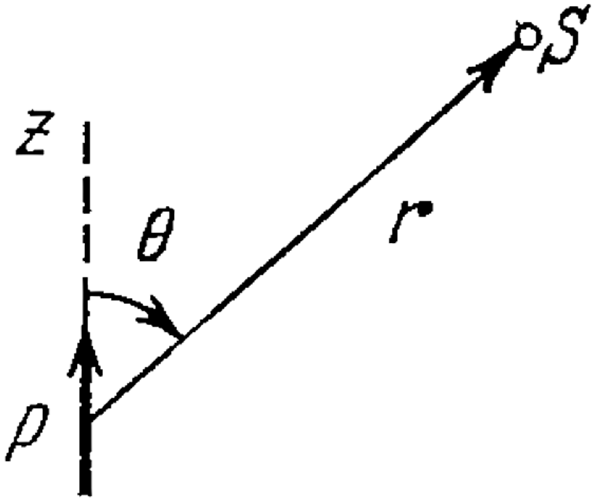
39. Demonstrate that the potential of the field generated by a dipole with the electric moment p (fig) may be represented as $\varphi = pr / 4\pi\varepsilon_0 r^3$, where r is the redius vector. Using this expression, find the magnitude of the electric strength vector as a funcition of r and θ.



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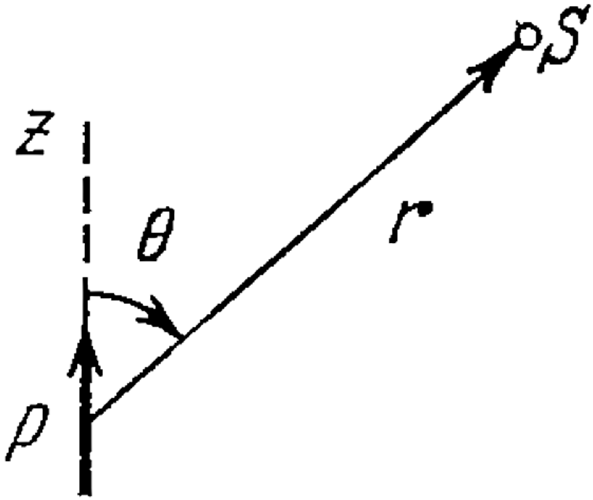
40. A point dipole with an electric moment p oriented in the positive direction of the z axis si located at the origin of coordinates. Find the projections E_z and $E_\perp$ of the electric field strength vector (on the plane perpendicular to the z axis at the poiny S. At which points is E

perpendicular to p ?



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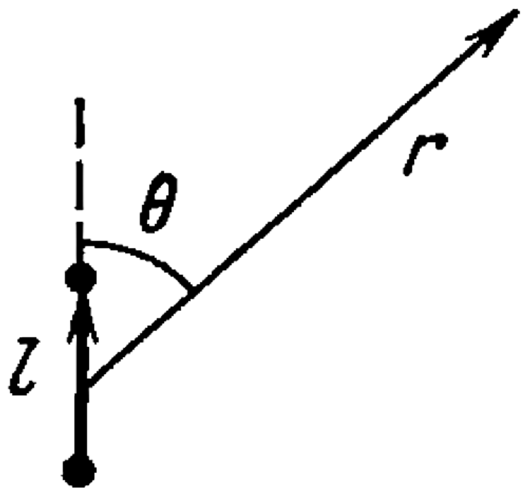
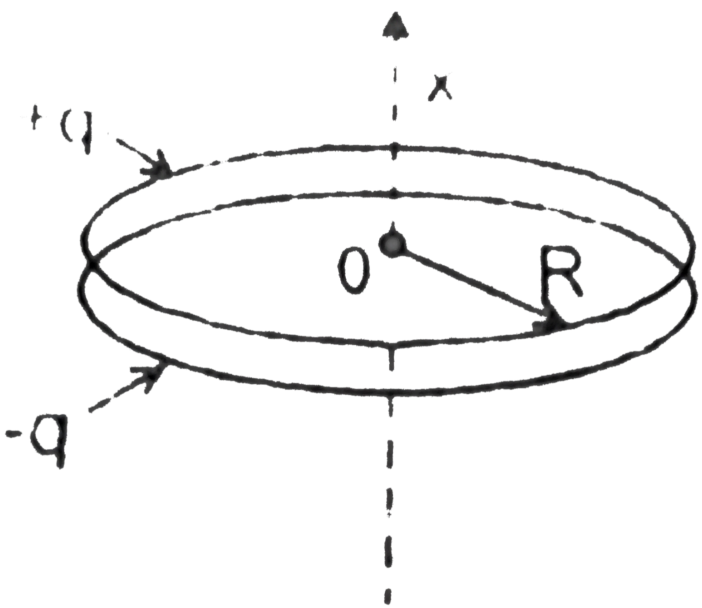
41. A point electric dipole with a moment p is placed in the external uniform electric field whose strength equals E_0. With $p \uparrow \uparrow E_0$. In this case one of the equipotential surfaces enclosing the dipole from a sphere. Find the radius of this sphere.

42. Two this parallel threads carry a uniform charge with linear densities $lamnda$ and $-\lambda$. The distance between the threads is equal to l. Find the potential of the electric field and the magnitude of its strength vector at the distance $r > \; > l$ at the angle θ to the vector 1 (fig).



43. Two coaxial rings, each of radius R, made of thin wire are separated by a small distance $l(l < < R)$ and carry the charges q and $-q$. Find the electric field potential and strength at the axis of the system as a function of the x coordinate (see figure). Investigate these functions at $|x| > > R$



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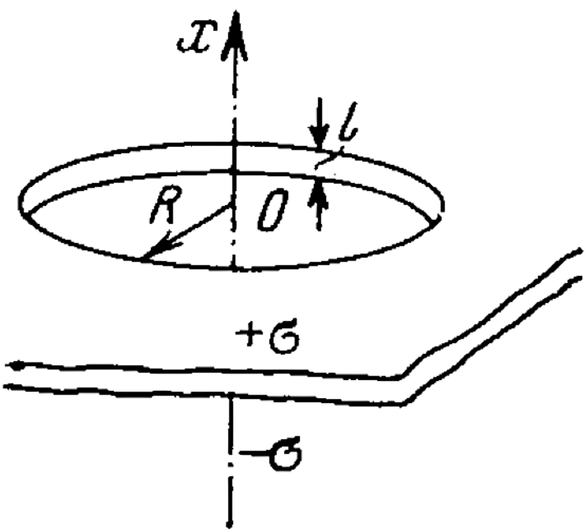
44. Two infinite planes sepated by a distance l carrying a uniform surface charge of densities σ and $-\sigma$. The planes have round coaxial holes of radius R, with $l < < R$. Taking the origin O and the x cordinates axis as shown in the figure, find the potentail of the electric field and the projection of its strength vector E_x on the area of the system as functions of the x cordiante. Draw the appoximate plot $\varphi(x)$.



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45. An electric capacitor consists of this round parallel plates. each of radius R, separated by a distance $l(l < < R)$ and uniformly charged with surface densities σ and $-\sigma$. Find the potential of the electirc field and the magnitude of tis strength vector at the axes of the capacitor as functions of a distanace x from the plates if $x > > l$. Investigate and obtained expressions at $x > > R$.

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46. A dipole with an electric moment p is located at a distance r from a along thread charge uniformly with a linear density λ. Find the force F acting on the dipole if the vector p is oriented

(a) along the thread

(b) along the radius vector r

(c) at the right angles to the thread and the radius vector r.

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47. Find the interaction force between two water molecules separated by a distance $l = 10mm$ if their electric moments are oriented along the same straight line. The moment of each molecule equals $p = 0.62.10^{-29} C. m.$

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48. Find the potential V of an electrostatic field $\vec{E} = a\left(y\hat{i} + x\hat{j}\right)$, where a is a constant.

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49. Find the potential $\varphi(x, y)$ of an electrostatic field $E = 2axyi + a\left(x^4 - y^2\right)j$, where a is a constant, I and J are the unit vectors of the x and y axes.

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50. Determine the potentail $\varphi(x, y, z)$ of an electrostatic field $E = ayl + (ax + bz)J + byk$, where a and b are constants, I, j, $k$are the unit vectors of the axes x, y, z.

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51. The field potentail in a certain region of space depends only on the x coordinate as $\varphi = -ax^3 + b$, where a and b are constants. Find the distribution of the space charge $\rho(x)$.

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52. A uniformly distributed space charge fills up the space between two large parallel plates separated by a distance d. The potential difference between the plates is equal to zero ? What will then be the field strength near the other plate ?

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53. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre and a, b are constants. Then the charge density inside the ball is:

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Conductors And Dielectrics In An Electric Field

1. A small ball is suspended over an infinite horizontal conducting plane by means of an insulating elastic thread of stifiness k. As soon as the ball was charged it decended by $x cm$ and its separation from the plane become equal to l. Find the charge of the ball.

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2. A point charge q is located at a distance l from the infinite conducting plane. What amount of work has to be performed in order to slowly remove this charge very far from the plane.

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3. Two point charges q and $-q$ are separated by the distance l, both being located at a distance $l/2$ from the infinite conducting plane. Find :

(a) the modulus of the electric force acting on each charge,

(b) the magnitude of the electric field strength vector at the midpoint between these charges.

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4. A point charges q is located between two mutually perpenicular conducting hlaf-planes . Its distance from each half-plane is equral to l. Find the molecules of the vector p is perpendicular to the planes.

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5. A point dipole with an electric moment p is located at a distance l from an infinite conducting plane. Find the modulus of the vector of the force acting on the dipoel if the vector p is perpendicular to the plane.

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6. A point charge q is located at a distance l from an infinite conduting plane. Determine the surface density of charges induced on the plane as a function of separaction r from the base of the perpendicular drawn to the plane from the chagre.

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7. A thin infinitely long thread carrying a charge λ per unit length is oriented parallel to the infinite conducting plane. The distance between the thread and the plane is equal to l. Find :

(a) the moducles of the vector of the force acting on a unit length of the thread ,

(b) the disribution of surface chagre density $\sigma(x)$ over the plane, where x is the distance form the plane perpendicular to the conducting surface and passing through the thread.

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8. A very long straight thread is oriented at right angles to an infinite conducting plane, its end is separated from the plane by a distance l. The thread carries a uniform charge of linear density λ. Suppose the point O is the trace of the thread on the plane . FInd the surface density of the induced charge on the plane

(a) at point O.

(b) as a function of a distance r from the point O.

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9. A thin wire ring of radius R carries a charge q. The ring si oriented parallel to an infinite conducting plane and is spearated by a distance l from it. Find :

(a) the surface chagre density at that point fo the plane symmetrical with respect to the ring,

(b) the strength and the potential of the electric field at the centre of the ring.

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10. Find the potential φ of an uncharged conducting sphere outside fo wihich a point charge q is located at a distance l from the sphere's centre.

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11. A point charge q si located at a distance r from the centre O of an uncharged conducting conducting spherical layer whose inside and outside radii are equal to R_1 and R_2 respectively. Find the potentail at the point O if $r < R_1$.

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12. A system consists of two concentric spheres, with the inside sphere of radius a carrying a positive charge q_1. What charge q_2 has to be diposited on the outsie sphere of radius b to reduce the potentail φ depend in this case on a distance r from the centre of the system ? Draw teh appoximate plot of this dependence.

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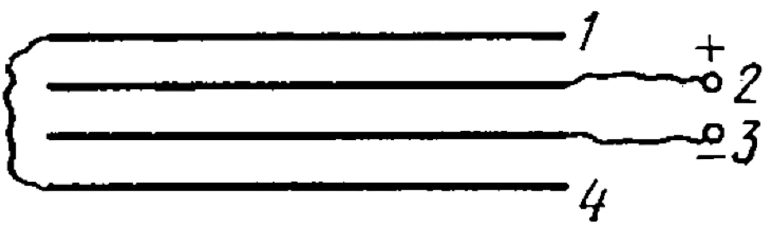
13. Four large metal plates are located at a small distance d from one another as shown in Fig. The exremen plates are interconnected



by means of a conductor while a potential difference $\Delta\varphi$

is applied to inernal plates. Find :

(a) the values of the electric field strength between neighbouring plates,

(b) the total charge per unit area of each plate.

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14. Two infinite conduting plates 1 and 2 are separated by a distance l. A point chagre q is located between the plates at a distance x from plate 1. Find the charges induced on each plate.

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15. Find the electric force experienced by a charge reduced to a unit area of an arbitary conductor if the surface density of the charge equals σ.

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16. A metal ball of radius $R = 1.5cm$ has a charge $q = 10\mu C$. Find the molecules of the vector fo the resultant force acting on a charge located on one half of the ball.

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17. When an uncharged conducting ball of radius R is placed in an external uniform electric field, a surface charge densityh $\sigma = \sigma_0 \cos \theta$ is induced on the ball's surface charge (here σ_0 is a constant, θ is a polar angle). Find the magnitude of the resultant electric force acting on an induced charge of the same sign.

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18. An electric field of strength $E = 1.0 kV / cm$ produces plarization in water equivalent to the correct orientation of only one out of N . The electric moment of a water molecule equals $p = 0.62.10^{-29}$ C.m.

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19. A non-polar molecule with polarzabillity β is located at a great distance l from a polar molecule with electric moment p. Find the magnitude of the interaction force between the molecules if the vector p si oriented along a straight line passing through both molecules.

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20. A non-polar molecule is located at the axis of a thin uniformly charged ring of rasius R. At what distance x from the ring's centre is the magnitude of the force F acting on the given molecule

(a) equal to zero, (b) maximum ?

Draw the appoximate plot $F_x(x)$.

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21. A point charge q is located at the centre of a ball made of uniform istopic dielectric with permittivity epsilon. Find the polarizaion P as a function of the radius vector r relative to the centre of the system, as well as the chagre q' inside a sphere whose radius is less than radius of the ball.

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22. Demonstrate that at a dielectric-conductor interface the surface density of the dielectric's bound charge $\sigma' = -\sigma(\varepsilon - 1)/\varepsilon$' where ε is the permittivity, σ is the density of the charge on the conductor.

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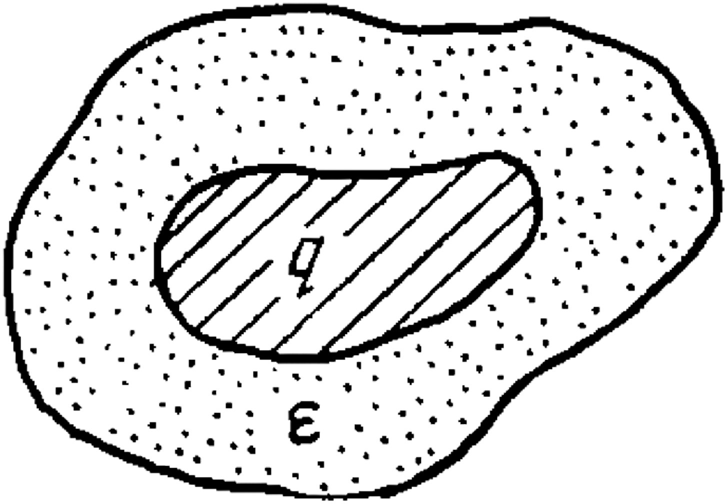
23. A conductor of orbitrary shape, carrying a charge q, is surrounded with uniform dielectric of permittivity ε (Fig).



Find the total bound charges at the inner and outer surfaces of the dilectric.

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24. A uniform istropic dielectric si shaped as a spherical layer with radii a and b. Draw the approximate plots of the electric field strength E and the potential φ vs the distance r from the centre fo the layer if the dielectric has a certain positive extraneous charge distributed uniformly,

(a) over the internal surface of the layer, (b) over the volume of the layer.

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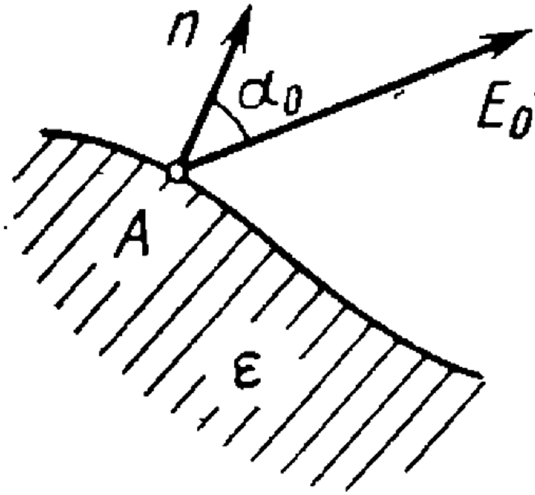
25. Near the point A (Fig) lying on the boundary between glass and vacumm the electric field strength in vacumm is equal to $E_0 = 10.0V/m$, the angle between the vector E and n, as well as the surface density of the point charges at the point A.



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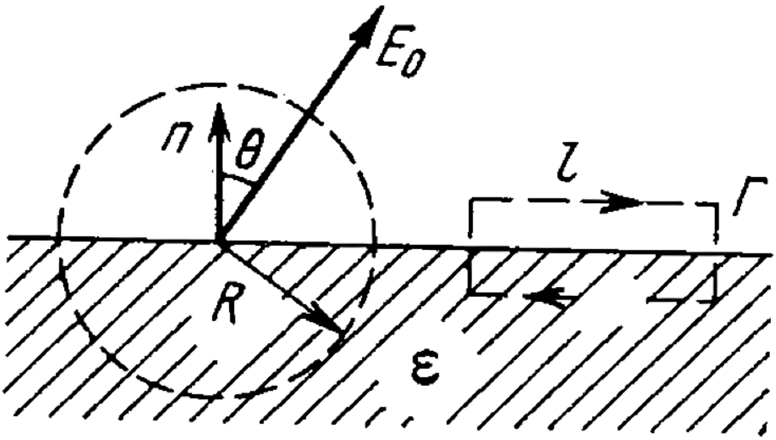
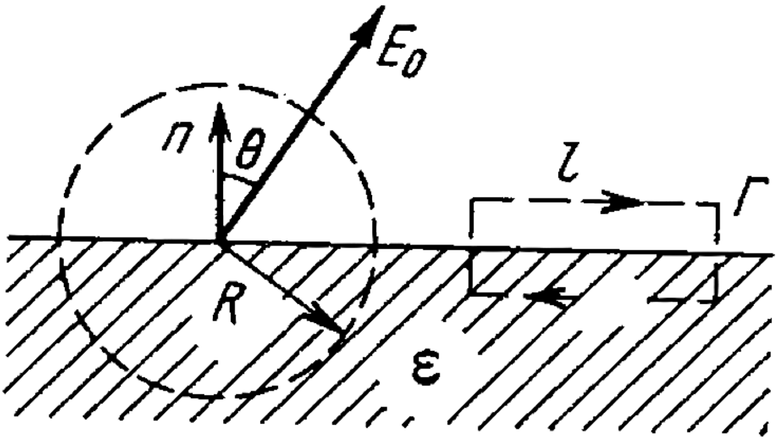
26. Near the point plane surface of a uniform isotropic dielectric with permittivity ε the electric field strength in vacumm is equal to E_0 the vector E_0 forming an angle θ with the normal of the dielectric's surface (FIg). Assuming the field to be uniform both inside and outside the dielectric, Find:



(a) the flux of the vector E through a sphere of radius R with centre located at the surface of the dielectric,

(b) the circulation of the vector D around the closed path I' og length l (see fig) whose plane is perpendicular to the surface of the dielectric and parallel to the vector E_0.



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27. An infinite plane of uniform dielectric with permittivity ε is uniformly charged with extraneous chagre fo space density ρ. The thickness of the plate is equal to $2d$. Find:

(a) the magnitude of the electric field strength and the potential as functions of distance l from the middle point of the plane.(where the potential is assumed to be equal to zero), having chosen teh x coriditnate axis perpendicular to the plate, draw the approximate plots of teh projection $E_x(x)$ of the vector E and the potentail $\varphi(x)$, plots fo the projection $E_x(x)$ of the vector E adn the potential $\varphi(x)$,

(b) the surface and space denstites of the bound charge.

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28. Extraneous chagres are uniformly distributed with space density $\rho > 0$ over a ball of radius R made of uniform istropis dielectric with permittivity ε. Find :

(a) magnitude of the electric field strength as a function of distance r from the centre of the ball, draw teh approixmate plots $E(r)$ adn $\varphi(r)$,

(b) the space and surface densities of the bound charges.

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29. A round dielectric disc of radius R and thickness d is statically polarized so that it gains the uniform polarzation P. With the vector P lying in the plane of the disc. Find the strength E of the electric field at the centre of the disc if $d < \; < R$.

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30. Under certain condinates the polarrization of an infinite uncharged dielectric plate , takes the form $P = P_0$ is a vector perpendicular to the plate, x is the distance from the of the electric field inside the plate and the potentail difference between its surface.

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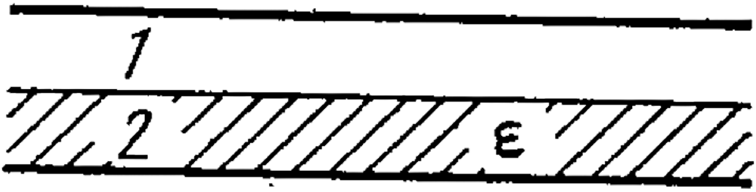
31. Initially the space between the plates of the capacitor is filled with air, and the field strength in the gap is equal to E_0. Then half the gap is filled with uniform isotropic dielectric with permittivity ε as shown in Fig. Find the moduli of the introduction of the dielectric

(a) deos not change the voltage across the plates,

(b) leaves the charges at the plates constant.



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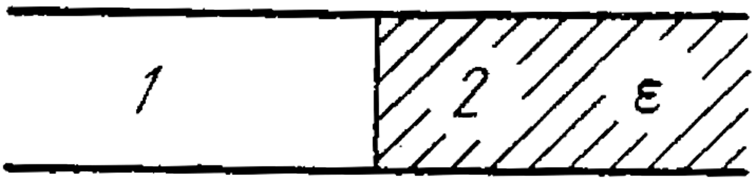
32. Solve the forgoing problem for the case when half the gap is filled with the dielectric in the way shown in fig.



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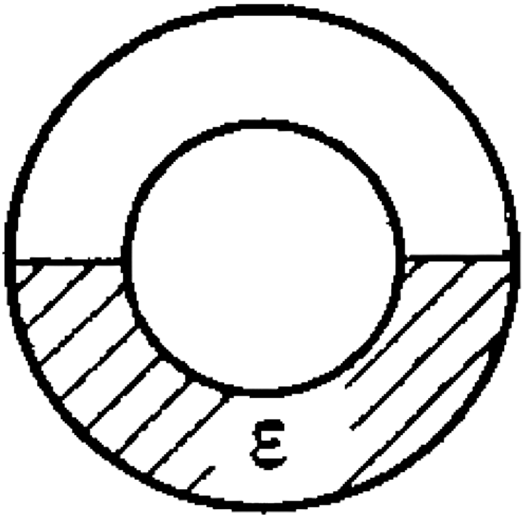
33. Half the space between two concentricv elecrodes of a sphereical capacitor is filled , as shwon in Fig, with unifrom istropic dielectric with permittively ε. The charge of the capacitor is q. Find the magnitude of the electric field strength between teh electrodes as a function of distance r from the curvature centre of teh electrodes.



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34. Two small identical balls carrying the charges of the same sign are suspended from the same point by insulating threads of equal length. When the surrounding space was filled with kerosene the divergence angle between the threads remained constant, What is the density of the material of which the balls are made ?

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35. A unifrom electric field of strength $E = 100V/m$ is generated inside a ball made of uniform istropic dielectric with permitivity $\varepsilon = 5.00$. The radius of the ball is $R = 3.0cm$. Find the maximum surface density of the bound chagres and the total bound charge of one sign.

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36. A point charge q is located in vacumm at a distance l from the plane surface of a unifrom isotropic deilectric filling up all the half-space. The permittivity of the dielectric equals ε. Find :

(a) the surface density of the bound chagres as a function of distanc e r from the point charges q'. anayse the obtained result at $l - .0$,

(b) the total bound charge on the surface of the dielectric

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37. Making use of the formulation and the soulution of the foregoing problem, find the magnitude fo the force exerted by the charges bound on the surface of the dielectric on the point charge q.

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38. A point charge q si located on the plane dividing vacumm and infinite uniform istropic dielectric with permittivity $eposilon$. Find the moduli of the vectors D and E as well as the potentail φ as funtions of distance r from the charge q.

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39. A small conducting ball carrying a charge q is located in a uniform an infinite boundary plane between the dielectrics and vacumm. Find the surface density of the bound chagres on the boundary plane as a function of distance r from the ball. Analysse the obtained result for $l \to 0$.

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40. A half-space filled with uniform istropic dielectrics with permittivity ε has the conducting boundary plane. Inside the dielectric at a distance l from this plane, there is a small metal ball possensing a charge q. Find the surface density of the bound chagres at the boundary plane as a function plane as a function of distance r from the ball.

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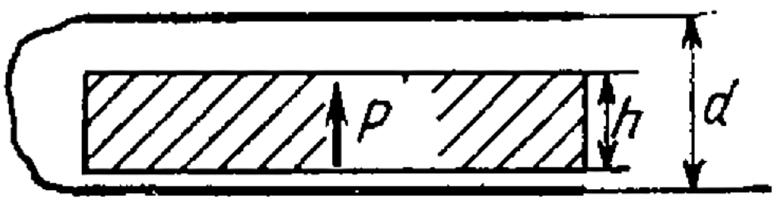
41. A plate of thickness h made of uniform statically polarized dielectric is placed inside a capacitor whose parallel plates are interconnected by a conductor. The polarization of the dielectric is equal



to P (Fig). The separation between the capacitor plates is d. Find teh strength and induction vectors for the electric field both inside and outside the plates.

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42. A long round dielectric cyclinder is polarized so that teh vector $P = \alpha r$, where α is a positive constant and r is the distance from the axis. Find the space density ρ' of bound chagres as a function of distance r from the axis.

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43. A dielectric ball is polarized uniformly and statically. Its polarization equals P. Taking into account that a ball ploarized is this way may be represented as a result of a small shift of all positive chagres of the dielectric relative to all negative charges,

(a) find the electric field strength E inside the ball,

(b) demonstrate that the field outside the ball is that of a dipole located at the centre of the ball, the potential of that field being equal to $\varphi = p_0 r / 4\pi\varepsilon_0$, where p_0 is the electric moment of the ball, and r is the distance from its centre.

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44. Utilizing the solution of the foregoing problemm, find teh electric field strength E_0 in a spherical cavity in an inifite statically polarized unifrom dielectric if the dielectric polarization is P, and far from the cavity the field strength is E.

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45. A uniform dielectric ball is placed in a unifrom electric fileld of strength E_0. Under these conditions teh dielectric becomes polarized uniformly. Find the electric field strength E inside teh ball and the polarization P of the dielectric whose permittively equals ε. Make use of the reslult obtained in Problem 3.96

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46. An infinielty long round dielectric cyclinder is polarized uniformly and statically, the polarization P being perpendicular to the axis of the cyclinder. Find the electric field strength E inside teh dielectric.

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47. A long round cylinderical made of uniform dielectric is placed in a uniform electric field of strength E_0. The axis of the cylinder is perpendicular to vector E_0. The axis of the cylinder is perpendiucular to vector E_0. Under these conditions the dielectrics becomes polarized unifromly. making use of the result obtained in the foregoing probem, find the electric field strength E is the cylinder and the polarization P of the distance whose permittivity is equal to ε.

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Electric Capacitance Energy Of An Electric Field

1. Find the capacitance of an isolated ball-shaped conductor of radius R_1 surrounded by an adjacent concentric layer of dielectric with permittivity ε and outside radius R_2.

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2. Two parallel plate air capacitance C, were connected in series to a battery with emf ξ. Then one of the capacitors was filled up with uniform dielectric with permittivity ε. How many times did the electric field strength in that capacitor decrease ? What amount of charge flows throgh the battery ?

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3. The space between the plates of a parallel-plate capacitor is filled consecutively with two dielectric layers 1 and 2 having the thickness of d_1 and d_2 and the permittivities $es\pi lon_1$ and $es\pi lon_2$ respectively. The area of each plate is equal to S. Find :

4. The gap between the plates of a parallel-plate capacitor is filled with istropic dielectrc whose permittlvity ε varies linearly from $es\pi lon_1$ to $\varepsilon_2 (\varepsilon_2 > \varepsilon_1)$ in the direction perpendicular to the plates. The area of each plate equals S, the separation between the plates is equal to d. Find :

(a) the capacitance of the capacitor,

(b) the space density of the bound chagres as a function of a if the charge of the capacitor is q and E in it is directed toward the growing ε values.

5. Find the capacitance of a spherical capacitor whose electrodes have radii R_1 and $R_2 > R_1$ and which is filled with istropic dielectric whose permittivity varies as $es\pi lon = a/r$, where a is a constant , and r is the distance from the centre of the capacitor.

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6. A cylindrical capacitor is filled with two cyclindrical layers of dielectric with permittivity $es\pi lon_1$ and $es\pi lon_2$. The inside radii of the layers are equal to R_1 and $R_2 > R_1$. The maximum permissible values of electric field strength reaching teh breakdown value for both dielectrics simulttaneously ?

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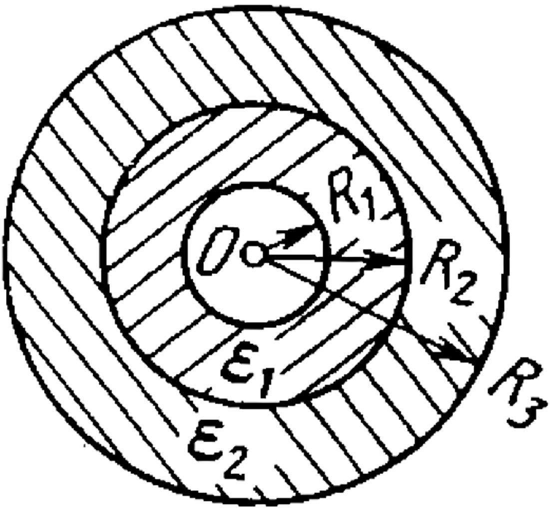
7. There is a double-layer cylindrical capacitor whose parameters are shoen in Fig. The breakdown field strength values for these dielectrics are equal to E_1 and E_2 respectively. What is the breakdown voltage of this capacitor if $\varepsilon_1 R_1 E_1 < \varepsilon_2 R_2 E_2$?



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8. Two long straight wires wtih equal cross-sectional radii a are located parallel to each other in air. The distanace between their axes equals b. Find the mutal capacitances $b > \, > a$.

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9. A long straight wire is located parallel to an infinite conducting plate. The wire is located parallel to an infinite conducting plate. The wire cross-sectional radius is equal to a, the distance between the axis of the wire and the plane equals b. FInd the mutual capacitance of this system per unit length of the wire under the condition $a < \, < b$.

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10. Find the capacitance of a system of two indentical metal balls of radius a if the distance between their centres is equal to b, with $b > > a$. The system is located in a uniform dielectric wtih permittivity ε.

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11. Determine the capacitance of a system consisting of a metal ball of radius a and an infinite conducting plane separated from the centre of the ball by the distance l if $l > > a$.

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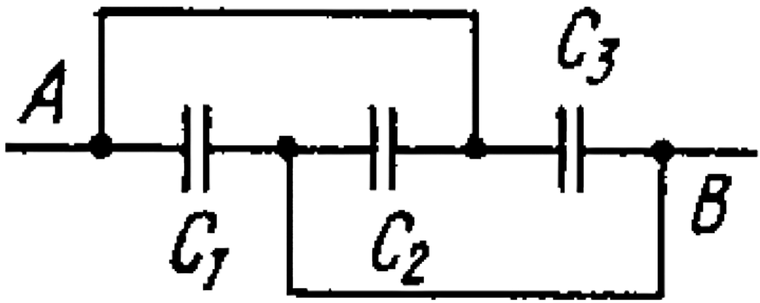
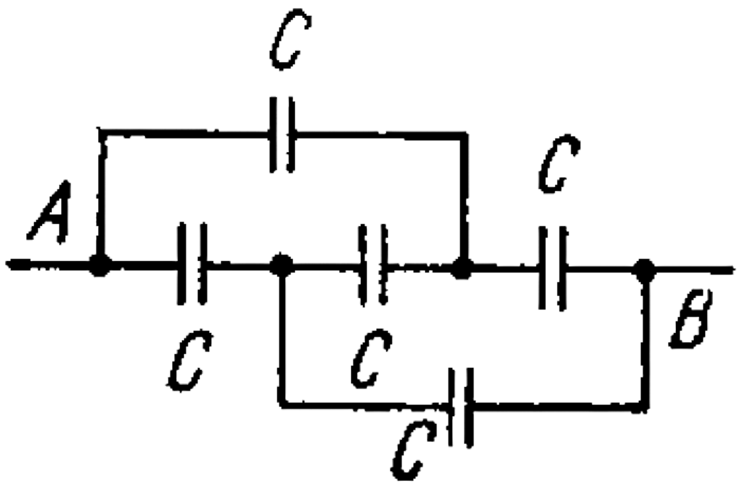
12. Find the capacitance of a system of identical capacitors between points A and B are shown in

(a) Fig. A (b) Fig B





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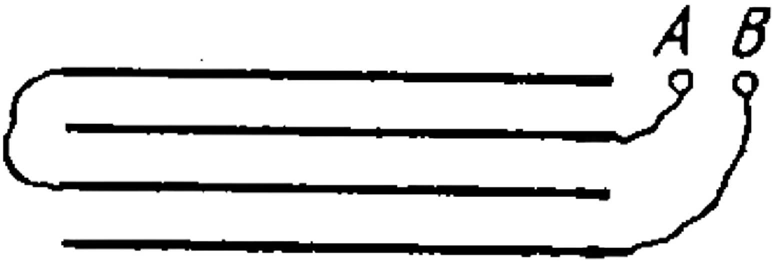
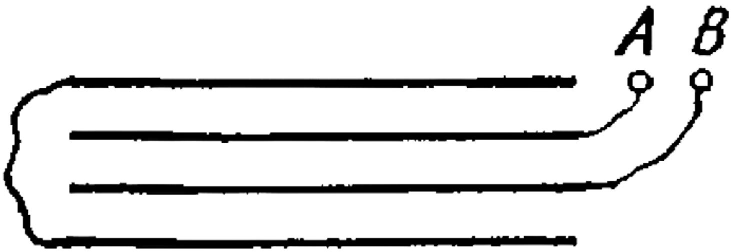
13. Four identical metal plates are located in air at equal distances d from one another. The area of each plate is equal to S. Find teh capacitance of the system between points a and B if the plates are interconnected as shown (a) Fig A, (b) FIg B





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14. A capaitor of capacitance $C_1 = 1.0 \mu F$ withstands teh maximum voltage $V_1 = 6.0 kV$ while a capacitor of capacitance $C_s = 2.0 \mu F$, the maximum voltage $V_s = 4.0 kV$. What voltage will the system of these two capacitors withsatand if they are connected in sereis ?

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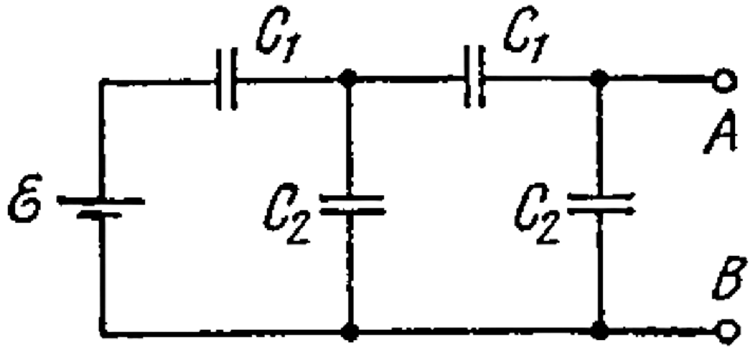
15. Find the potential difference between points A and B of the system shown in Fig. if the emf is equal to

$E = 100V$ and the capacitance ratio $C_2 / C_1 = \eta = 2.0.$



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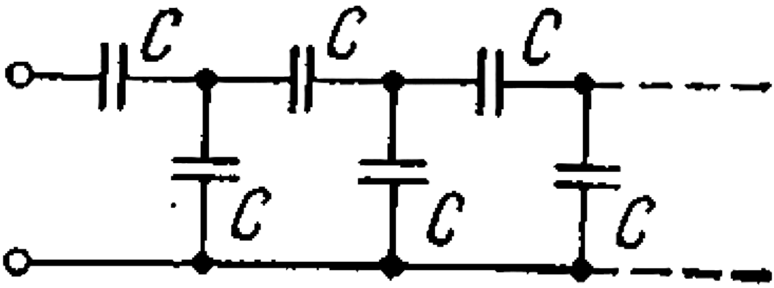
16. Find the capacitance of an infinite circuit formed by the repetitioin of the same link consisting of two indentical capacitors, each with capacitors C (fig).



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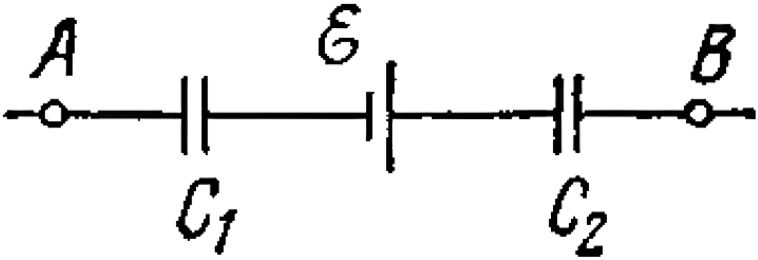
17. A circuit has a section Ab shown in fig. The emf of the source equals $E = 10V$, the capacitances are equal to $C_1 = 1.0\mu F$ and $C_2 = 2.0\mu F$, and the potential difference $\varphi_A - \varphi_B = 5.0V$. Find the voltage across each capacitor.



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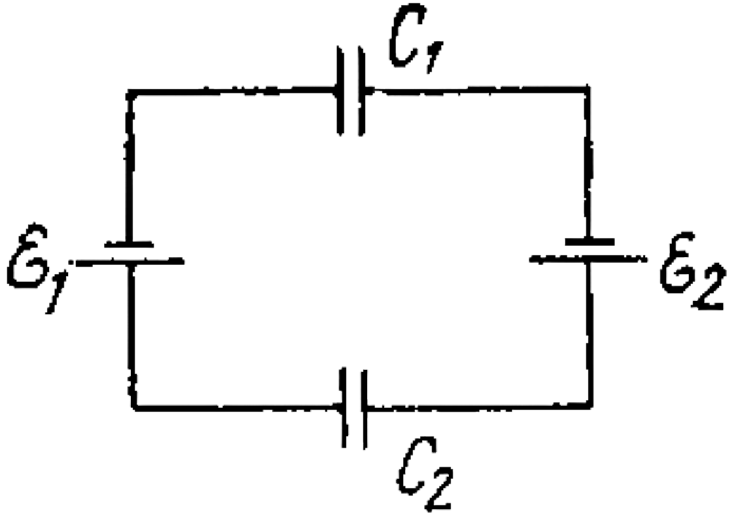
18. In a circuit shown in fig find the potentail difference between the left and right plates of each capacitor.



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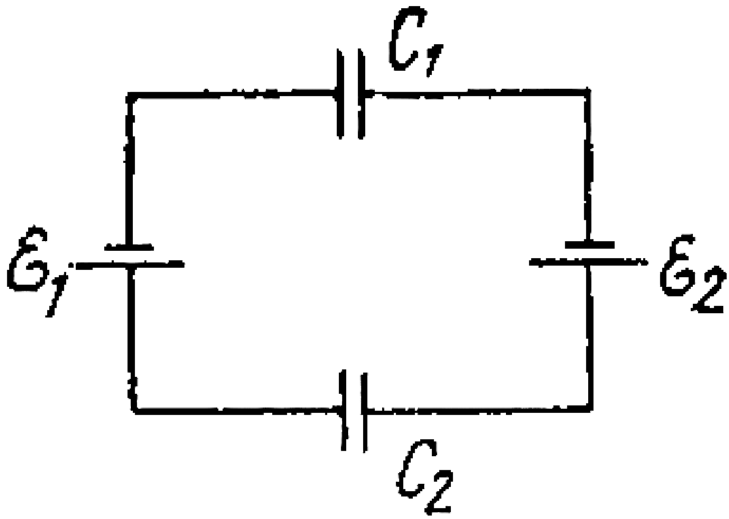
19. Find the charge of each capacitor in the circuit shown in Fig.



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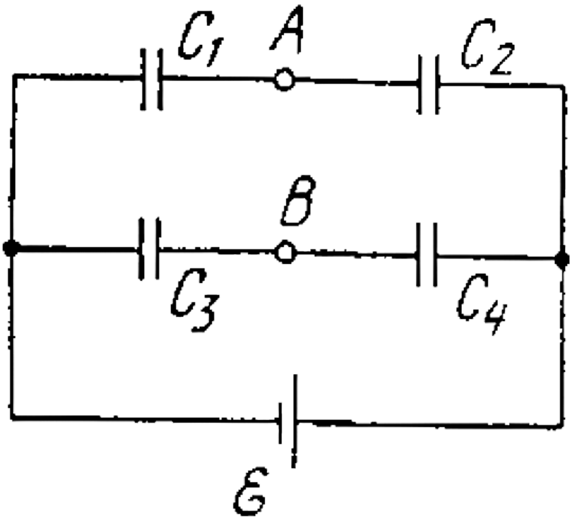
20. Determine the potential differnece $\varphi_A - \varphi_B$ between points A adn B of the circuit shown in Fig. Under what condition is it equal to zero ?



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21. A capacitor of capacitance $C_1 = 1.0 \mu F$ charged up to a voltage $V = 110V$ is connected in parallel to the teminals of a circuit consisting of two uncharged capacitors connected in series and possessing the capacitances $C_s = 2.0\mu F$ and $C_s = 3.0\mu F$. What charge will flow through the connecting wires ?

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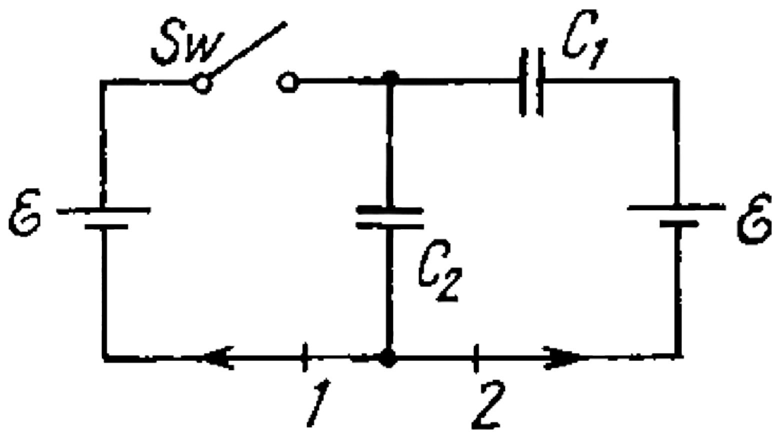
22. What charges will flow after the shorting of the swich Sw in the circuit illustrated in Fig through sections 1 and 2 in the directions indicated by the arrown?



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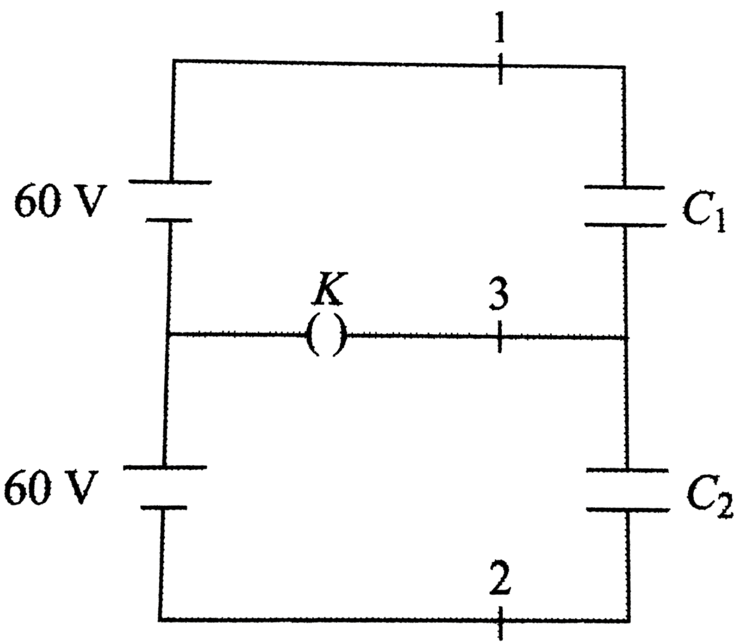
23. In the circuit shown , the emf of each battery is $60V$ and $C_1 = 2\mu F$ and $C_2 = 3\mu F$. Find the charges that will flow through the sections $1, 2$ and 3 after the Key is closed.



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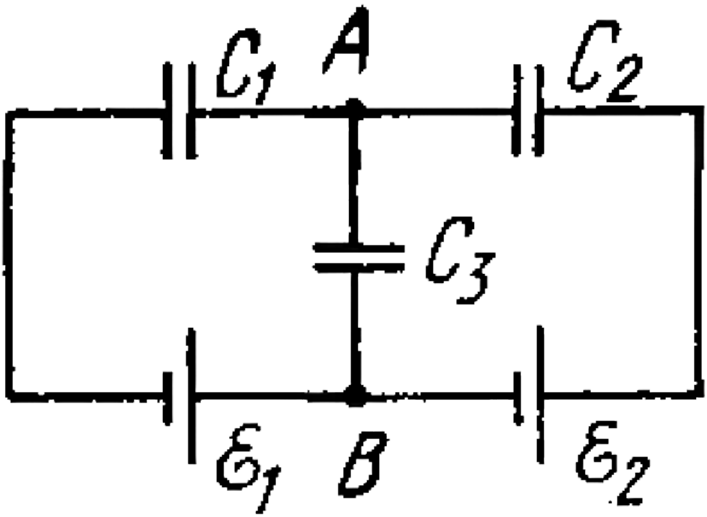
24. Find the potential difference $\varphi_A - \varphi_B$ between points A and B of the circuit shown in Fig.



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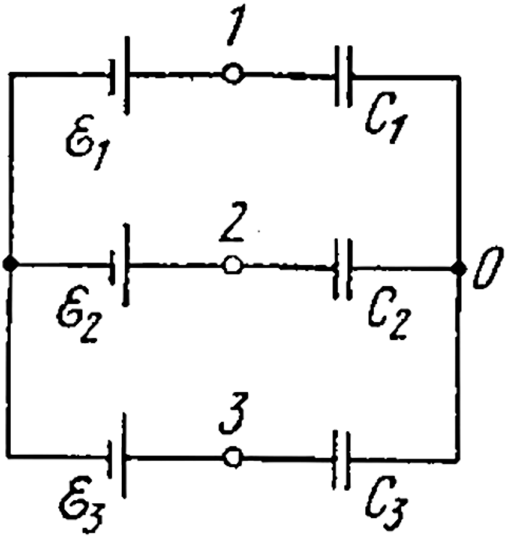
25. Determine the potential at point 1 of the circuit shown in Fig., assuming the potential at the point O to be equal to zero.



using the symmetry of the formula obtained, write the expressions for the potentials at points 2 and 3.

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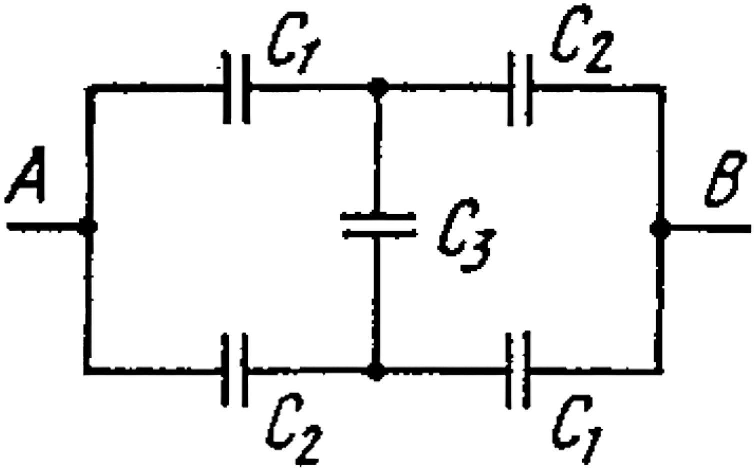
26. Find the capacitance of the circuit shown in Fig, between points A and B.



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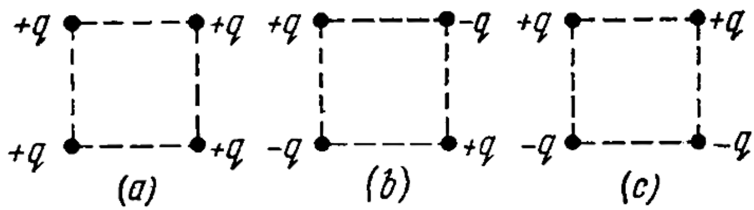
27. Determine the interaction energy of the point charges located at the corners at the corners of a square

with the side a in the circuit shown in Fig.



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28. There is an infinite straight chain of alternating charges q and $-q$. The distance between teh neighbouring charges is equal to a. Find the interaction energy of each charge with all the others.

Instruction . Make use of the expansion of In $(1+\alpha)$ in a power series in α.

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29. A point charge q is located at a distance l from an infinite tonducting plane. Find the interaction energy of that charge with chose induced on the plane.

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30. Calculate the interaction energy of two balls whose charges q_1 and q_2 are spherically. The distanace between teh centres of the balls is equal to l.

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31. A capacitor of capacitance $C_1 = 1.0\mu F$ carrying initially a voltage $V = 300V$ is connected in parallel with an uncharged capacitor of capacitance $C_2 = 2.0\mu F$. Find the increment of the electric energy of this system by the moment equilibrium is reached. Explain the result obtained.

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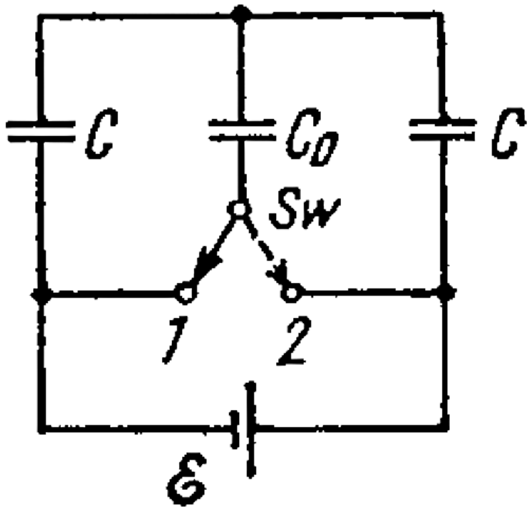
32. What amount of heat will be generated in the circuit shown in Fig. after the swich Sw is shifted from position

2 ?



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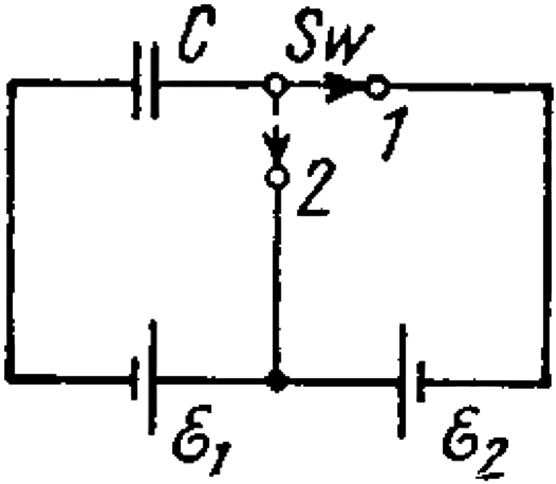
33. What amount of heat will be generated in the circuit shown in Fig. after the swich Sw is shifted from position

2 ?



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34. A system consists of two thin concentric metal shells of radii R_1 and R_2 with corresponding charges q_1 and q_2. Find the selfenergy values W_1 and W_2 of each shell, the interaction energy of the shells W_{12}, and the total electric energy of the system.

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35. A charge q is distributed uniformly over the volume of a ball of radius R. Assuming the permittivity to be equal to unity, find :

(a) the electrostatic self-energy of the ball,

(b) the ratio of the energy W_1 stored in the ball to the energy W_s pervadinting the surrounding space.

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36. A point charge $q = 3.0m, uC$ is located at the centre of a spherical layer of uniform isotropic dielectric with permittivity $\varepsilon = 3.0$. The inside radius of the layer is equal to $a = 250mm$, the outside radius is $b = 500mm$.

Find the electrostatic energy inside the dielectric layer.

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37. A spherical shell of radius R_1 with uniform charge q is expanded to a radius R_2. Find the work performed by the electric forces in this process.

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38. A sperical shell of radius R_1 with a unifrom charge q has a point charge q_0 at the its centre . Find the work perfomed by the electric forces during the shell expansion form radius R_1 to radius R_2.

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39. A spherical shell is uniformly charged with the surface density σ. Using the energy conservation law, find the magnitude of the electric force acting on a unit area of the shell.

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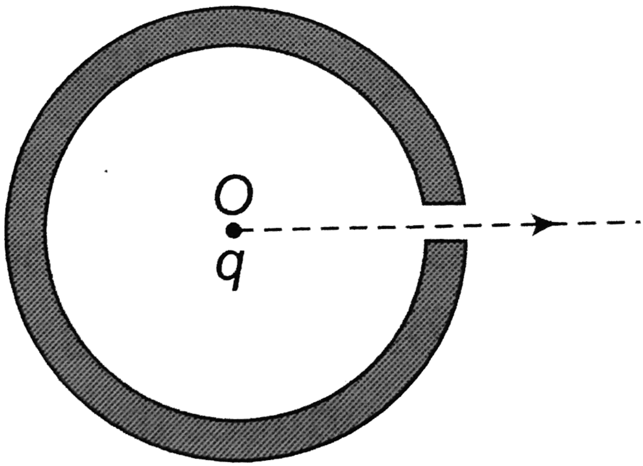
40. A point charge q is located at the centre O of a spherical uncharged coducting layer provided with small orifice. The inside and outside radii of the layer are equal to a and b respectively. The amount of work that has to be performed to slowly transfer the charge q from teh point O through the orifice and into infinity is



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41. Each plate of a parallel -plate air capacitor has an area S. What amount of work has to be performed to slowly increases teh distance between the plates from x_1 to x_2 if

(a) Capacitance of the capacitor which is equal to q, or

(b) the voltage across the capacitor, which is equal to V, is kept constant in the process?

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42. Inside a parallel-plate capacitor there is a plate parallel to the outer plates, whose thickness is equal to $\eta = 0.60$ of the gap width. When the plates is absent the capacitor cpaacitance equals $c = 20\mu F$. First, the capacitor was connected in parallel to a constant voltage source producting $V = 200V$, then it was disconnected for it, after which the plates was slowly removed from teh gap. FInd the work perfomed during the removel, if the plate is

(a) made of metal, (b) made of glass.

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43. A parallel-plate capacitor was lowered into water in a horizontal position, with water filling up the gap between the plates $d = 1.0mm$ wide. Then a constant voltage $V = 500V$ was applied to the capacitor. Find the water pressure increment in the gap.

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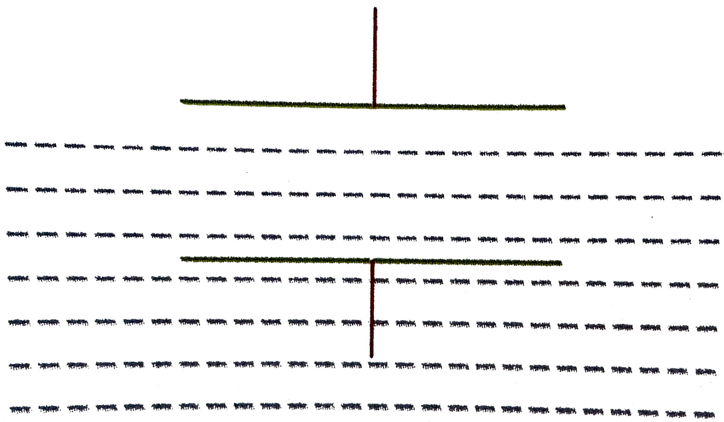
44. A parallel plate capacitor is located horizontally, so that one of its plates is submerged into liquid while the other is over the surface. The dielectric constant of the liquid is equal to k. Its density is equal to ρ. To what height will the level of the liquid in the capacitor rise after its plates gets a charge of surface density σ ?



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45. A cylindrical layer of dielectric with permittivity ε is inserted into a cylindrical capacitor to fill up all the space between the electrodes. The mean radius of the electrodes equals R, the gap between them is equal to d, with $d < < R$. The constant voltage V is applied across the electrodes of the capacitor. Find the magnitude of the electric force pulling the dielectric into the capacitor.

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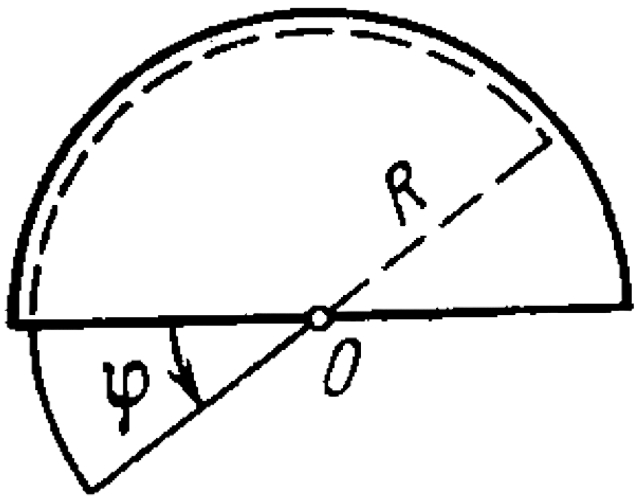
46. A capacitor consists of two stationary plates shaped as a semi-circle of radius R adn a movable plate made of dielectric with permittivity ε and capacble of rotoning about an axis O between the stationary plates (fig). The thickness of the movables plate is equal to d which is practically the separation between teh stationary plates. A potential difference V is applied to the capacitor. FInd the magnitude of the moment of forces relative to the axis O acting on teh movable plate in the position shown in the figure.



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Electric Current

1. A long cylinder with uniformly charged surface and crosssectional radius $a = 1.0cm$ moves with a constant velocity $v = 10m/s$ along its axis. An electric field strength at the surface of the cylinder is equal to $E = 0.9k\frac{V}{c}m$. Find the resultign concection current , that is, the current caused by mechanical transfer of a charge.

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2. An air cylindrical capacitor eith a dc voltage $V = 200V$ applied across it is being submerged vertivally into a vessel filled with water at a velocity $v = 5.0mm/s$. The electrodes of the capacitors are separated by a distance $d = 2.0mm$, the mean curvature radius of the electrodes is equal to $r = 50mm$. Find the current flowing in this case along lead wires, if $d < < r$.

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3. At the tempearture $0^\circ C$ the electric resistance of conductor 2 is η times that of conductor 1. Thier temperatures coeficients of resistance are equal to α_2 and α_1 respectively. Find the tempearture coefficient of resistance of a circuit segment consisting of these two conductors when they are connected

(a) In series , (b) In parallel .

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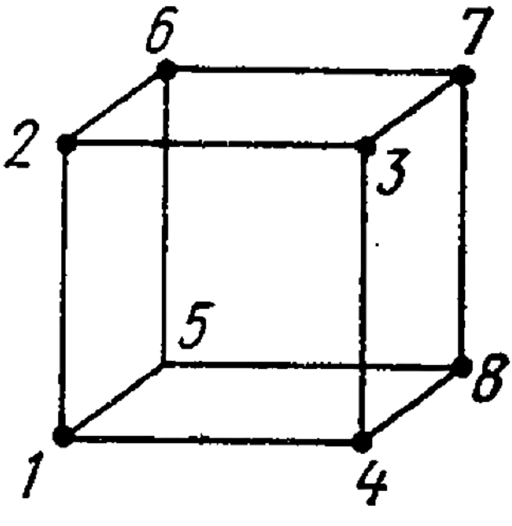
4. Find the resistance of a wire frame shaped as cube (Fig) when measured between points (a) 1.7, (b) 1.2, (c) 1.3. The resitance of each edge of the frame is R



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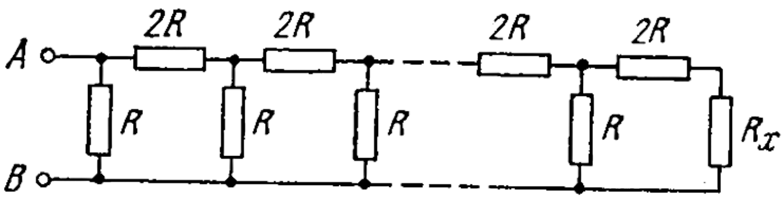
5. At what value of teh resistances R_x in the circuit shown in Fig. Will the total resistance between points A and B be independent of the number of cells ?



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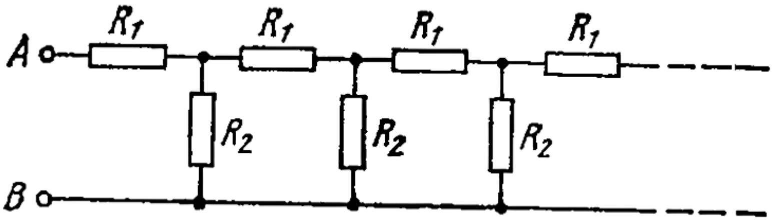
6. Fig. shows an infinite circuit formed by the repetition of the same link, consisting of resistance $R_1 = 4.0 \Omega$ and

$R_2 = 3.0\Omega$. Find the resistance of this circuit between points A and B.



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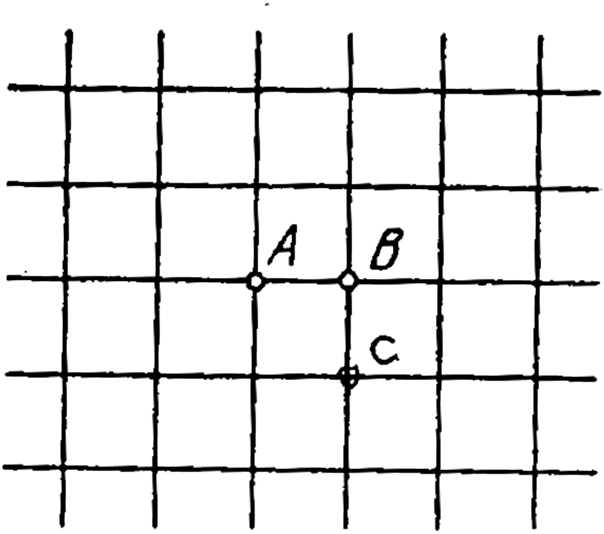
7. There is an infinite wire grid with square cells (Fig). The resistance of each wire between neighbouring joint connections is equal to R_0 . Find the resistance R of the whole grid between points A and B.

Instruction. Make use of principles of symmetry and superposition.



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8. A homegoneous poorly condcuting medium of resistivity ρ fills up space between two thin coaxial ideally conducting cylinder is l. The radii of the cylinders are equal to a and b with $a < b$, the length of each

cylinder is l. Neglecting the edge effects , find the resistance of the medium between the cylinders.

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9. A metal ball of radius a is surrounded by a thin concentric metal shell of radius b. The space between these electrodes is filled up with a poorly conducting homogenous medium of resistivity ρ. Find the resistance of the interelectrode gap. Analyse the obtained solution at $b \to \infty$.

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10. The space between two conducting concentric spheres of radii a and $b(a < b)$ is filled up with homongeneous poorly conducting medium. The capacitance of such a system equals C. Find the resistivity of the medium if the potential difference between the spheres, when they are disconnected from an external voltage , decreases η-fold during the time interval Δt.

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11. Two metal balls of the same radius a are located in a homongenous poorly conducting medium with resistivity ρ. Find the resistance of the medium between the balls provided that the separation between them is mush greater than the radius of the ball.

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12. A metal ball of radius a is located at a distance l from an indinite ideally conducting plane. The space around the ball is filled with a homongeous poorly conducting medium with resistivity ρ. In the case of $a < < l$ find :

(a) the current density at the conducting plane as a function of distance r from the ball if the potentail difference between the ball and the plane is equal to V ,

(b) the electric resistance of the medium between the balll and the plane.

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13. Two long parallel wires are located in a poorly conducting medium with respectivity ρ. The distance between the axes of the wires is equal to l, the cross - section radius of each wire equals a. In the case $a < < l$ find,

(a) the current density at the point equally removed from the axes of the wire by a distance r if the potential difference between teh wires is equal to V,

(b) the electric resistances of the medium per unit length of the wires.

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14. The gap between the plates of a parallel-plate capacitor is filled with glass of resistivity $\rho = 100 G\Omega m$, The capacitance of the capacitors equals $C = 4.0 nF$. Find the leakeage current of the capacitor when a voltage $V = 2.0 kV$ is applied to it.

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15. Two conductors of aribitary shape are embedded into an infinite homogenous poorly conducting medium with respectivity ρ and permittivity ε. Find the value of a product RG for this system where R is the resistance of the medium between the conductors, and C is the mutual capacitance of the wires in the presence of the medium.

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16. A conductor with respectivity ρ bounds on a dielectric with permittivity ε. At a certain point A at the conductor's surface the electric displacement equals D the vector D being directed away from the conductor and forming an angle α with the normal of the surface. Find the surface density of charges on the conductor at the point A and the current density in the conductor in the vicinitity of the same point.

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17. The gap between the plates of a parallel-plate capacitor is filled up with an inhomongeous poorly conducting medium whose conductivity varies lineraly in the direaction perpendicular to the plates form the $\sigma_1 = 1.0pS/m \to \sigma_2 = 2.0pS/m$. Each plate has an area $S = 230cm^2$, and the separation between the plates is $d = 2.0mm$. Find teh current flowing thorugh the capacitor due to a voltage $V = 300V$.

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18. Demonstrate that the law if refraction of direct current lines at the boundary between two conducting media has the form $\tan\alpha_1\sigma_2/\sigma_1$, where σ_1 and σ_2 are the conductivies of the media, α_2 and α_1 are the angles between the current lines and the normal of the boundary surface.

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19. Two cylindrical conductors with equal cross-sections and different resistivites ρ_1 and ρ_2 are point end to end. Find the charge at the boundary of the conduction if a current I flows from conductor 1 to conductor 2

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20. The gap between the plates of a prallel-plate capacitor is filled up with two dielectric layers 1 and 2 thickness d_1 and d_2 permittivities ε_1 and ε_2 and resistivities ρ_1 and ρ_2. A dc voltage V is applied to the capacitor with electric field directed from layer 1 to layer 2 find σ the surface density of extraneous charges at the boundary between the dielectric layers and the condition under with $\sigma = 0$.

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21. An inhomegenous poorly conducting medium fills up the space between plates 1 and 2 of parallel-plate capacitor. Its permittivity and resistivity vary from values

ε_1, ρ_1 at the plate 1 to vlaues ε_2, ρ_2 at plate 2. A dc voltage is applied to the capacitor througgh which a steady current I flows from plate 1 to plate 2. Find the total extraneous charge in the given medium.

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22. The space between the plates of a parallel -plate capacitor is filled up with inhomogneous poorly conducting medium whose resistivity varies linearly in the direction perpendicular to the plates. The ratio of the maximum value of resistivity to the minimum one is equal to η The gap width equals d. Find the volume density of the charge in the gap if a voltage V is applied to the capacitor. ε is assumed to be 1 everywhere.

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23. A long round conductor to cross-sectional area S is made of material whose resistivity depends only on a distance r from the axis of the conductor as $\rho = \alpha / r^4$, where α is a constant. Find :

(a) the resistance per unit length of such a conductor,

(b) the electric field strength in the conductor due to which a current I flow though it.

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24. A capacitor with capacitance $C = 400pF$ is connected via a resistance $R = 650\Omega$ to a source of voltage V_0. How soon will the voltage developed across the capacitor reach a value $V = 0.90 V_0$?

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25. A capacitor filled with dielectric of permittivity $\varepsilon = 2.1$ losses half the charge acquired during a time interval $\tau = 3.0 \text{ min}$. Assuming the charge to leak only thorugh the dielectric filler, calculate its resistivity.

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26. A circuit consists of a source of a constant $emf \xi$ and a resistance R amd a capacitor with capacitance C

connected in series. The internal resistance of the source is negligible. At a moment $t = 0$ the capacitance of the capacitor is abruply decreased η-fold. FInd the current flowing through the circuit as a function of time t.

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27. An ammeter of zero resistance and a volt meter are connected in series to a battery of emf 6.0 volt and certain internal resistance. When a resistance R is connected in parallel with the voltmeter the readings of the voltmeter becomes half of its initial reading and the reading of the ammeter becomes 2 times to its initial reading (before R is connected). Find the voltmeter reading in volt after the connection of the resistance.

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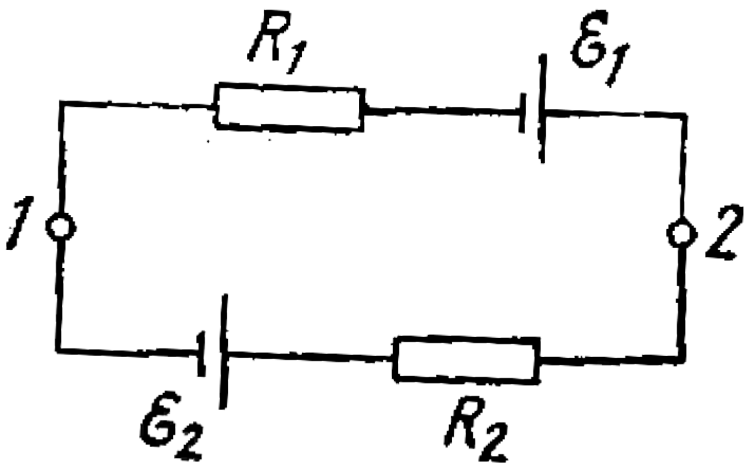
28. Find a potentail difference $\varphi_1 - \varphi_2$ between points 1 and 2 of the circuit shown in Fig if $R_1 1 = 10\Omega$, $R_2 = 20\Omega$, $E_1 = 5.0V$, and $E_2 = 2.0V$. The internal resisances of the current sources are negligible.



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29. Two sources of equal emf are connected to an external resistance R. The internal resistance of the two sources areR_1 and $R_2 (R_1 > R_1)$. If the potential difference across the source having internal resistance R_2 is zero, then

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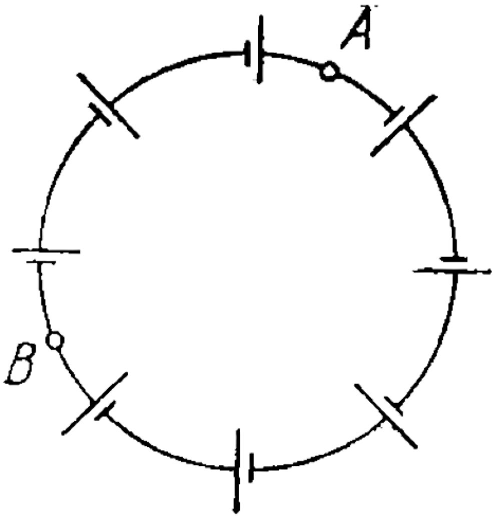
30. N sources of current with different emf's are connected as shown in Fig. The emf of the sources are proportional to their internal resistancs, i.e., $E = \alpha R$, where α is an assigned constatant. The lead wire resistance is neglible. Find:

(a) the current in the circuit ,

(b) the potential differences between points A and B dividing the circuit in n and $N-n$ links.



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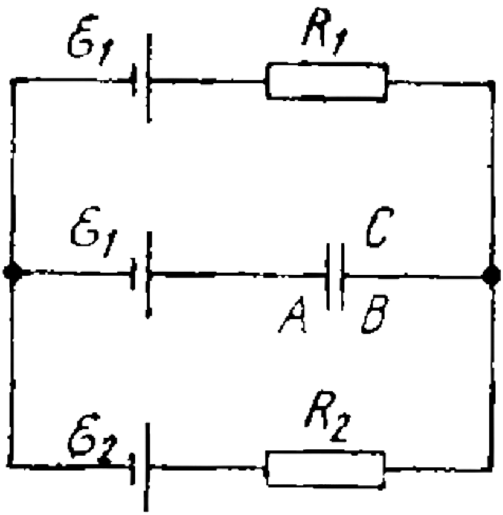
31. In the circuit shown in Fig the sources have $emf's \xi_1 = 1.0V$ and $\xi_2 = 2.5V$ and teh resistances have the values $R_1 = 10\Omega$ and R_(2) = 20 Omega. The internal resistances of the sources are neglibile . Find a potential differences $\varphi_A - \varphi_B$ between the plates A and B of the capacitance C.



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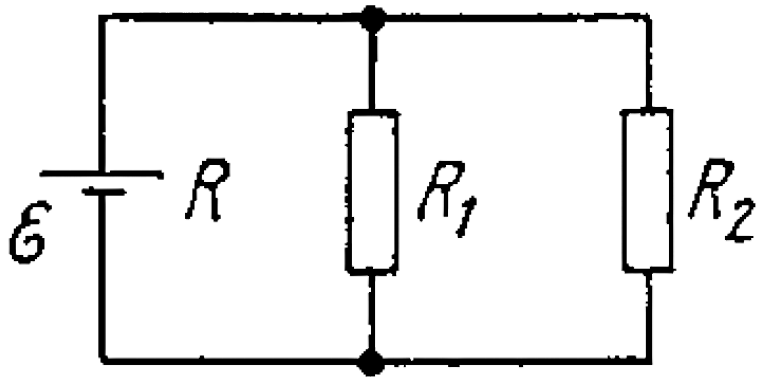
32. In the circuit shown in Fig. the emf of the sources is equal to $\xi = 5.0V$ and the resistances are equal to $R_1 = 4.0\Omega$ and $R_2 = 6.0\Omega$. The internal resistance of the source equals $R = 1.10\Omega$. Find the currents flowing through the resistances R_1 and R_2.



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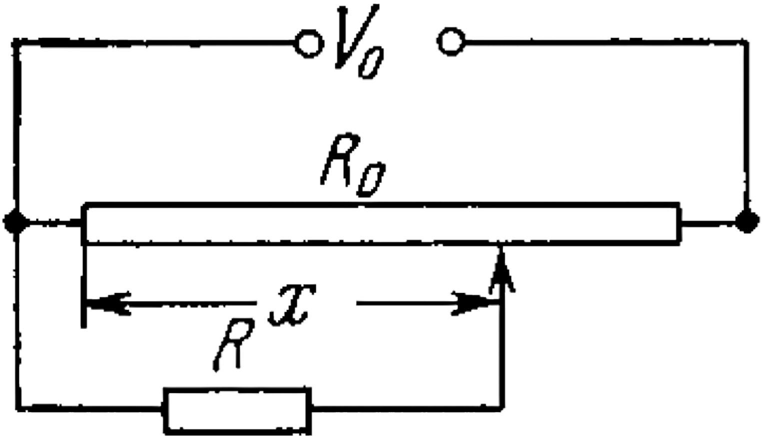
33. Fig. illustrates a potentiometric circuit by means of which we can very a voltage V applied to a certain device possessing a resistance R. The potentiometer has a length l and a resistance R_0 and voltage V_0 is applied to its terminals. Find the voltage V fed to the device as a funciton of distanace x. Analyse separately the case $R > > R_0$.



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34. Find the emf and the internal resistance of a source which is equivalent to two batteries connected in parallel whose $emf's$ are equal to E_1 and E_2 and internal resistances to R_1 and R_2

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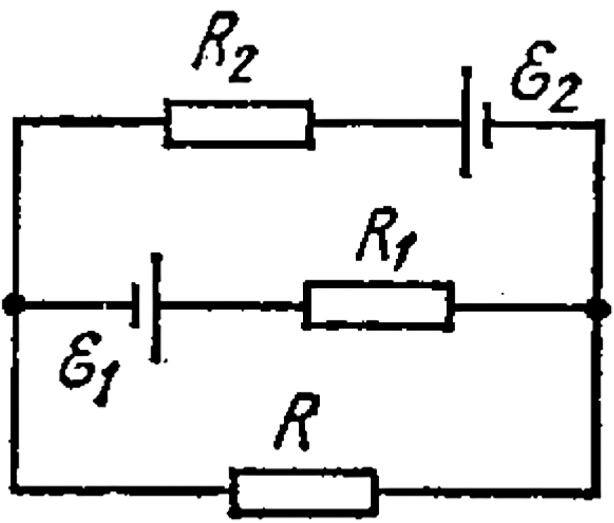
35. Find the magnitude and direction of the current flowing through the resistance R in the circuit shown in Fig. if the emf's of the sources are equal to $E_1 = 1.5V$ and $E_2 = 3.7V$ and the resistances are equal to $R_1 = 10\Omega, R_2 = 20\Omega, R = 5.0\Omega.$ The internal resistances of the sources are neglible.



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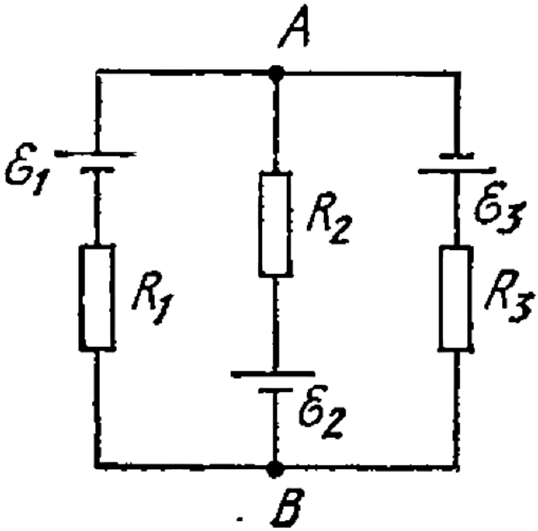
36. In the circuit shown in Fig, the sources have $emf's \xi_1 = 1.5V, \xi_2 = 2.0V, \xi_3 = 2.5V$, and the resistances are equal to $R_1 = 10\Omega, R_2 = 20\Omega, R_3 = 30\Omega.$ The internal resistances of the sources are negligible. Find : ltbrtgt (a) the current flowing thorugh teh resistance R_1 ,

(b) a potential differences $\varphi_A - \varphi_B$ between the points

A and B between the points A and B.



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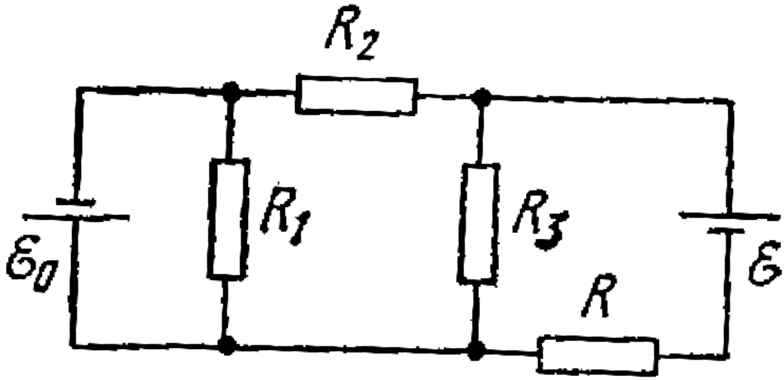
37. Find the current flowing current flowing thorugh the resistance R in the circuit shown in Fig. The internal resistances of the batteries are negilble.



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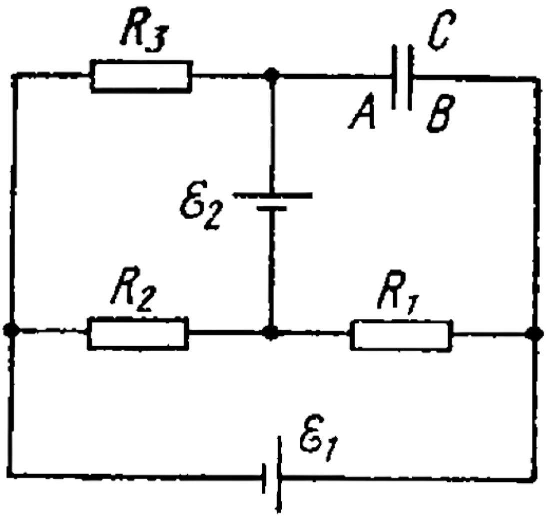
38. Find a potential difference $\varphi_A - \varphi_B$ between the plates of a capacitor C in the circuit shown in Fig, if the sources have $emf's E_1 = 40V, E_2 = 1.0V$ and the resistances are equal to $R_1 = 10\Omega, R_2 = 20\Omega,$ and $R_3 = 30\Omega$. The internal resistances of the sources are negligble.



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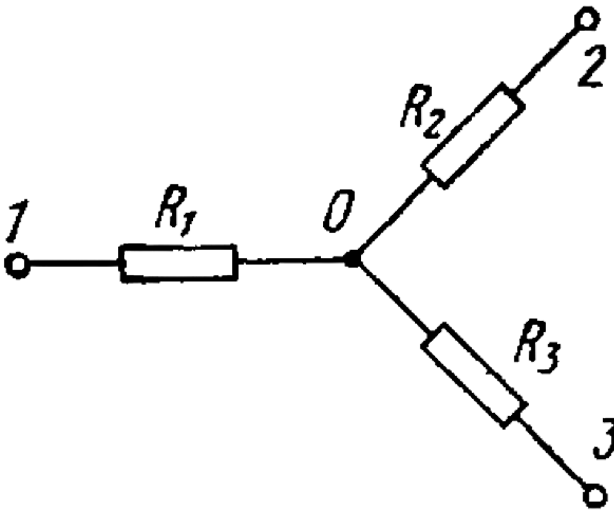
39. Find the current flowing through the resistance R_1 of the circuit shown in Fig. If the resistances are equal to $R_1 = 10\Omega$. $R_2 = 20\Omega$ and $R_3 = 30\Omega$, and the potential of points 1,2 and 3 are equal to $\varphi_1 = 10V$, $\varphi_2 = 6V$, and

$\varphi_3 = 5V$



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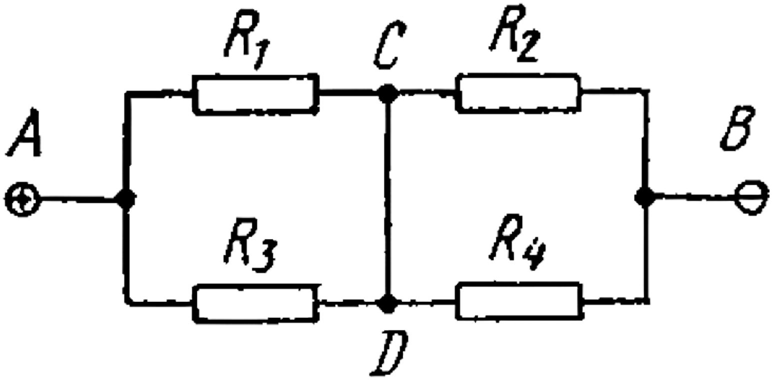
40. A constant voltage $V = 25V$ is maintained between points A and B of the circuit (Fig). Find the magnitude and direaction of the current flowing through the segment CD if the resistances are equal to

$R_1 = 1.0\Omega$, $R_2 = 2.0\Omega$, $R_3 = 3.0\Omega$ adn $R_4 = 4.0\Omega$.



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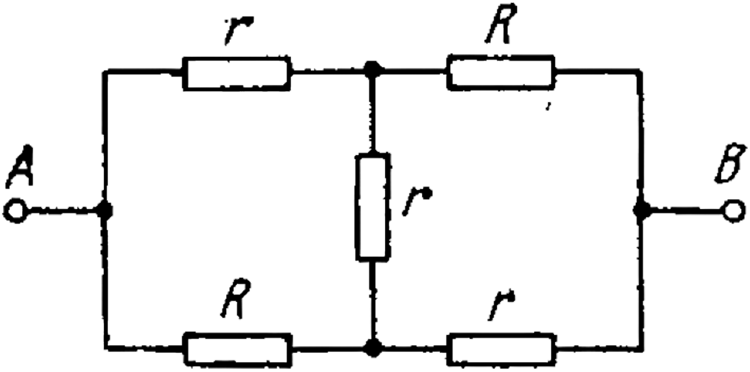
41. Find the resistance between points A and B of the circuit shown in Fig.



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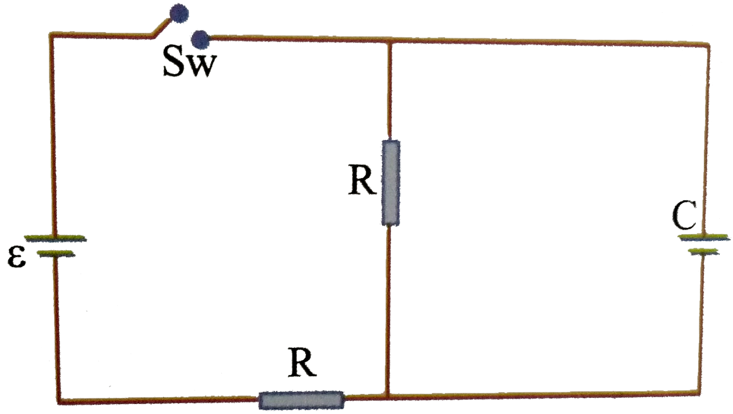
42. Find how the voltage across the capacitor C varies with time t after closing of the switch S_w at the moment

$t = 0.$



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43. What amount of heat will be generated in a coil of resistance R due to a charge q passing through it if the current in the coil

a. decreases down to zero uniformly during a time interval t_0?

b. decrases down to zero having its value every t_0 seconds?

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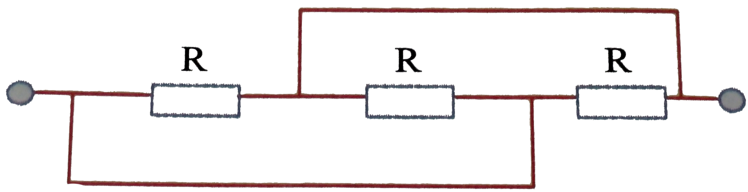
44. 

A dc source with internal resistance R_0 is loaded with three identical resistance R as shown in the figure. At what value of R will the thermal power generated in this circuit be the highest?

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45. Make sure that the current distribution over two resistances R_1 and R_2 connnected in parallel corresponds to the minimum thermal power generated in this circuit.

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46. A storage battery with $emf E = 2.6V$ loaded with an external resistance produces a current $I = 1.0A$. In this case the potential difference between the terminals of the storage battery equals $V = 2.0V$. Find teh thermal power generated in the battery and the power develop in it electric forces.

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47. A voltage V is applied to a dc electric motor. The armature winding resistance is equal to R. At what value of current flowing through the winding resistance is equal to R. At what value of current flowing through the winding will the useful power of the motor be the highest ? What is it equal to? What is the motor efficiency in this case ?

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48. How much (in per cent) has a filament diameter decreased due to evaporation if the maintances of the previous temperature due to evaporation if the maintenance of the previous temperatur required an increases of the voltage by $\eta = 1.0\%$? The amount of heat transfereed fromt the filament into surrounding space is assumed to be propotional to the filament surface area.

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49. A conductor has a temperature-independent resistance R and a total heat capacity C. At the momenet $t = 0$ it is connected to a dc voltage V. Find the time dependence of a conductor's temperature T assuming the thermal power dissipated into surrounding space to very as $q = k(T - T_0)$, where k is constant, T_0 is the enviroment temperature (equal to the conductor's temperature at the initial moment).

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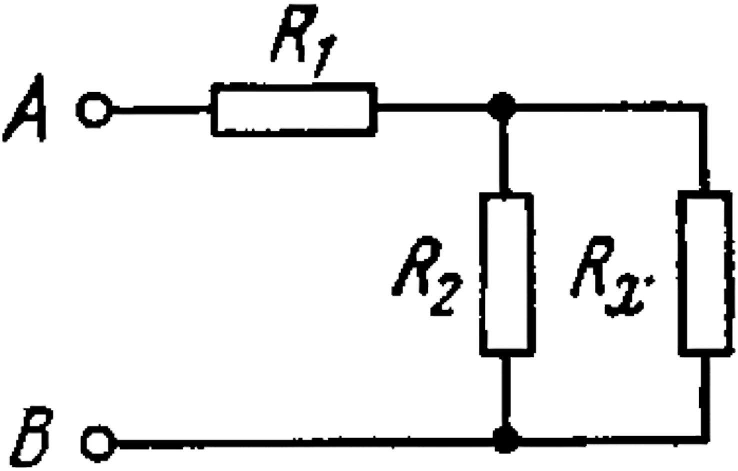
50. A circuit shown in Fig, has resistances $R_1 = 20\Omega$ and $R_2 = 30\Omega$. At what value of the resitanace R_x will the thermal power generated in it practically independent of small variations of that resistance? The voltage between the points A and B is supposed to be constant in this case



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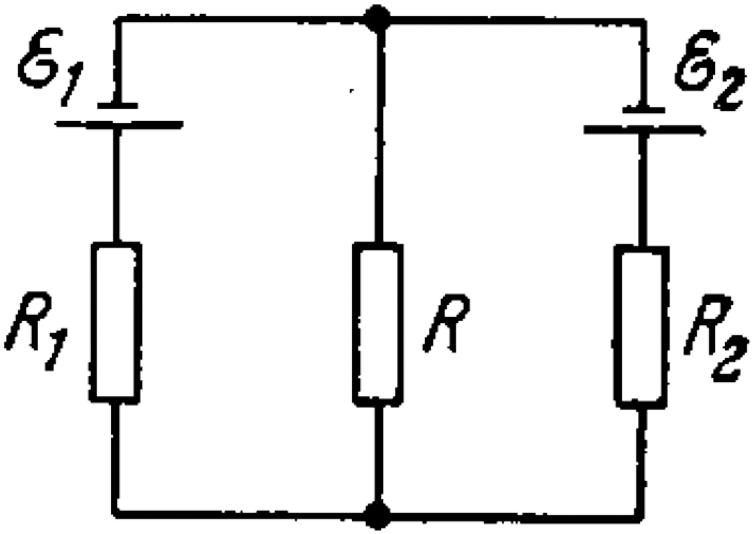
51. In a circuit shown in Fig, resistances R_1 and R_2 are known , as well as emf's ξ_1 and ξ_2. The internal resitances of the sources are negatible. At what value of the resitance R will teh thermal power generated in it be the highest ? What is it equal to ?



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52. A series parallel combination battery consisting of a large number $N = 300$ of identical cells, each will an inernal resistance $r = 0.3\Omega$, is loaded with an external resistances $R = 10\Omega$. Find the number n of parallel groups consisting of an equal number of cells connected in series, at which the external resistance generates the highest thermal power.

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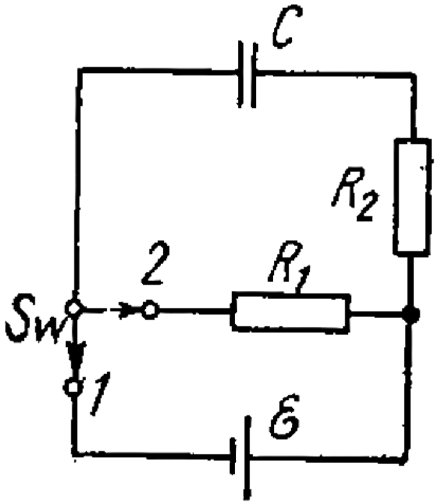
53. A capacitor of capacitance $C = 5.00 \mu F$ is connected to a source of constant $emf \xi = 200V$ (Fig). Then the swich Sw was thrown over from contact 1 to conatact 2. Find the amount of heat generated in a resistance

$R_1 = 500\Omega$ if $R_2 = 300\Omega$



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54. Between the plates of a parallel-plate capacitor there is a metallic plate whose thickness takes up $\eta = 0.60$ of the capacitor gap. When that plate is absent the capacitor has a capacity $C = 20nF$. The capacitor is connected to a dc voltage source $V = 100V$. The metallic plate is slowly extraced from the gap. Find :

(a) the energy increment of the capacitor,

(b) the mechanical work performed in the process of plate extraction.

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55. A glass plate totally fills up the gap between the electrodes of a prallel-plate capacitor whose capacitance in the absence of that glass plate is equal to $C = 20nF$. The capacitor is connected that glass voltage source $V = 100V$. The plate is slowly, and without friction, extracted from the gap. Find teh capacitor energy increment and the mechanical work perfomed in the process of plate extraction.

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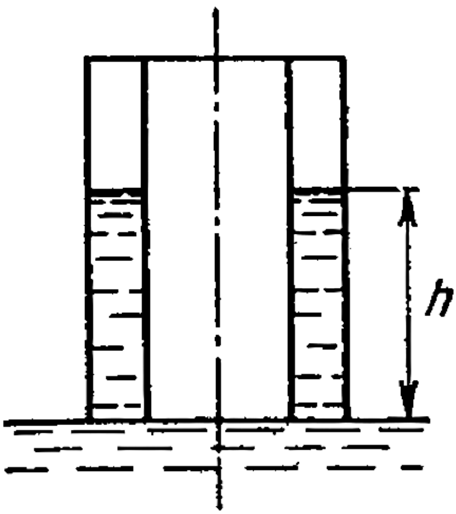
56. A cylindrical capacitor conneced to a dc voltage source V touches the surface of water with its end (Fig) The sepration d between the capacitors electrodes is substantially less than their mean radius. Find a height h to which the water level in the gap will rise. The, capilary effects are to be negelected.



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57. The radii of spherical capacitor electrodes are equal to a and b, with $a < b$. The interlectordes ε and resistivity ρ. Inititally the capacitor is not charged. At the moment $t = 0$ the internal electorde gets a charge q_0 Find:

(a) the times variation of the charge on the internal elecrtordes,

(b) the amount of the heat generated during the spreading of the charge.

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58. The electrodes of a capacitor of capacitance $C = 2.00 \mu F$ carry opposite charges $q_0 = 1.00 mC$. Then the electores are interconnected through a resistanace $R = 5.0 M\Omega$. Find:

(a) the charge flowing thorugh that resistance during a time interval $\tau = 2.00 s$,

(b) the amount of heat generated in the resistance during the same interval.

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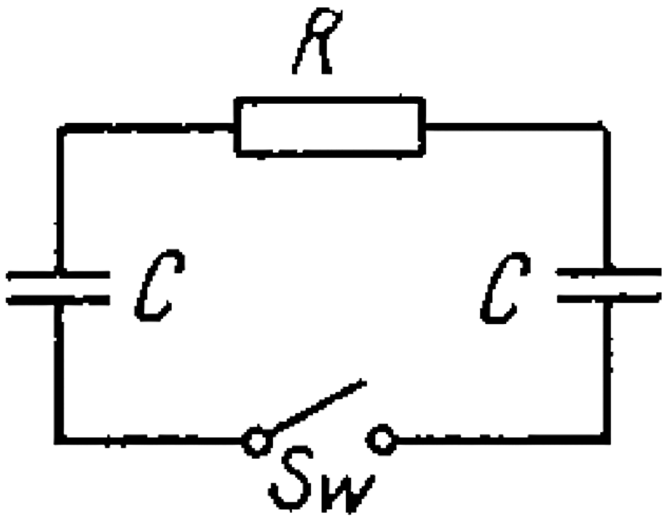
59. In a circuit shown in fig. the capacitance of each capacitor is equal to C and the resistance, to R One of the capacitor was connected to a voltage V_0 and then at the moment $t = 0$ was shorted by means of the swich Sw. Find:

(a) a current I in the circuit as a function of time t:

(b) the amount of generated heat provided a dependence $I(t)$ is known.



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60. A coll of radius $r = 25cm$ wound of a thin a copper wire of length $l = 500m$ rotates with an angular velocity $\omega = 300rad/s$ about its axis. The coll is connected toa baliistic galvanometer by means of sliding contacts. The total resistanace of the circuit is equal t $R = 21\Omega$. Find teh specific total resistance of the circuit is equal to $R = 21\Omega$. Find the specfiic charge of current carries in copper if a sudden stoppage of the coil makes a charge $q = 10nC$ flow through the galvanometer.

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61. Find the total linear momentum of the electrons in a conductor of length $l = 1000m$ carrying a current

$I = 70A.$

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62. A copper wire carries a current of density $f = 1.0A/mm^2$. Assuming that one free electron corresponds to each cooper atom, evalutea the distance which will be covered by an electron during its displacement $l = 10mm$ along the wire.

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63. A straight copper wire of length $l = 1000m$ and cross sectional area $S = 1.0mm^2$ carries a current $I = 4.5A$.

Assuming that one free electron corresponds to each copper atom, find,

(a) the time it takes an electron to displace from one end of the wire to the other,

(b) the sum of electric froces acting on all free electrons in the given wire.

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64. A homongeous proton beam acceletated by a potentiail difference $V = 600kV$ has a round cross-section of radius $r = 5.0mm$. Find the electric fiel dstrength on the surface of the beam and the potentia difference between the surface of the beam and the potential difference between the surface and the axis of the beam if the beam current is equal to $I = 50 mA$.

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65. Two large parallel plates are located in vacumm. One of them serves as a cathoide, a source of electrodes whose initial velocity is neglible . An electrones flows direcee toward the opposite plate produces a space charge causing the potential int eh gap betwnen the plates to between the plates to very as $\varphi = ax^{1/3}$, where a is positive constant, and x is the distnaace form the cathode. Find:

(a) the volume density of the space charge as a funciton of x,

(b) the current density.

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66. The air between two parallel plates separated by a distance $d = 20mm$ is inoized by X-ray radisation. Each plate has an area $S = 500cm^2$. Find the concentration of positive ions if at a voltage $V = 100V$ a current $I = 30\mu A$ flows between the paltes, which is well below the saturation current. The air ion mobilities are $u_0^+ = 1.37cm^2/(V.s)$ and $u_0 = 1.91xm^2/(V.s)$

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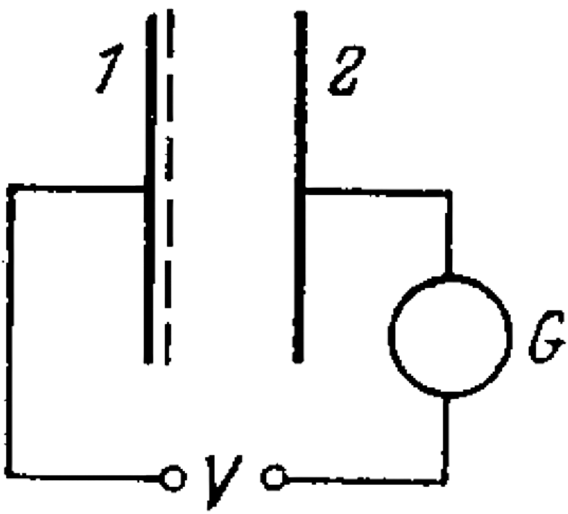
67. A gas is ionized in the immeiate vicinity of the surface of plane electrode I (Fig) separated from electrodes 2 by a distanae l. An alternating voltage varying with time t as $V = V_0 \sin \omega t$ is applie dto the electrodes. On decreasing the frequency ω it was observed that the galvonometer G indicates a current only at $\omega < \omega_0$, where ω_0 is a certain cut-off frequency. FInd the mobility of ions reaching electrode 2 under these conditions.



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68. The air between two closely located plates is uniformly ionized by ulraviolet radiation. The air volume between the plates is equal to $V = 500 cm^3$, the observed saturation current is equal to $I_{sat} = 0.48 \mu A$. Find:

(a) the number of ion pairs produced in unit voume per unit time,

(b) the equilibriium concentration of ion paris if tghe recombination coefficient for air lions is eaual to $r = 1.67.10^{-8} cm^3 / s$

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69. Having been operated long enough, the ionixer producing $n_1 = 3.5.10^9 cm^{-3}. S^{-1}$ of one pairs per unit volume of air per unit time was switched off. Assuming that the only process tending to reduce the numnber of ions in air is thier recombination with coefficient $r = 1.67.10^{-5} cm^3 / s$, find how soon after the ioner concentration decreases $\eta = 2.0$ times.

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70. A parallel-plate air capacitor whose plates are separated by a distance $d = 5.0 mm$ is first chagred to potential dufferebce $V = 90V$ and then disconneced from a dc voltage the capacitor decreases by $\eta = 1.0\%$

taking into account that the average number of ion pairs formed in air under standard contions per unit volume per unit time is equal to $n_1 = 5.0 cm^{-3} s^{-1}$ and that the given voltage corresponds to the saturations current.

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71. The gap between two plane of a capacitor equal to d is filled with a gas. One of the plates emits V_0 electrones per second which, moving in an electric field, ionize gas molecules, this way each electrons produces α new electrons (and ions) along a unit length of its path. FInd the electrons at the opposite plate, negelecting the ionization of gas molecules by formes ions.

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72. The gas between the capacitor plates separated by a distance d is unifromly ionized by ultraviolet radiation so that n_1 electrons per unit volume per second are formed. These electrons moving in the electric field of the capacitor ioinze gas molecules , each electrons producing α new electrons (and ion) per unti length of its path.Neglecting teh ionization by ions, find the electronic current density at the plate possessing a higher potential.

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Constant Magnetic Fiels Magnetics

1. A current $I = 1.00$ A circulates in a round thin-wire loop of radius $R = 100mm$. Find the magentic induction

(a) at the centre of the loop,

(b) at the point lying on the axis of the loop at a disatnace $x = 100mm$ from its centre.

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2. A regular polygon of n sides is formed by bending a wire of total length $2\pi r$ which carries a current i. (a) Find the magnetic field B at the centre of the polygon. (b) By letting $n \rightarrow \infty$, deduce the expression for the magnetic field at the centre of a circular current.

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3. Find the magentic inducrtion at the centre of a recentagular wire frame whose diagonal is equal to $\varphi = 30^{\circ}$, the current flowing in the frame equlas $I = 5.0A.$

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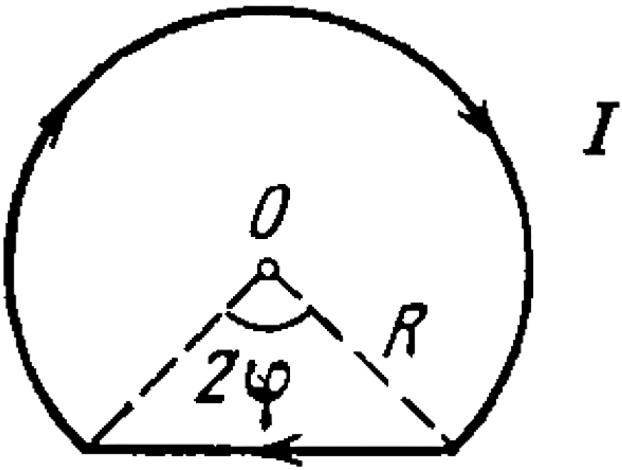
4. A current $I = 5.0A$ A flows along a thin wire shaped as shwon in Fig. The radius of a curved part of the wire is equal to $R = 120mm$, the angle $2\varphi = 90^{\circ}$. Find the magentic induction of the field at the point O.



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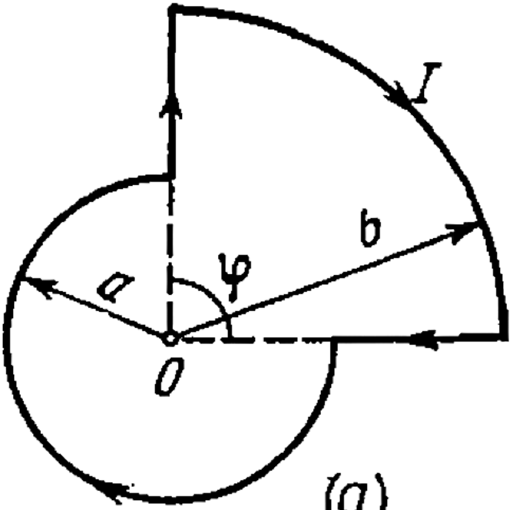
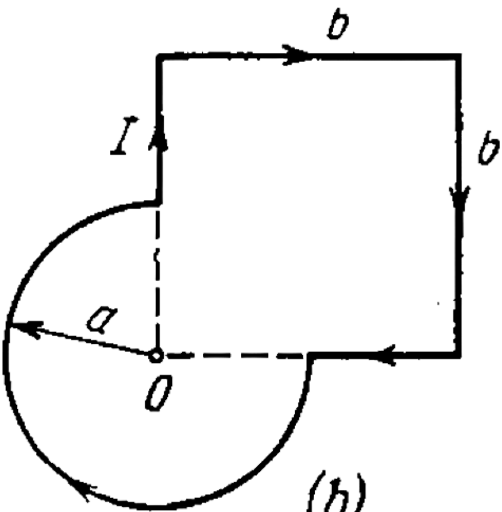
5. Find the magnetic induction of the field at the point O of a loop with current I, whose shape is ilustrated

(a) in Fig. the radil a and b as welll as the angle φ are known,

(b) In Fig , the radius a and the side b are known.



(a)



(b)

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6. A current I flows radius along a lengthy thin-walled tube of radisu R with longiitual slit of width h. Find the induction of the magnietic field inside the tube under the condition $h < \; < R$

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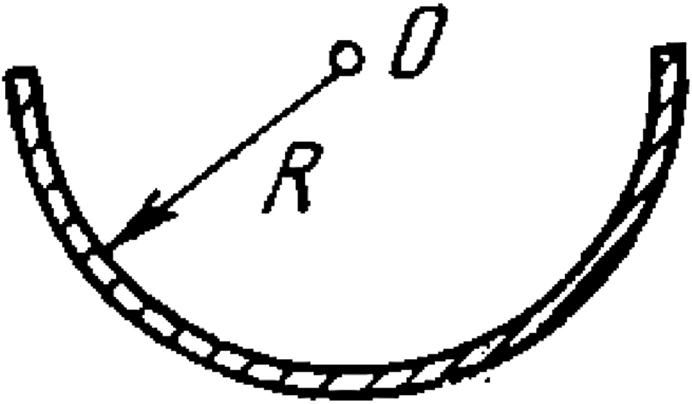
7. A current I flows in a long straight wire with cross-section haviing the form of a thin half-ring of radius R (Fig). Find the induction of the magnitude field at the point O.



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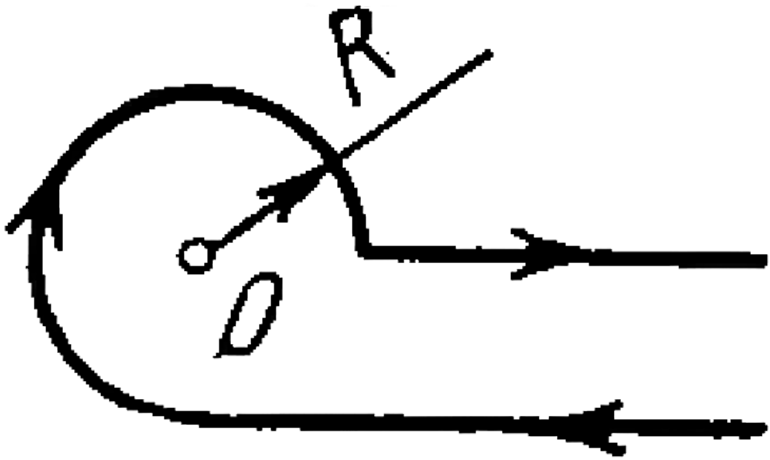
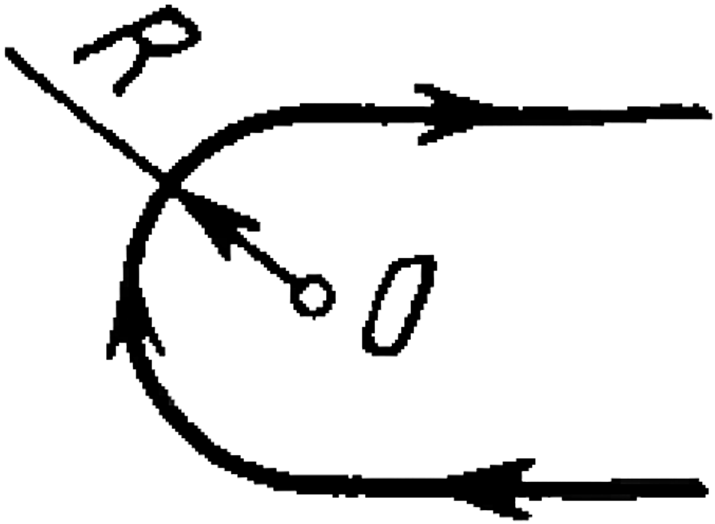
8. Find the magentic induction of the field at the pont O if a current-carrying wire has the shape shown in Figa,b,c The raidius of the curved part of the of the weir is R the linear parts are assumed to be very long.

(a)





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9. A very long wire carrying a current $I = 5.0A$ A is bent at right angles. Find the magnetic induction at a point lying on a perpendicular to the wire, drawn through the point of hending at a distance $l = 35cm$ from it.

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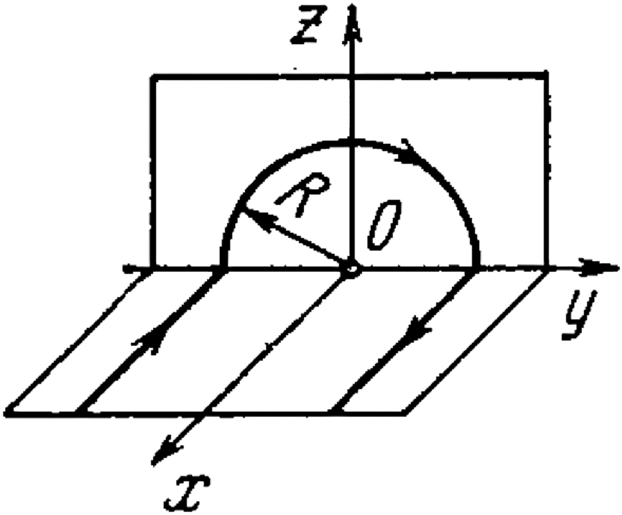
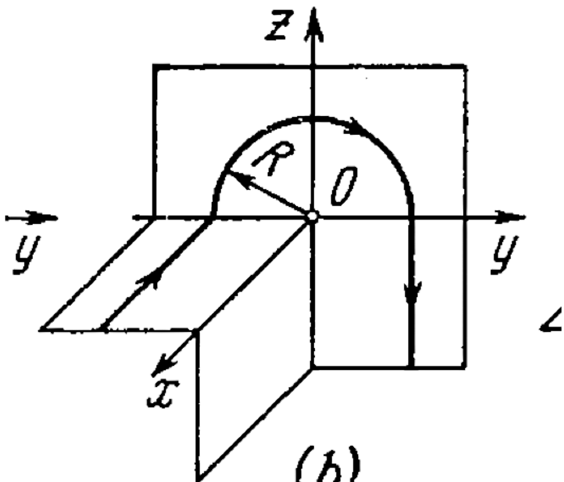
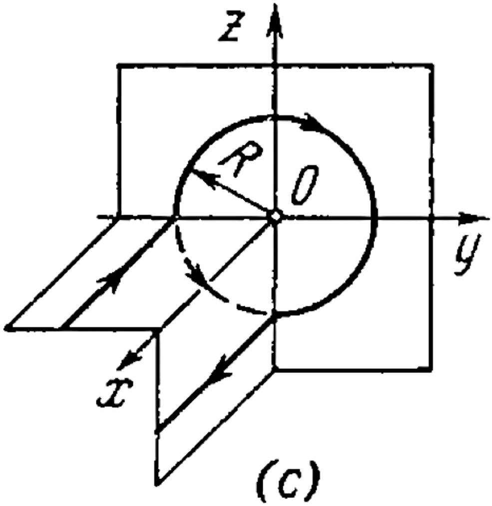
10. Find the magnetic induction at the point O if the wire carrying a current $I = 8.0A$ has the shwon in Fig.





(б)



(c)

The radius of the curved part of the wire is $R = 100mm$, the linear parts of the wire are very long.

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11. Find the magntiude and diraction of the magnitude induction vector B

(a) of an infinite palne carrying a current of linear density I, the vector i is the same at all points of the plane,

(b) of two parallel infinite planes carrying currents of linear densities a dn -1, the vectors i and $-i$ are cohnstant at all points of the corresponding planes.

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12. A unifrom current of density f flows inside an infinite plate of thickness $2d$ parallel to its surface . Find the magentic induction induced by this current as a funcition of the distance x from the median palane of the plate. The magnitude permeability is assumed to be equal to unity both inside and outside the plates.

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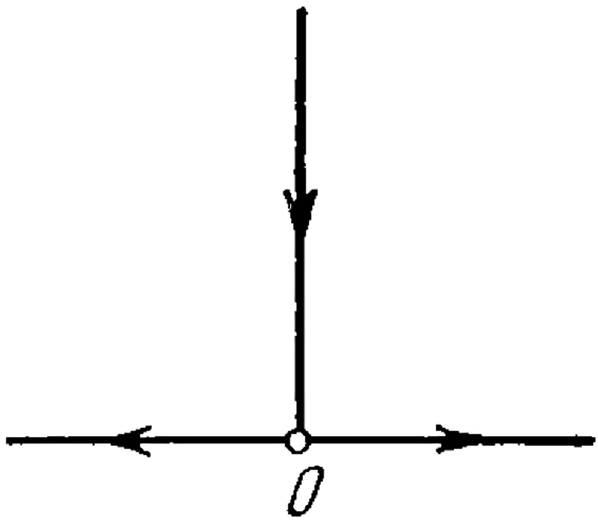
13. A direct current I flows along a lengthly straight wire. From the point O (fig) the current sperads radially all over an infinite conducting plane paerpendicular to the wire. Find the magnatic induction at all points of space.



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14. A current I flows along a round loop. Find the intergal $\int B dr$ along the axi so the loop within the range from $-\infty$ to $+\infty$. Expain the result obtained.

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15. A direct current of density j flows along a round unifrom staright wire with cross-section radius R. Find the magnectic induction vector of this current at the point whose position relative to the axis of the wire is defined by a radius vector r. The magentic permeabilility is assumed to be equla to unity thoughhout all the space.

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16. Inside a long staight unifrom wire of round cross-section there is a long round cylindrical cavity whose axis is parallel to the axis of the wire and displaced from the latter by a distance 1. A direct current of density j flows along the wire. Find the magnedtic induction inside the cavity. Consider, in particular , the case $l = 0$.

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17. Find the current density as a funciton of distance r from the axis of a radially symmetrical parallel stream of electrons if the magentic induction inside the strems varies as $B = br^2$, wheree b and alpha` are positive contans.

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18. A very long straight solenoid has a cross section radius R. A number of turns per unit length is equal to n. Find the magnetic induction at the centre of the coil when a current I flows thougth it.

Watch Video Solution

19. A very long straight solenoid has a cross section radis R and n turns per unit lenghth. A direct current Iflows throguh the solenoid. Suppose that x is the distance from the end of the the solenoid, measured along its axis. Find:

(a) the magnetic induction B on the axis as a funciton of x, draw an approximate plot of B vs ratio x / R,

(b) the distance x_0 to the point on the axis at which the value of B differs by $\eta = 1\%$ from that in the middle section of the solnoid.

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20. A thin conducting strip of width $h = 2.0cm$ is tightly woudnd in the spahe of a very long coil with cross-seciton radius $R = 2.5cm$ to make a single-layer straight solenoid. A direct curretnt $I = 5.0$ A flows through the strip. Find the magnetic inductin inside and outside the solenoid as a funcition of the distanance r from its axis.

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21. $N = 2.5.10^3$ wire turns are uniformly wound on a woodern toroidal core of very smalll cross-section. A current I flows through the wire. Find the magentic induction inside the core to that at the centre of the toroid.

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22. A direct current $I = 10A$ a flows in a long straight round conductor. Find the magnetic flux through a half of wire's cross-section per one meter of its length.

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23. A very long straight solenoid carries a current i. The cross-sectional area of the solenoid is equal to S, the number of turns per unit length is equal to n. Find the flux of the vector B through the end plane of the solenoid.

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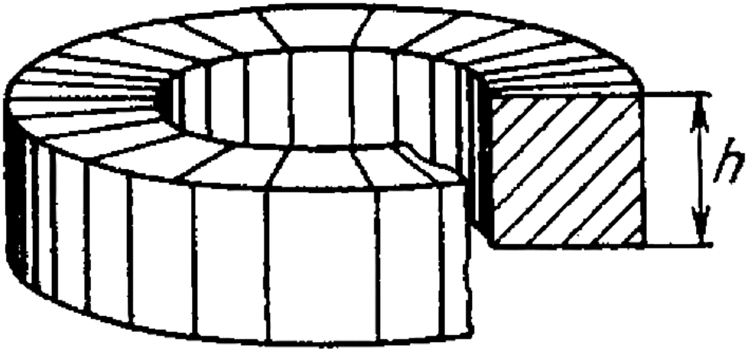
24. Fig, shows a toridal solenoidi whose cross-section is rectangular. Find the magnetic flux thorugh the winding equlals $I = 1.7A$, the total number of turns Is $N = 1000$, the ratio of the outside diameter to the inside one is

$\eta = 1.6$, and the height is equal to $h = 5.0cm$.



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25. Find the magnetic moment of a thin round loop with current if the radius of the loop is equal to $R = 100mm$ and the magnetic induction at its centre is equal to $B = 6.0\mu T$.

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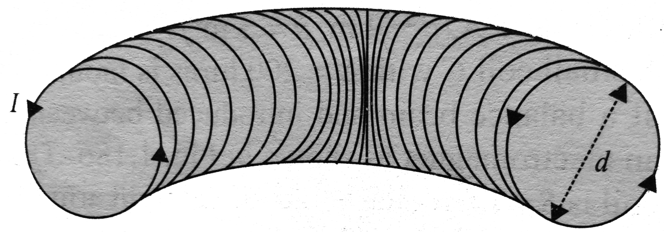
26. Calculating the magnetic moment (in Am^2) of a thin wire with a current I=8A, wound tightlly on a half a tore (see figure). The diameter of the cross section of the tore is equal to d=5cm, and the number of turns is N=500.



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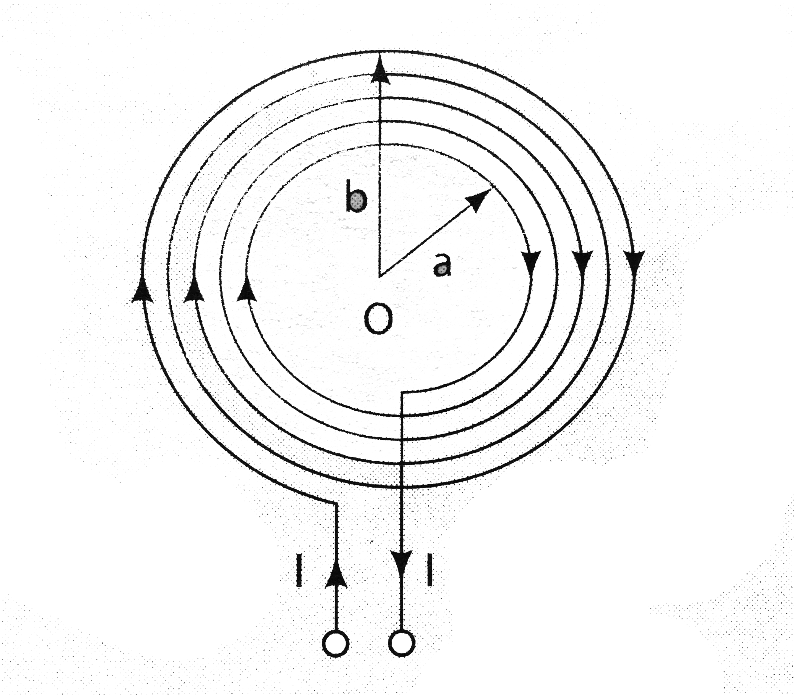
27. A thin insulated wire forms a plane spiral of $N = 100$ turns carrying a current $i = 8mA$. The inner and outer radii are equal to $a = 5cm$ and $b = 10cm$. Find the magnetic induction at the centre of the spiral



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28. A non-conducting thin disc of radius R charged uniformly over one side with surface density σ, rotates about its axis with an angular velocity ω. Find (a) the

magnetic field induction at the centre of the disc (b) the magnetic moment of the disc.

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29. A non-conducting sphere of radius $R = 50mm$ charged uniformly with surface density $\sigma = 10.0\mu C / m^2$ rotates with an angular velocity $\omega = 70$ rad/s about the asxis passign thorugh its centre. Find the magnetic induction at the centre of the sphere.

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30. A charge q is unifromly distributed over the volume of a unifrom ball of mass m and radius R which rotates with an angular velocity ω about the axis passing through its centre. Find the respective magnetic moment and its ratio to the mechanical moment.

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31. A long dielectric cylinder of radius R us statically plartized so that at all the its points the polarization is equal to $P = \alpha x$, where α is a positive constant, and r is the distance from the axis. The cylinder is set into ratation about its axis with an angular velocity ω. FInd the magnetic induction B at the centre of the cylinder.

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32. Two protons move parallel to each other with an equal velcity $v = 300km/s$. Find the ration of forces of magentic and electricla of the protons.

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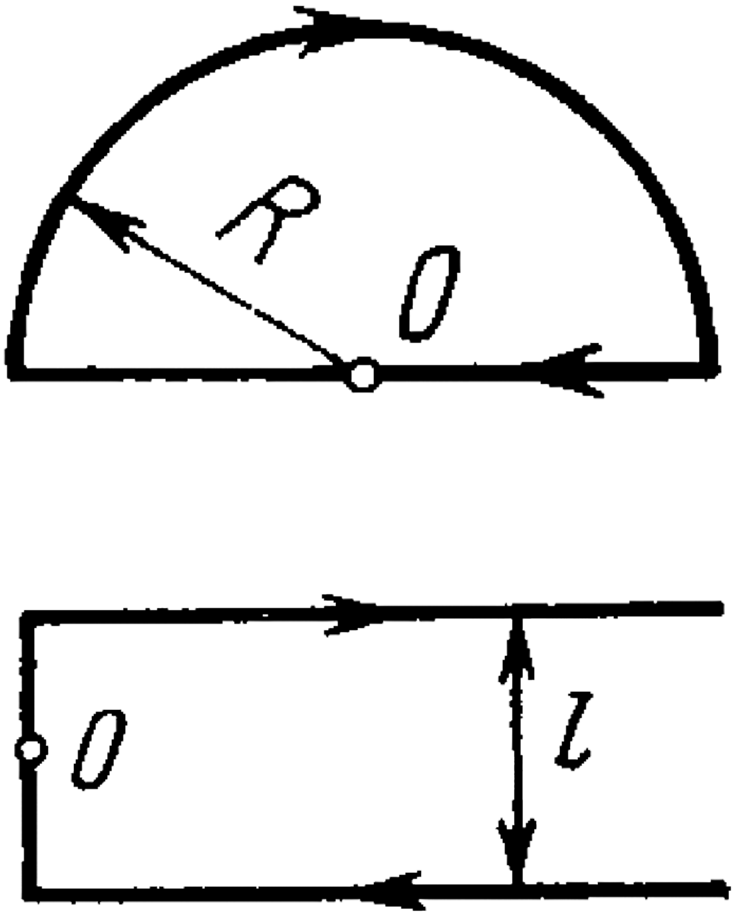
33. Find the magtiude and direction of a force vector acting on a unit length of a thin wire, carrying a current $I = 8.0A$, at a point O. If the wire is hent as shown in (a) Fig with curvature radius $R = 10cm$

(b) Fig the distance between the long parallel segments of the wire being equal to $l = 20cm$.



(b)

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34. A coil carrying a current $10mA$ is placed in a uniform magnetic field so that its axis coincides with the field direction. The single layer winding of the coil is made of copper wire with diameter $0 \cdot 1mm$, radius of turns is equal to $30mm$. At what value of the induction of the external magnetic field can the coil winding be ruptured? Breaking stress is $3 \cdot 1 \times 10^8 Nm^{-2}$.

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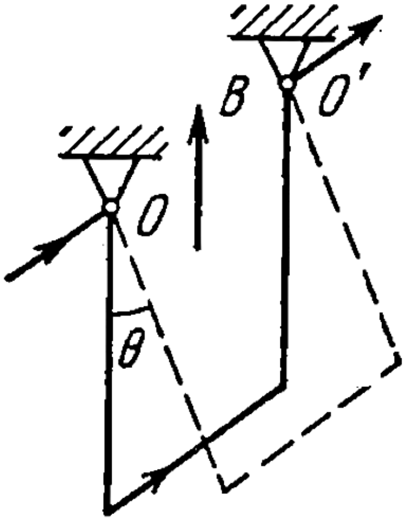
35. A copper wire with cross-sectional area $S = 2.5mm^2$ bent to make three sides of a square can turn about a horizontal axis OO' (Fig). The wire is located in unifrom vertical magnetic field. Find the magnetic induction if on passing a current $I = 16A$ through the wire the latter deflects by an angle $\theta = 20^\circ$.



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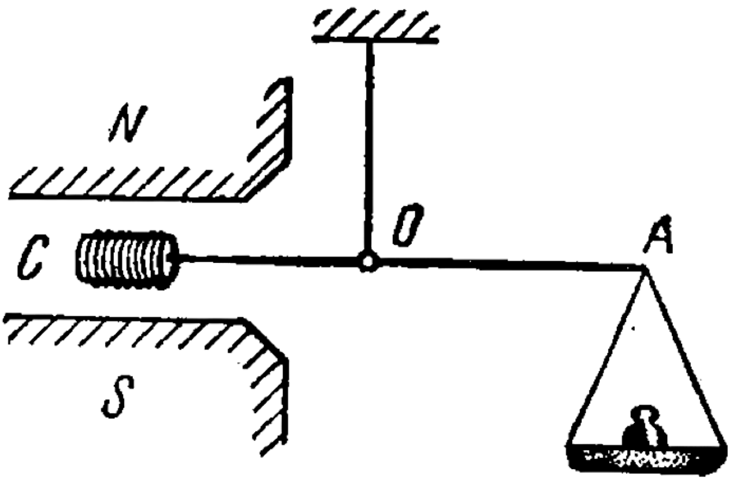
36. A small coil C with N = 200 turns is mounted on one end of a balance beam and introduced between the poles of an electromagnet as shown in Fig. The cross sectinal area of the coil is $S = 1.0cm^2$, the length of the arm OA of the balance beam is $l = 30cm$. When there is no current in the coil the balance is irl equilibrium. On passing a current $I = 22mA$ through the coil the equiibrium is restroed by putting the additional counterweight of mass $\Delta m = 60mg$ ont he balnace pan. Find the magnetic induction at the spot where the coil is located.



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37. A square frame carrying a current $I = 0.9A$ is located in the same plane as a long straght wire carrying a current, $I_0 = 5.0A$. The frame side has a length $a = 8.0cm$. The axis of the frame passing thorugh the midpoints of opposite sides is parallel to the wire and is separated from it by the distance which is $\eta = 1.5$ times greater than the side of the frame. FInd:

(a) Ampere force acting on the frame,

(b) the mechnical work to be performed in order to turn the frame throguh 180° about its axis, with the currents maintained constant.

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38. Two long parallel wires of negligible resistance are connected at one end to a reasitance R and at the other end to a dc voltage source. The distance between the axes of the wires is $\eta = 20$ times greater than the cross-sectional radius of each wire. At what value of resistance R does the resultant force of interaction between the wires turn into zero ?

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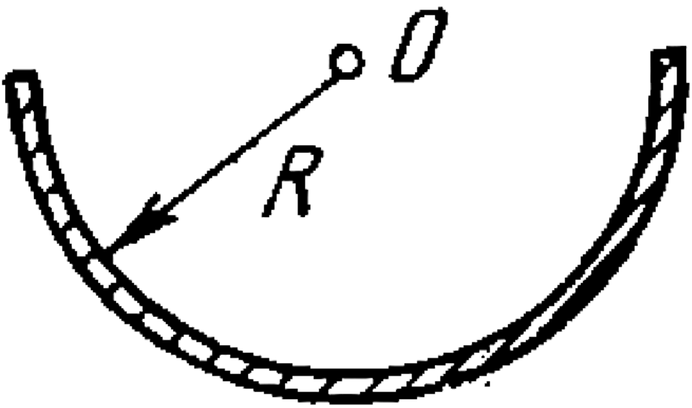
39. A direct currenty I flows in a long straight conductor whose cross-sectional has the from of a the half-ring of radius R. The same current flows in the opposite direction along a thin condocutor located on the "axis" of the first conductor (point O in FIg). Find teh magnetic interaction force between them reduced to a unit of thier length.



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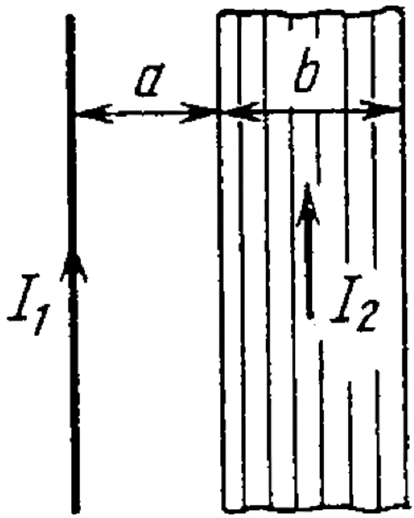
40. Two long thin parallel conductors of the shape shown in Fig. carry direct currents I_1 and width of the right-hand conductor is equal to b. With both conductors lying in one plane, find the magnetic interaction force between them reduced to a unit of their length.



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41. A system consists of two parallel planes carrying currents producing a unifrom magnetic field of induction B between the planes. Outside this space there is no magnetic field. Find the magnetic force acting this space there is no magentic field. Find the magnetic force acting per unit area of each plane.

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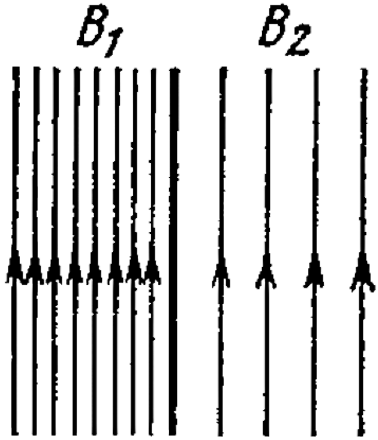
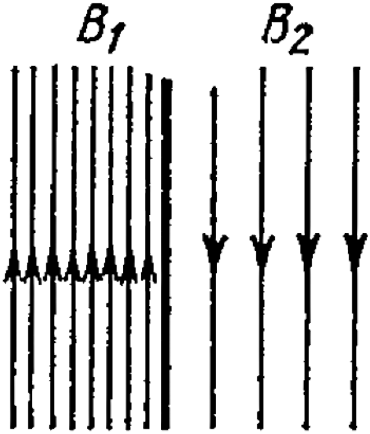
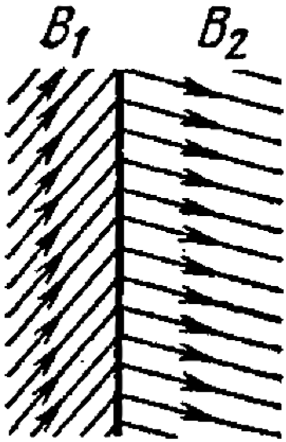
42. A conducting current-carrying plane is placed in an external unifrom magnetic field. As a result, the magnetic induction becomes equal to B_1 on one of the plane and too B_2 on the other. Find the magnetic force acting per unit area of teh plane in hte cases illiustrated in FIg. Determine the direction of the current in the plane in each case.



(a)



(b)



(c)

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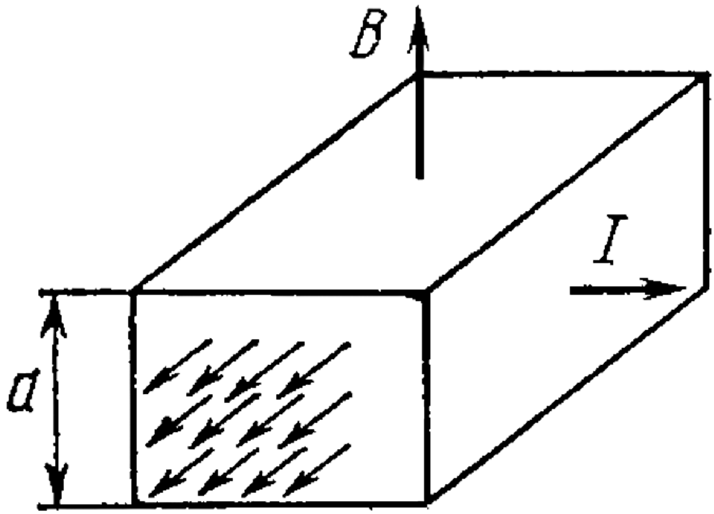
43. In an electromagnetic pump designed for transferring molten metals a pipe section with metal is located in unifrom magnetic field of induction B (Fig) A curent I is made to flow across this pipe section in the direaction perpendicular both to the vector B and to the axis of the pipe. FInd the gauge pressure produced by the pump if $B = 0.10T, l = 100A,$ and $a = 2.0cm,$



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44. A current I flows in a long thin walled cylinder of radius R. What pressure do the walls of the cylinder experience ?

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45. What pressure does that the laterial surface of a long staraight solenoid with n turns per unit length experience when a current I flows throguh it?

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46. A current I flows in a long single layer solenoid with cross-sectional radius R. The number of turns per unit length of the solenoid equals n. Find the limiting current at which the winding may ruputure if the tensile strength of the wire is equal to F_{lim}.

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47. A parallel plate capacitor with area of each plate equal to S and the separation between them to d is put into a stream of conducting liquid with respectivity ρ. The liquid moves parallel to the plates with a constant velocity v. The whoel system is located in a unifrom magentic field of induction B, vector B being parallel to the plates are interconnected by means of an exteranal resistance R. What amount of power is genrated in that resistance? At what value of R is the generated power the highest? What is this highest power equla to ?

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48. A straight round copper conductor of radius $R = 5.0mm$ carries a current $I = 50A$ Find the potentail difference between the axis of the conductor and its surface. The concentration of the conduction electrons in copper is equal to $n = 0.9.10^{33} cm^{-3}$.

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49. In Hall effect measurements ina sodium conductor the strength of a transervse field was found to be equla to $E = 5.0 \mu V / cm$ with a current density $j = 200A / cm^2$ and magentic induction $B = 1.00T$. Find the conentrations of the condiction electrons and its ratio to the total number of atoms in the given conductor.

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50. Find the mobility of the conduction electrons in a copper conductor if in Hall effect measuremaents performed in the magnetic fileld of induction $B = 100mT$ the transverse electric field strength of the given conductor turned out be $\eta = 3.1.10^3$times less than that of the longtudinal electric field.

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51. A small current-carrying loop is located at a distance r from a long straight conductor with current I. The magnetic moment of the loop is equal to p_m. Find the magnitude and direction of the force vector applied to the loop if the vector p_m

(a) is parallel to the stratight conductor,

(b) is oriented along the radius vector r,

(c) coincides in direction with the magnetic field produced by the current I the point where the loop is located.

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52. A small current-carrying coil having a megantic moment p_m is located at the axis of a round loop of radius R with current I flowing thorough it. Find the magnitude of the vector force applied to the coil if its distance from the centre of the loop is equal to x and the vector p_m coincides in direction with the axis of the loop.

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53. Find the interaction force of two coils with magnetic moment $p_{1m} = 43.0 mA. m^2$ and $p_{2m} = 6.0 mA. m^2$ and coilnear axis if the separation between the coils is equal to $l = 20cm$ which exceeds considerably their linear dimensions.

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54. A permanent magnent has the shape of a sufficiency thin disc magnetized along its axis. The radius of the disc is $R = 1.0cm$. Evaluate the magnitude of a molecular current I' flowing along the rin of the disc, lying at a distance $x = 10cm$ from its centre, is equal to $B = 30\mu T$.

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55. The magnetic induction in vacumm at a plane surface of a uniform istropic magnetic is equal to B, the vector B forming an angle α with the normal of the surface. The permeability of th emagnetic is equal to μ. Find the magnitic of the magnetic induction B in the magnetic in the vicinity of its surface.

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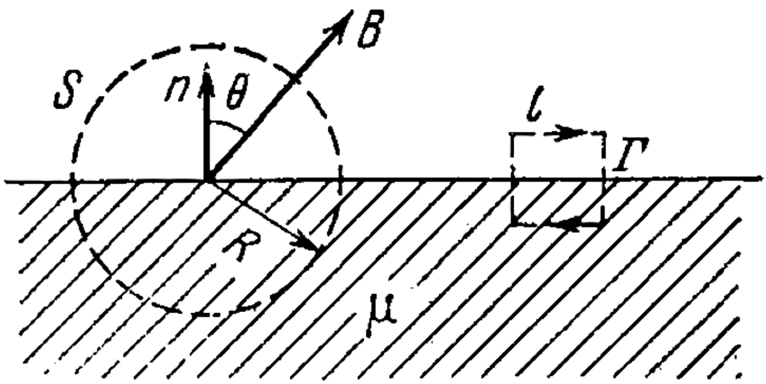
56. The magentic induction in vacumm at a plaen surface of a magentic is equal to B and the vector B forms an angle θ with the normal n of the surface (Fig). The permeability of the magnetic is equal to μ. Find:

(a) the flux of the vector H through the spherical surface

S of radius R, whose centre lies on the surface of the magentic,

(b) the circulation of the vector B around the square path I' widh side l located as shwon in the fig.



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57. A direct current I flows in a long round unifrom cylindrical wire made of permagnetic with sesceptibility

χ. Find

(a) the surface molecule current I_s,

(b) the volume mulecule current I'_v.

How are these currents directed toward each other?

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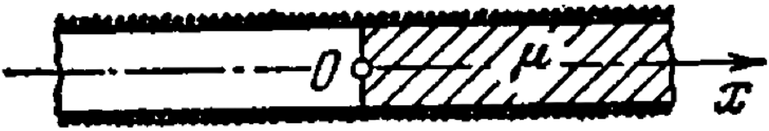
58. Half of an infinitely long straight current-carrying solenoid is filled with magnetic substance as shown in Fig. Draw the appoximater plots of magnetic induction B, strength H and magnetization J on the axis as functions of x.



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59. An infinitely long wire with a current I flowing in it is located in the boundary plane between two non-conducting media with permeabilities μ_1 and μ_2 . Find the modulus of the magnetic induction vector thorughout the space as a function of the distance r

from the wire. It should be horne in mind that the lines of the vector B are circles whose centres lie on the axis of the wire.

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60. A round current-carrying loop lies in the plane boundary between magnetic and vacumm. The permeability of th emagnetic is equal to μ Find the magnetic induction B at an arbitary point on the axis of the loop if in the absence of th e magnetic the magnetic induction at the same point becomes equal to B_0 . Genralize the obtained result to all poins of the field.

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61. When an ball made of uniform magnetic is introduced into an external unifrom magnetic induction B inside the ball with permeability μ, recall that the magnetic field is inside a unifromly mag netized ball is unifrom and its strength is equal to $H' = J/3$, where J is the magnetization.

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62. $N = 300$ turns of thin wire are uniformly wound on a permanent magnet shaped as a cylinder whose length is equla to $l = 15cm$. When a current $I = 3.0A$ was passed through the wring the field outside the magnet disappeared. Find the coercive force H_e of the materail from which the magnet was manufaucured.

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63. A permanent magnety is shaped as a ring with a narrow ghap between the poles. The mean diameter of the ring equals $d = 20cm$. The width of the gap is equal to $b = 2.0mm$ and the magnetic induction in the gap is equal to b = 40mT'. Assuming that the scattering of the magnetic flux at the gap edges is negligible, find the modulus of the magnetic fleid strength vector inside the magnet.

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64. An iron core shaped as a tore number of turns mean $R = 250mm$. The supports a winding with the total number of turns $N = 1000$. The core has a cross-cut of width $b = 1.00mm$. With a current $I = 0.85$ A flowing through the winding, the magnetic induction in the gap is equal to $B = 0.75T$. Assuming the scarttering of the magnetic flux at the grap edges to be negligible, find the permeaiility of iron under these conditions.

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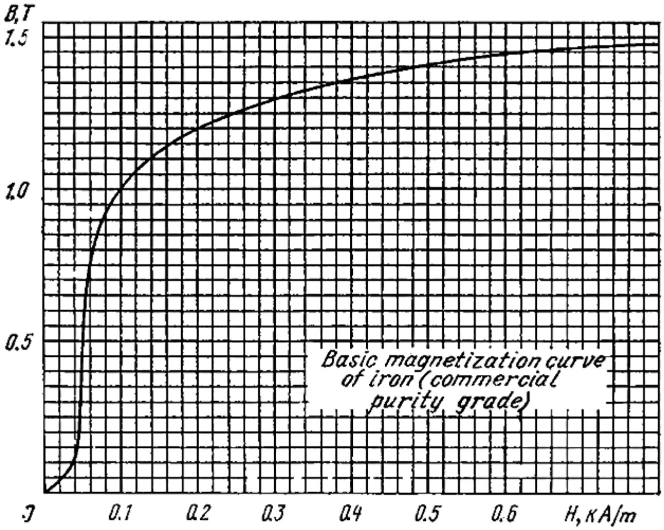
65. Fig illustrates a basic magnetization curve of iron (commerical purity grade). Using tis plot, draw th permeability μ as a function of the magnetic filed strength H. At what value of H is the permeability the greatest ? What is $\mu_{\max}$ equal to ?



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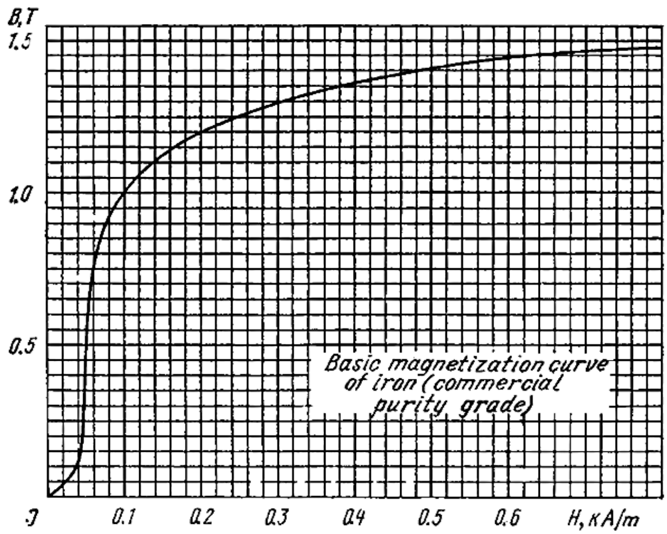
66. A thin iron ring with mean diameter $d = 50cm$ supports a winding consisting of $N = 800$ turns carrying current $I = 3.0A$. The ring has a cross-cut of width $b = 2.0mm$. Neglecting the scattering of the magnetic flux at the gap edges, and using the plot shown in FIg. find the permeabitliy of iron under these conditions.



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67. A long thin cylinder rod mode made of paramegnetic with magnetic suspectibilty χ and having a cross-carrying coil. One end of the rod is located at the coil centre where the magnetic induction equal to B wheares the other end is located in the region where the magnetic field is practically absent. What is the force that the coil exerts on the rod ?

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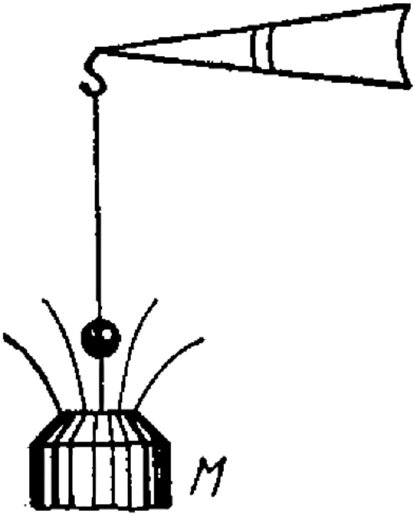
68. In the arrangement shown in Fig it is possible to measure (by means of a balance) the force with which a paramagnetic ball of volume $V = 41mm^3$ is attrated to a pole of the electromagnet M. The magnetic induction at the axis of the poleshoe depends on the height x as $B = B_0$ exp $\left(-ax^2\right)$, where $B_0 = 1.50T$, $a = 100m^{-2}$. Find:

(a) at what height x_m the ball experiences the maximum attraction,

(b) the magnetic susceptibility of the paranagnetic if the maximum attraction force equals $F_{\max} = 160 \mu N$.



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69. A small ball of volume V made of paramagnetic with susceptibility χ was slowly displace along the axis of a current-carrying coil from the point where the magnetic induction equals B out to the region where the magnetic field is the practically absent. What amount of work was performed during this process ?

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Electromagnetic Induction

1. A wire bent as a parabola $y = ax^2$ is located in a uniformed magnetic field of induaction B , the vector B being perpendicular to the plane $x - y$. At moment $t = 0$ a connector starts sliding translationwise from the parabola apex with a constant acceleration ω . Find the emf of electromagnetic induction in the loop thus formed as a function of y

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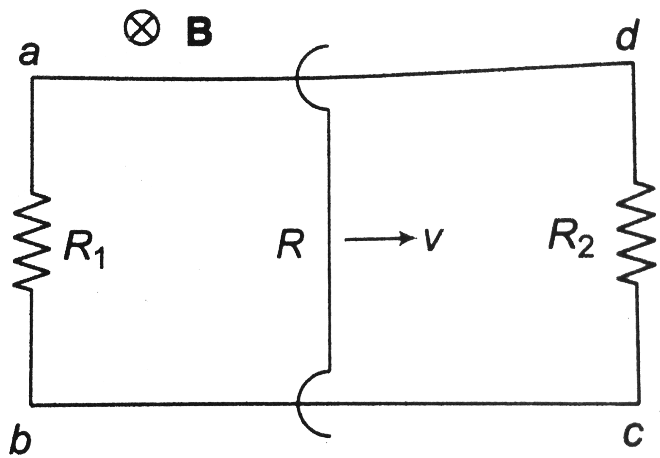
2. A rectangular loop with a sliding connector of length l is located in a uniform magnetic field perpendicular to the loop plane. The magnetic induction is equal to B. The connector has an electric resistance R, the sides ab and cd have resistances R_1 and R_2. Neglecting the self-inductance of the loop, find the current flowing in the connector during its motion with a constant velocity v.



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3. A metal disc of radius $R = 25cm$ rotates with a constant angular velocity ω = 130 rad s^{-1} about its axis. Find the potential difference between the center and rim of the disc if

(a) the external magnetic field is absent,

(b) the external uniform megnetic field $B = 5.0$mT directed perpendicular to the disc.

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4. A thin wire AC shaped as a semi-circle of diaameter $d = 20cm$ rotates with a constant angular velocity

$\omega = 100$ rad/s in a unifrom magnetic field of induction $B = 5.0 mT$, with $\omega \uparrow \uparrow B$. The rotation axis passes through the end A of the wire and is perpendicular to the diameter AC. Find the value of a line intergal $\int E dr$ along the wire from point A to C. Generalize the botained result.

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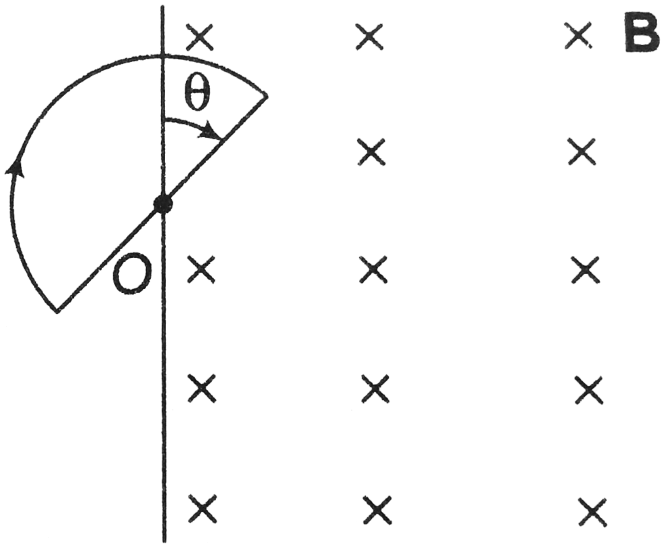
5. A wire loop enclosing as semicircle of radius R is located on the boudary of uniform magnetic field B. At the moment $t = 0$, the loop is set into rotation with a costant angular acceleration α about an axis O coinciding with a line of vector B on the boundary. Find the emf induced in the loop as a function of time. Draw the approximate plot of this function.The arrow in the figure shows the emf direction taken to be positive.



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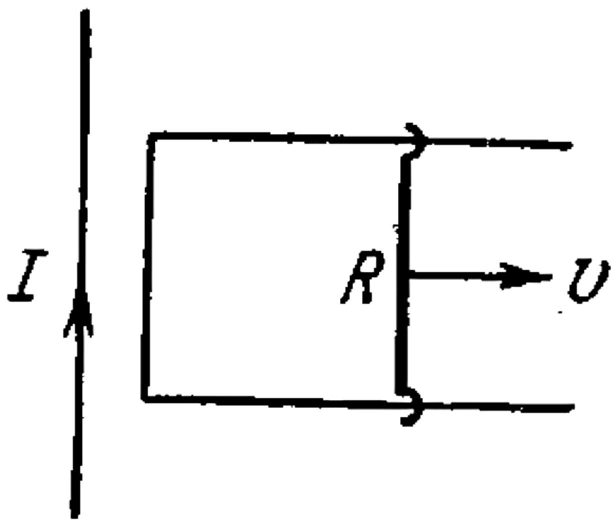
6. A long straight wire carrying a current I and a II-shaped conductor with siding connector are located in the same plane as shown in Fig. The connector of length

l and resistance R sides to the right with a current induced in the loop as a function of separation r between the connector and the stragiht wire. The resistance of the II-shaped conductor and the self-induced of the loop are assumed to be negligible.



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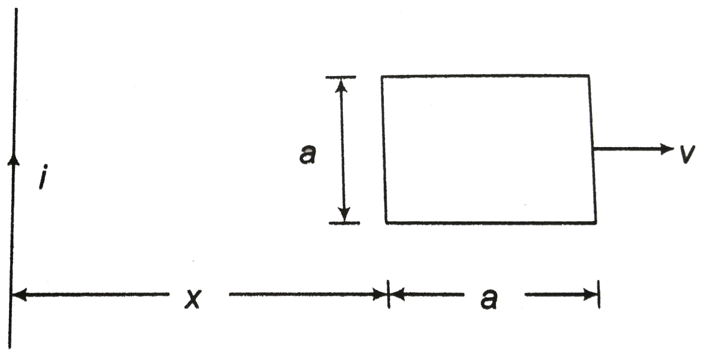
7. A square frame with side a and a long straight wire carrying a current i are located in the same plane as m shown in figure. The fram translates to the right with a constant velocity v. Find the emf induced in the frame as a function of distance x.



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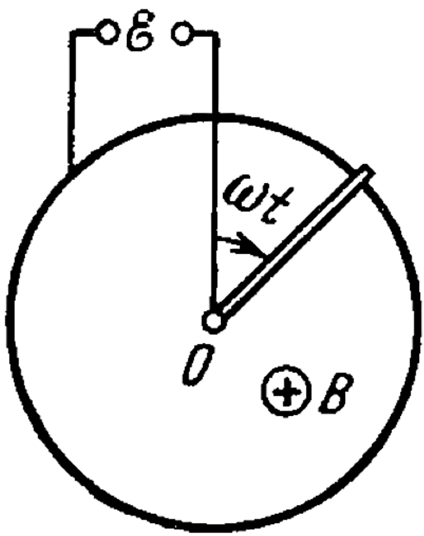
8. A metal rod of mass m can rotate about a horizontal axis O, sliding along a circular conductor of radius a (fig).

The arrangment is located in a unifrom magnetic field of induction B directed perpendicular to the ring plane. The axis and the ring are connected to an emf source to form a circuit of resistance R. Neglecting the friction, circuit induction and ring resistance, find the law according to which the source and must very to make the rod rotate with a constant angular velocity ω.



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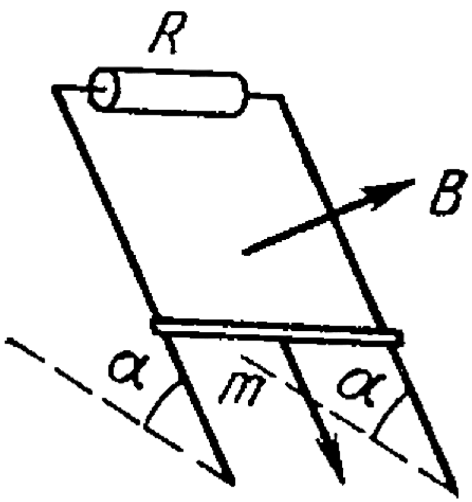
9. A copper connector of mass m slides down two smooth cooper bars, set at an angle α to the horizontal due to gravity (Fig). At the top the bars is equal to l. The system is located in a unifrom magnetic field of induction B, perpendicular to the plane in which the connector slides. The resistances of the bars, the connector and the sliding contacts, as well as the self-inductance of the loop, are assumed to be negligible. Find the steady-state velocity of the connector.



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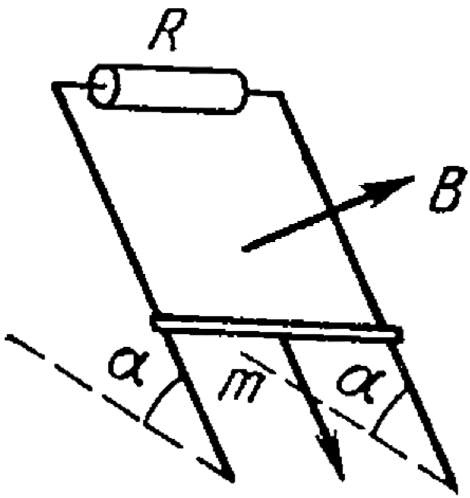
10. The system differs from the one examined in the foregoing problem (Fig) by a capacitor of capacitance C replacing the resistance R. Find the accelearation of the connector.



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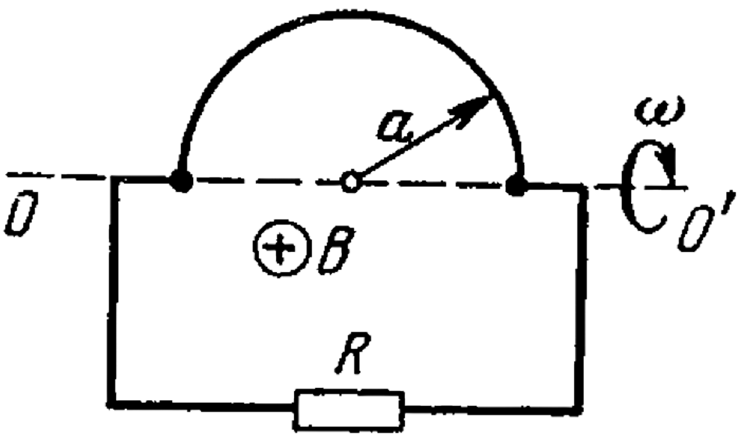
11. A wire shaped as a semi-circle of radius a rotates about sn sxis OO' with an angular velocity ω in a unifrom magnetic field of induction B' (Fig). The rotation axis is perpendicular to the field direction. The total resistance of the circuit is equal to R. NEglecting the magnetic field of the induced current, find the meand amount of thermal power being generated in the loop fueing a rotation period.



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12. A small coil is intorduced between the poles of an electromagnent so that its axis coincides with the magnetic field direction. The cross sectional ara of the coil is equal to $S = 30mm^2$, the its diameter a balistic galvanometer connected to the coil indicates a charge $q = 4.5\mu C$ flowing through it. Find the magnetic induction magnitude between the poles provided the total resistance of the electric circuit equals $R = 40\Omega$

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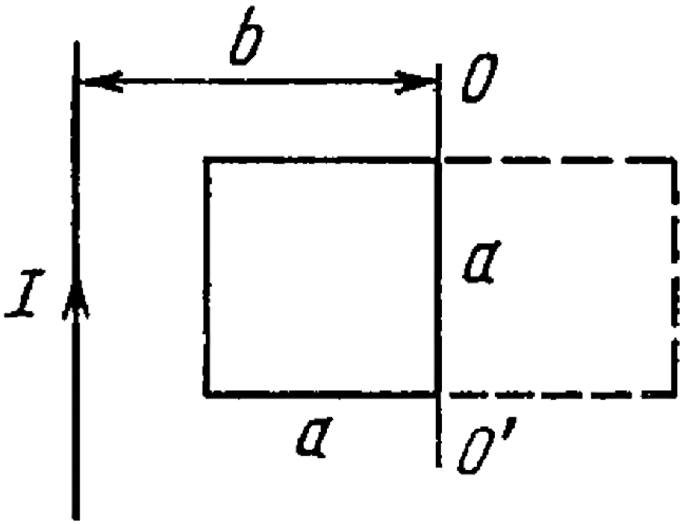
13. A square wire frame with side a and a straight conductor carrying constant current I are located in the same plane (Fig). The inductance and the resitance of the frame are equal to L and R respectively. The frame was turned throgh 180° about the axis OO'separated fromt the current carrying conductor by a distance b. FInd the electric charge having flown through the frame.



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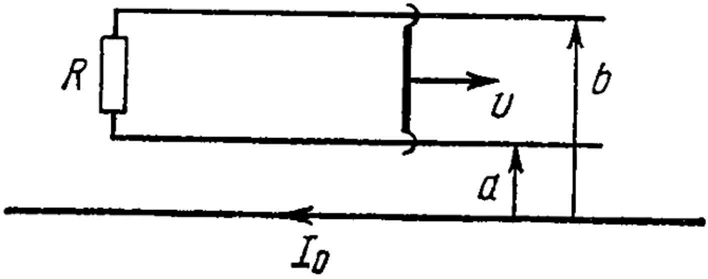
14. A long straight wire carries a current I_0. At distances a and b from it there are two other wires, parallel to the former one, which are interconnected by a resistance R (Fig). A connector slides without friction along the wires with a constant velocity v. Assuming the resistances of the wires, the conductor, the sliding contacts, and the self-inductance of the frame to be negligable, find:

(a) the magnitude and the direction of the current induced in the connector,

(b) the force required to maintain the connector's velocity constant.



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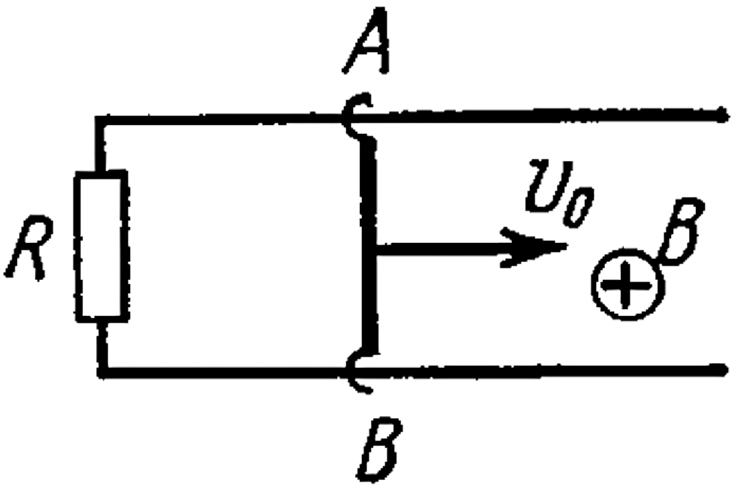
15. A conductor rod AB of mass m slides without friction over two long conducting rails separated by a distance (Fig) At the left end the raidls are interconnected by a resistance R. The system is located in a unifrom magnetic fileld perpendicular to the plane of the loop. At the moment $t = 0$ the rod AB starts moving to the right with an initial velocity v_0. Neglecting the resistances of the rails and the rod AB, as wellas the self -indcuctance, find:

(a) the distance covered by the rod until it comes to a standsill,

(b) the amount of heat generated in the resitance R during this process.



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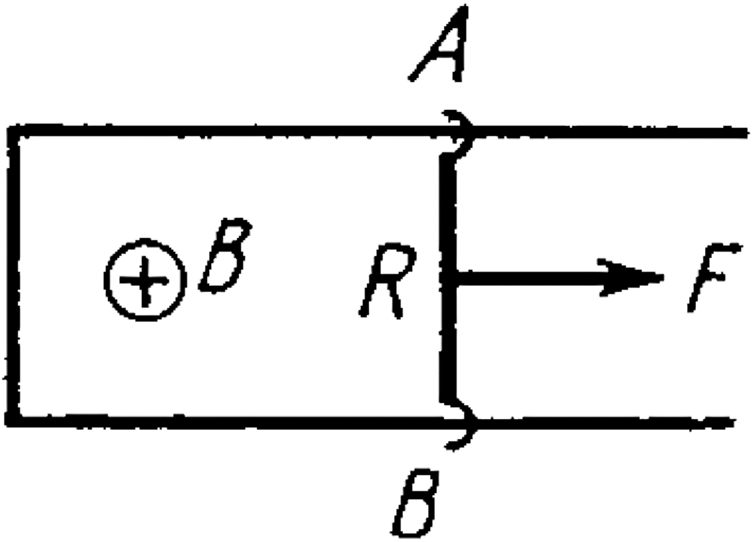
16. A connector AB can slide without frictiion along a II-shaped conductor located in a horizontal plane (Fig). The connector has a length l, mass m and resistance R. The whole system is located in a unifrom magnetic field of induction B directed vertically. At the moment $t = 0$ a constant horizontal force F starts acting on the connector shifting it translationwise to the right. Find how th e velocity o fhte connector varies with time t. The inductance of the loop and the resistance of the II-shaped conductor conductor are assumed to be negligible



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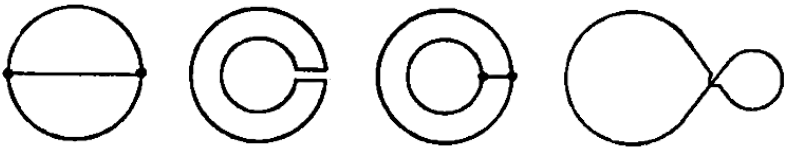
17. Fig. illustrates plane figures made of thin conductors which are located in a uniform magnetic field directed away from a reader beyond the plane of the drawing. The magnetic induction starts diminshing. Find how the currents induced in these loops are directed.



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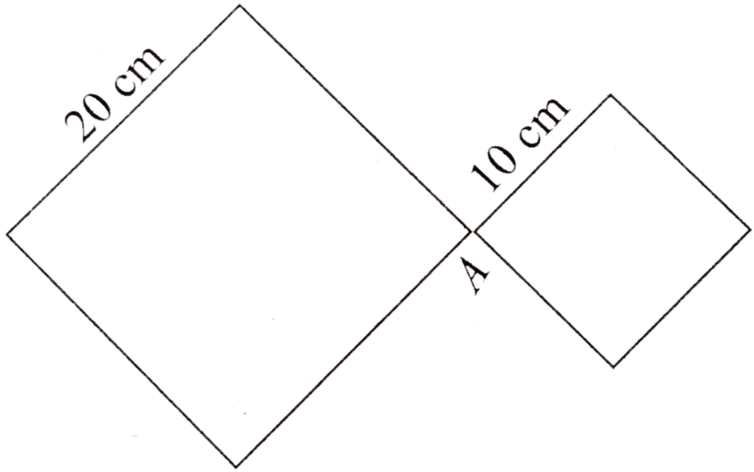
18. A plane loop is shaped as two squares (Fig) and placed in a uniform magnetic field at right angle to the loop's plane. The magnetic induction varies with time as $B = B_0 \sin(\omega)t, where B_0 = 10mT$ and $(\omega) = 100rads^{-1}$. The wires do not touch at point A. If resistance per unit length of the loop is $50m(\Omega)/m$, then amplitude of current induced in the loop is



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19. A plane loop is shaped as two squares (Fig) and placed in a uniform magnetic field at right angle to the loop's plane. The magnetic induction varies with time as $B = B_0 \sin(\omega)t, where B_0 = 10mT$ and $(\omega) = 100rads^{-1}$

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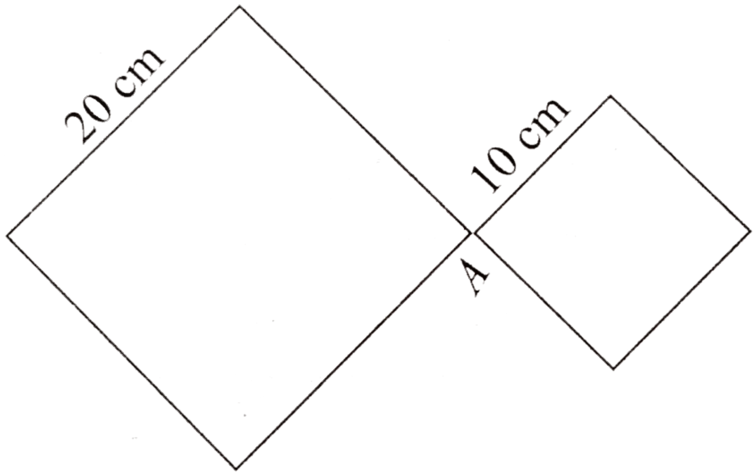

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20. A π shaped metal frame is located in a uniform magnetic field perpendicular to the plane of the conductor and varying with time at the rate

$(dB / dt) = 0. I0T / \sec$. A conducting connector starts moving with an acceleration $a = I0cm / \sec^2$ along the parallel bars of the frame. The lenght o0f the connector is equal to $l = 20cm$. Find the emf induced in the loop $t = 2\sec$ after the beginnig of the motion, if at the moment $t = 0$ the loop area and the magnetic induction are equal to zero. The inductance of the loop is to be neglected.

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21. In a long staright solenoid with cross-sectional radius a and number of turns per unit length n a current varies with a constant velocity$\dot{I}A / s$. Find the magntidue of the eddy current field strength as a function of the distance

r from the solenoid axis. Draw the appoximate plot of this function.

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22. A long straight solenoid of cross-sectional diameter $d = 5cm$ and with $n = 20$ turns per one cm of its length has a round turn of copper wire of cross-sectional area $S = 1.0mm^2$ tightly put on its winding. Find the current flowing in the turn if the current in the solenoid winding is increased with a constant velocity $\dot{I} = 100A/s$. The inductance of the turn is to be neglected.

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23. A long solenoid of cross-sectional radius a has a thin insulates wiere ring tightly put on its winding, one half of the ring has the resistance η times that of the other half. The magneticv induction produced by the solenoid varies with the time as $B = bt$, where b is a constant. Find the magnitude of the electric field strength in the ring.

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24. A thin non-conducting ring of mass m carrying a charge q can freely rotate about its axis. At the initial moment the ring was at rest and no magnetic field was present. Then a practically unifrom magnetic field was switched on, which was perpendicular to the planeof the ring and increased with time according to a certain law $B(t)$, Find the angluar velocity ω of the ring as a function of the induction $B(t)$.

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25. A thin wire ring of radius a and resitance r is located inside a long solenoid is equal to l, its cross-sectional radius , to b. At a certain moment the solenoid was connected to a source of a constant voltage V. The total resistance of the circuit is equal to R. Assuming the the radial force acting per unit length of the ring.

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26. A magentic flux through a statinary loop with a resistance R varies during the tiem interval τ as $\Phi = at(\tau - t)$. Find the amount of heat generated in the loop during that time. The inductance of the loop is to be neglected.

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27. In the middle of a long solenoid there is a coaxial ring of square cross-seciton, made of conducting materaial with respectivity are equal to h its inside and outside radii are equal to a and b respectively. Find the current induced in the ring if the magnetic induction produced by the solenoid varies with time as $B = \beta t$, where βt, where β is constant. THe inductance of the ring is to be neglected.

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28. How many meters of a thin wire are required to manufacture a solenoid of length $l_0 = 100cm$ and inductance $L = 1.0mH$ if the solnoid's cross -sectional diameter is condiserably less than its length ?

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29. Find the inductance of a solenoid of length l whose winding is made of copper wire of mass m. The winding resistance is equal to R. The solenoid diameter is considerably less than its length.

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30. A coil of inductance $L = 300mH$ and resitance $R = 140m\Omega$ is connected to a constant voltage source. How soon will the coil current reach $\eta = 50\%$ of the steady-state value ?

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31. Calculate the time constant τ of a straight solenoid of length $l = 1.0m$ having a single-layer winding of copper wire whose total mass is equal to $m = 1.0kg$. The cross-sectional diameter of the solenoid is assumed to be considerably less than its length.

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32. Find the inductance of a unit length of a cable consisting of two thin-walled coaxial metallic cylinders if the radius of the outside cylinder is $\eta = 3.6$ times that of the inside one. The permeabitity of a medium between the cylinders is assumed to be equal to unity.

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33. Calculate the inducatance of a doughunt solenoid whose inside radius is equal to b and cross-section has the form of a square with side a. The solenoid winding consists of N turns. The space inside the solenoid is filled up with unifrom paramagnetic having permeability μ.

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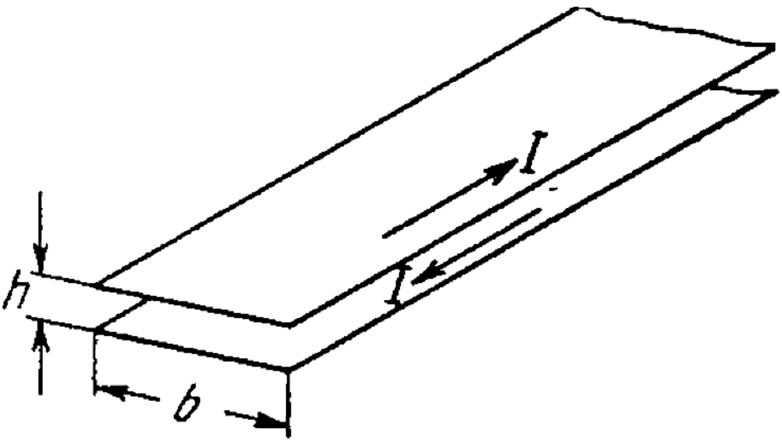
34. Calculate the inuctance of a unit length of a double tape line (Fig) if the tapes are separated by a distance h which is considerabley less than their width b, namely,

$b/h = 50.$



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35. Find the inductane of a unit length of a double line if the radius of each wire is η times less than the distance between the axes of the wires. The field inside the wires is to be neglected, the permeability is assumed to be equal to unity throughout, and $\eta > > 1$.

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36. A supercondutig round ring of radius a and inductance L was located in a unifrom magnetic fied of induction B. The ring plane was parallel to the vector B, and the current in the ring was equal to zero. Them the ring was turned through 90° so that its plane became perpendicular to the feild. FInd:

(a) the current induced in the ring after the turn,

(b) the work perfromed during the turn.

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37. A Current $I_0 = 1.9A$ flows in a long closed solenoid. The wire it is wound of is a superconducting state. Find the current flowing in the solenoid when the length of the solenoid is increased by $\eta = 5\%$.

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38. A ring radius $a = 50mm$ made of thin wire of radius $b = 1.0mm$ was located in a unifrom magnetic field with induction $B = 0.50mT$ so that the ring place was perpenficular to the vector B. Then the ring was cooled down to superconducting state, and the magnetic field was swichted off. Find the ring current after that. Note that the inductiance of a thin ring along which the surface current flows is equal to $L = \mu_0 a\left(In\frac{8a}{b} - 2\right)$.

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39. A closed circuit consits of a source of constant and E and a choke coil of inductance L connected in series. The active resistance of the whole circuit is equal to R. At the moment $t = 0$ the choke coil inductance was decreased abrupty η times. FInd the current in the circuit as a function of time t.

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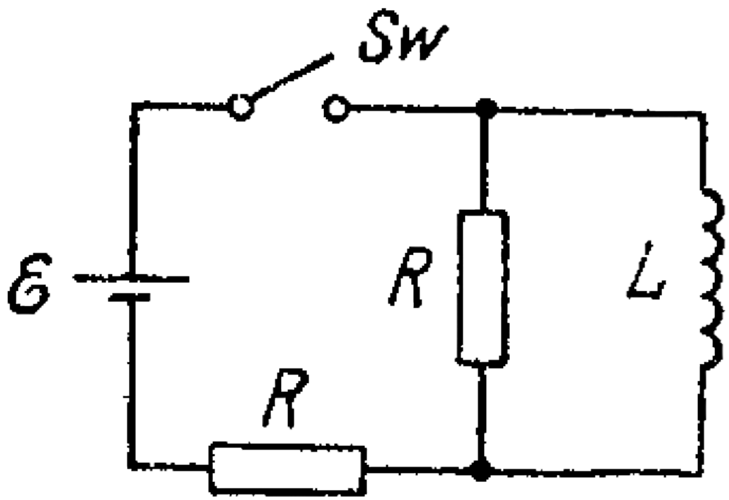
40. Find the time dependence of the current flowing through the inductance L of the circuit shown in Fig after the swich Sw is shorted at the moment $t = 0$.



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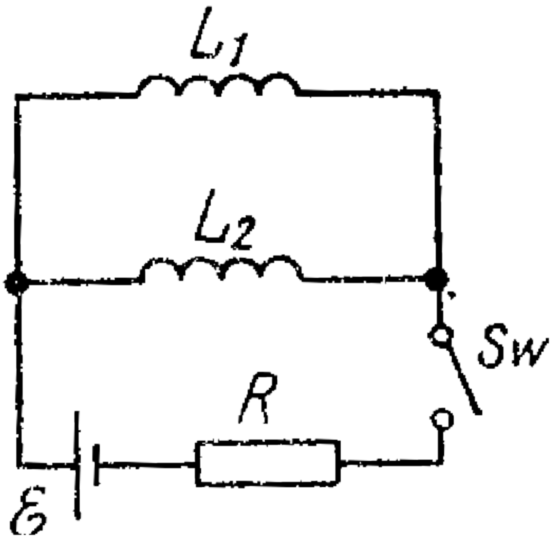
41. In the circuit shown in Fig. $emf E$, a resistance R, and coil inductances L_1 and L_2 are known. The internal resistance of the source and the coil resistances are neglible. Find the steady-state currents in the coils after the swich Sw was shorted.



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42. Calculate the mutual inductance of a long straight wire and a rectangular frame with sides a and b. The frame and the wire lie in the same plan, with the side b

being closent to the wire, separated by a distance l from it and oriented parallel to it.

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43. Determine the mutual inductance of a doughnut coil and an infinite straight wire passing along its axis. The coil has recatangular cross-section, its inside radius is equal to a and the outside one, to b. The length of the doughtnut's cross-sectinla side parallel to the wire is equal to h. The coil has N turns. The system is located in a unifrom magnetic with permeability μ.

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44. Two thin concentric wires shpaed as circles with radii a and b lie in the same plane. Allowing for $a < < b$, find:

(a) their mutual inductane,

(b) the magnetic flux through the surface enclosed by the outside wire, when the inside wire carries a current I.

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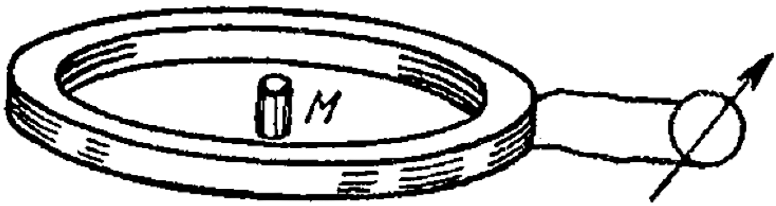
45. A small cylindrical magnet M (Fig) is placed in the centre of a thin coil of radius a consisting of N turns. The coil in connected to a ballistic galvanometer. The active resistance of the whole circuit is equal to R. Find the magnetic moment of the magnet if its removel from the coil results in a charge q flowing through the galvanometer.



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46. Find the appoximate formula expressing the mutual inductance of two thin coaxial loops of the same radius a if their centres are separated by a distance l, with $l > > a$

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47. There are two stationary loops with mutual inductance L_{12}. The current is one of the loops starts to be varied as $I_1 = \alpha t$ where α is a current, t is time. Find the time dependence $I_2(t)$ of the current in the other loop whose inductance is L_2 and resistance R.

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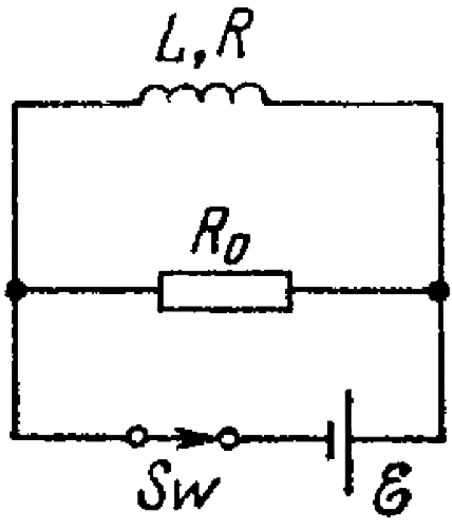
48. A coil of inductance $L = 2.0 \mu H$ and resitance $R = 1.0 \Omega$ is connected to a source of constant $emf E = 3.0 V$. A resistance $R_s = 2.0 \Omega$ is connected in parallel with the coil. Find the amount of heat generated in the coil after the swich Sw is disconnecied. The internal resistance of the source is negligible.



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49. An iron tor suports $N = 500$ turns. Find the magnetic field energy if a current $I = 2.0A$ preoduces a magnetic flux across the tore's cross-section equal to $\Phi = 1.0mWb$.

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50. An iron core shaped as a doughnut with round cross-section of radius $a = 3.0cm$ carreis a winding of $N = 1000$ turns through which a current $I = 1.0A$ flows. The mean radius of the doughnut is $b = 32cm$. Using the polt in Fig. Find the magnetic energy strored up in the core. A field strength H is suposed to be the same throughout the cross-section and equal to its magnitude in the centre of the cross-section.

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51. A thin ring made of magnetic has a mean diameter $d = 30cm$ and supports a winding of $N = 800$ turns.

The cross-sectional area of the ring is equal to $S = 5.0 cm^2$. The ring has a cross-cut of width $b = 2.0 mm$. When the winding carries a certain current, the permeability of the magnectic equals $\mu = 1400$. Neglectign the disipation of magnetic flux at the gap edges, find:

(a) the ratio of magnetic energies in the gap and in the magnetic,

the inductance of the system, do it two ways: using the flux and using the energy of the field.

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52. A long cylinder of radius a carrying a unifrom surface charge rotates about its axis with an anglur velocity ω.

Find the magnetic field energy per unit length of the cylinder if the linear charge density equals λ and $\mu = 1$.

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53. At what magnetic of the electric field srength in vacumm the volume energy density of this field is the same as that of the magnetic field with induction $B = 1.0T$ (also in vacumm).

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54. A thin uniformly charged ring of radius $a = 10cm$ rotates about its axsi with an angluaar velocity

$\omega = 100 rad / s$. Find the ratio of volume energy densities of magnetic and electric fields on the axis of the ring at a point removed from its centre by a distance $l = a$

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55. Using the expression for volume density of magnetic eneregy, demonstare that the amount of work contributed to magnetization of a unit volume of para or diamagentic, is equal to $A = -JB/2$.

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56. Two indentical coils, each of inductance L, are interconnected (a) in series, (b) in parallel. Assuminng the mutual insducane of the coils to be negliglible, find the inductance fo the system in both cases.

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57. Two solenoids of equal length and almost equal cross-sectional area are fully inserted into one another Find their mutual inductances are equal to L_1 and L_2.

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58. Demonstarate that the magnetic energy of interaction of two current-carrying loops located in vacumm can be represented as $W_{ia} = \left(\frac{1}{\mu_0}\right)\int B_1 B_2 dV$, where B_1 and B_2 are the magnetic inductions within a volume element dV, produced indiviually by the currents of the first and the secound loop respectively.

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59. Find the interaction energy of two loops carrying currents I_1 and I_2 if both loops are shaped as circles of radii a and b, with $a < < b$. The loops centres are located at the same point and their planes from an angle θ between them.

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60. The space between two concentric metallic spheres is filled up with a unifrom poorly conducting medium of resistivity ρ and permittivity ε. At what moment $t = 0$ the inside sphere obtains a certain charge. Find:

(a) the relation between the vectros of displacement current density and conduction current density at an arbitarry point of the medium at the same moment of time,

(b) the displacement current across an arbitrary closed surface wholly located in the medium and enclosing the internal sphere, if at the given moment of time the charge of that sphere is equal to q.

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61. A parallel plate capcitor is formed by two discs with a unifrom poorly conducting medium between them. The capacitor was initally charged and then disconnected form a voltage source. Neglecting the edge effects, show that there is no magnetic field between capcitor plates.

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62. A parallel plate air condenser whose each plate has an area $S = 100cm^2$ is connected in series to an ac circuit. Find the electric field strength amplitude in the capacitor if the sinusolidal current amplitude in lead wires is equal to $I_m = 1.0 mA$ and the current frequency equals $\omega = 1.6.\ 10^7 S^{-1}$.

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63. The space between the electrodes of a parallel-plate capacitor is filled with a uniform poorly conducting medium of conductivity σ and permittivity ε. The capacitor plates shaped as round discs are separted by a distance d. Neglecting the edge effects, find the magnetic field strength between the plates at a distance r from their axis if an ac voltage $V = V_m \cos \omega t$ is applied to the capacitor.

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64. A long straight solenoid has n turns per unit length. An alternating current $I = I_m \sin \omega t$ flows throught it. Find the displacement current density as a function of the distnace r from the solenoid equals R.

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65. A point charge q moves with a non-relatives velocity v = const. Find the displacement current density $\dot{d}$ at a point location at a distance r from the charges on a straight line

(a) coinciding with the charge path,

(b) perpendicualr to the path and passing through the charge.

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66. A thin wire ring of radius a carrying a charge q approcahes the observation point P so that its centre moves rectilinearly with a constant velocity v. The plane of the ring remians perpendicular to the motion direction. At what distance x_m from the point P will the ring be located at the moment when the displacement current density at the point P becomes maximum? What is the magnitude of this maximum density ?

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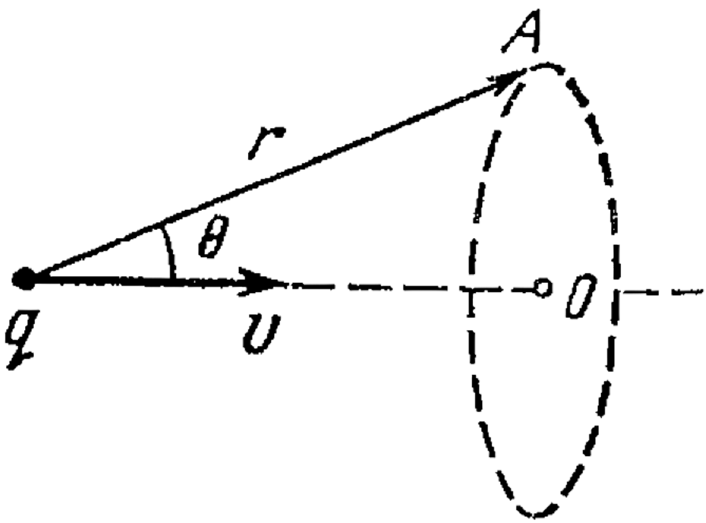
67. A point charge q moves with a non-relativestic velocity v = const. Applying the theorem for the circulation of the vector H around the dotted circle shown in Fig, H at the point A as a function of a radius vector r and velocity v of the charge.



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68. Using Maxwell's equacations. Show that

(a) a time dependent magnetic field cannot exist without an electric field,

(b) a unifrom electric field cannot exist in the presence of a time-dependence magnetic field,

(c) inside an empty cavity a unifrom electric (or magnetic) field can be time-dependent.

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69. Demonstrate that the law of electric charge conservation, i.e., $\nabla . J = - \partial \rho / \partial t$, follows from Maxwell's equactions.

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70. Demonstrate that Maxwell's equations $\nabla \times E = -\partial B / \partial t$ and $\nabla . B = 0$ are compatible, i.e., the first one does not contradict the secound one.

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71. In a certain region of the inertial reference frame there is magnetic field with induction B rotating with angluar velocity ω. Find $\nabla \times E$ in this region as a function of vectors ω and B

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72. In the interial reference frame K there is a unifrom magentic field the induction B. Find the electric feidl strength in the frame K' which moves relative to the frame K with a non-relatistic veclocity v, with $v \perp B$. To solve this problem, consider the forces acting an an imaginary charge in the frame K' is equal to zero.

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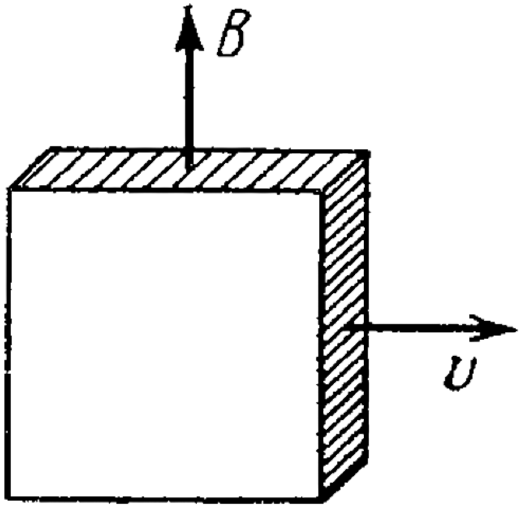
73. A large plate of non-ferromagnetic material moves with a constant velocity $v = 90cm/s$ in a unifrom magnetic field with induction $B = 50mT$ as shown in Fig. Find the surface density of electric charges appearing on the plate as a result of its motion.



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74. A long solid aluminum cylinder of radius $a = 5.0cm$ rotates about its axis in unidrom magnetic field with induction $B = 10mT$. The angluar velocity of rotation equlas $\omega = 45rad/s$ with $\omega \uparrow \uparrow B$ Neglecting the magnetic field of appearing chagres, find their spcae and surfaface densities.

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75. A non-relativistic point charge q moves with a constant velocity v. Using the field transformation formula. Find the magnetic induction B produced by this charge at the point whose position relative to the charge is determind by the radius vector r.

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76. Using Eqs. Demonstrate that if in the intertial reference frame K there is only electric or only magnetic field. In any other interial frame K' both electric and magnetic fiedls will coxist simutaneously, with $E' \perp B'$.

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77. In an interial reference frame K there is only magnetic field with induction $B = b(yl - x) / (x^2 + y^2)$, where b is a constane, i and j are the unit vectors of the x and y axes. Find the elecric field strength E' in the frame K' moving relative to the frame K with a constatn non-relative velocity $v = vk, k$ is the unit vector of the z-axis. The z' axis is assumed to coincule with the z axis. What is the shape of the field E' ?

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78. In an interial reference from K there is only electric field of strength $E = a(xl + y) / x^2 + y^2)$, where a is a constant, i find j are unit vectors of the x and y axes. Find the magtnetic induction B' in the frame K' moving relative to the freame K with a consant non-relativistic velocity $v = vklk$ is the unit vector of the z-axis. The z' axis is assumed to coincule with the z-axis. What is the shape of the magnetic induction B' ?

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79. Demostrate that the transformation forumulas (3.6h) fllow from the formulas $(3.6i)$ at $v < < c$.

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80. In an inertial reference frame K there is only a unifrom electric field $E = 8kV/m$ in strength. Find the modulus and direction

(a) of the vector E' (b) of the vector B' in the interial refrernce frame K' moving with a constant velocity v relative to the frame K at an angle $\alpha = 45^\circ$ to the vector E. The velocity of the frame K' is equla to a $\beta = 0.60$ fraction of the velocity of light.

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81. Solve a problme differing from the forgoing one by a magnetic field with induction $B = 0.8T$ replacing the electric field.

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82. Electromagnetic field has two invariant quatities. Using the transformation formulas $(3.6i)$ demonstrate that these quanties are

(a) EB, (b) $E^2 - c^2B^2$.

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83. In an interial reference frame K there are two uniform mutulaly perpendicular fields, an electric field of strength $E = 40kV/m$ and a magnetic fleid induction $B = 0.20mT$. Find the electric strength E' (or the magnetic induction B') in the reference frame K' where only one field, electric or magnetic, is observed.

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84. A point charge q moves unifromly and rectilnearly with a relativistic with a relativistic velocity of light $(\beta = v/c)$. Find the electric field strength E produced by the charge at the point whose radius vector relatives to the charge is equal to r and forms an angle θ with its velocity vector.

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Motion Of Charged Particle In Magnetic Field

1. At the moment $t = 0$ on electron leaves one plate of a parallel-plate capacitor with a neglible velocity. An accelerting volatage, varrying as $V = at$, where $a = 100V/s$ is applied between the plates is $l = 5.0cm$. What is the velocity of the of the electron at the moment it reaches the opposite plate?

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2. A proton accelarted by a potential differnce V gets into the unifrom electric field of a paralallel-plate capacitor whose plates extended over a length l in the motion direction. The field strenth varies with time as $E = at$, where a is a constant. Assuming the proton to be non-relatistic, find the angle between the motion directions of the proton before and after its fight throgh the capacitor, the proton gets in the field at the moment $t = 0$. The edge effects are to be neglected.

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3. A particle with specific charge q/m moves rectilinerarly due to an electric field $E = E_0 - ax$, where

a is a positive constant, x is the distance from the point where the particle was initially at rest. Find:

(a) the distance covered by the particle till the moment it came to a standstill,

(b) the acceleration of the particle at that moment.

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4. An electron starts moving in a unifrom electric fied of strength $E = 10kV/cm$. How soon after will the kinetic energy of the electron become equal to its rest energy ?

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5. Determine the accelration of a relativistic electron moving along a unifrom electric field of strength E at the moment when its kinetic energy becomes equal to T.

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6. At the moment $t=0$ a relativsitic proton files with a velocity v_0 into the region where there is a unifrom transverse electric field of strength E, with $v_0 \perp E$. Find the time dependence of

(a) the angle θ between the proton's velocity vector v and the initial direction of its motion,

(b) the projection v_x of the vector v on the initial direction of motion.

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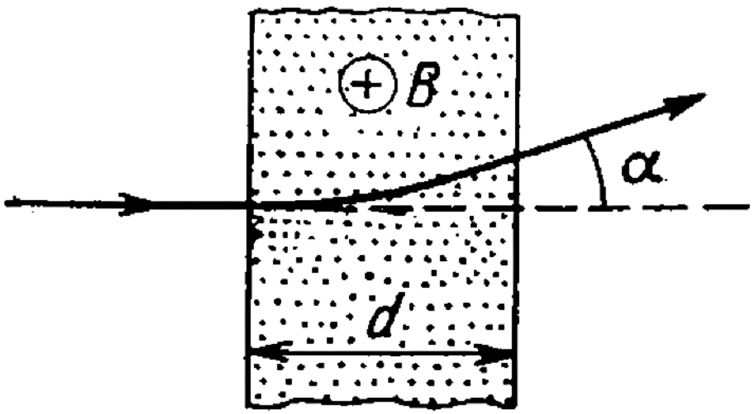
7. A proton accelarted by a potential differnce $V = 500kV$ fieles through a unifrom transverse magnetic filed the induction $B = 0.54T$. The field occupies a region of space $d = 10cm$ in thickness (Fig). Find the angle α through which the proton deviates from the initial direction of its motion.



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8. A charged particle moves along a circle of radius $r = 100mm$ in a unifrom magnetic field with induction $B = 10.0mT$. Find its velocity and perios of revolution if that particle is

(a) a non-relativistic proton,

(b) a relativistic electron.

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9. A relativistic particle with charge q and rest mass m, moves along a circle of readius r in a uniform magnetic field of induction B. Find:

(a) the modulus of the particl's momentum vector,

(b) the kinetic energy of the particle,

(c) the acceleartion of the particle.

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10. Up to what values of kinetic energy does the period of revolution of an electron and a proton in a uniform magnetic field exceed that at non-relativistic velocities by $\eta = 1.0\,\%$

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11. An electron accelerated by a potnetial difference $V = 1.0kV$ moves in a unifrom magentic field at angle

$\alpha = 30^\circ$ to the vector B whose modulus is $B = 29mT$.

Find the pithch of the helical trajectroy of the electron.

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12. A slightly divergent beam of non-relatistic charged particles accelearated by a potential difference V propagates from a point A along the axis of a straight solenoid. The beacm is brought into focus at a distance l from the point A at two successive values of magnetic induction B_1 and B_2. Find the spefic charge q/m of the particles.

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13. A non-relativistic electron originates at a point A lying on the axis of a striaght solenoid and moves with velocity v at an angle α to the axis. The magnetic induction of the field is equal to B. Find the distance r from the axis to the point on screen into which the electron strickes. The screeen into which the electron strikes. The screen is oriented at right angles to the axis and is located at a distance l from the point A.

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14. From the surface of a round wire of radius a carrying a direct current I an electron escapes with a velocity v_0 perpendicular to the surface. Find what will be the maximum distance of the electron from the axis of the wire before it turns back due to the action of the magnetic field generated by the current.

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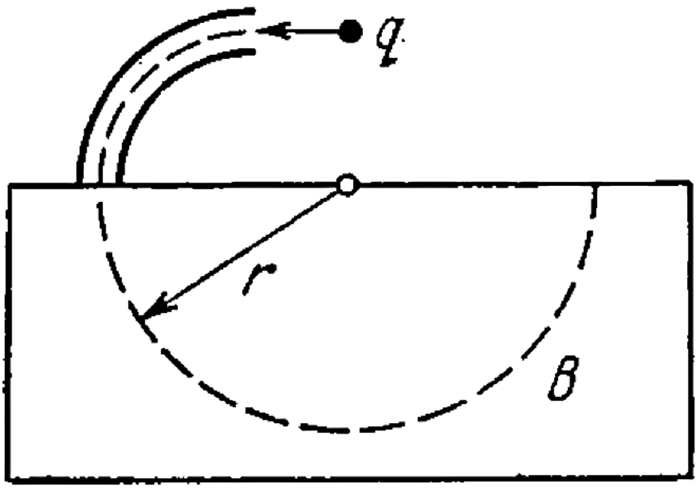
15. A non-relativistic charged particle files through the electric field of a cyclindrical capacitor and gets into a unifrom transverse magnetic field with induction B(fig). In the capacitor the particle moves along the are of a circle, in the magnetic field, along a semi-circle of radius r. The potential differnce applied to the capacitor is equal to V, the radii of the electrodes are equal to a and b, with $a < b$. Find the velocity of the particle and its specific charge q/m.



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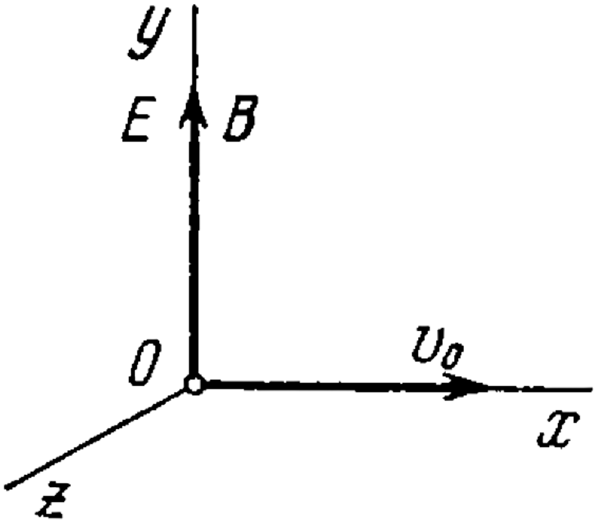
16. Unifrom electric and magnetic fields with strength E and induction B respectively are directed along the y axis (Fig). A particle with specific charge q/m leaves the origin O in the direction of the z axis with an initial non-realtive velocity v_0 find:

(a) the coordinate y_n of the particle when it crossses then y axis for the nth time,

(b) the angle α between the particle's velocity vector and the y axis at that moment.



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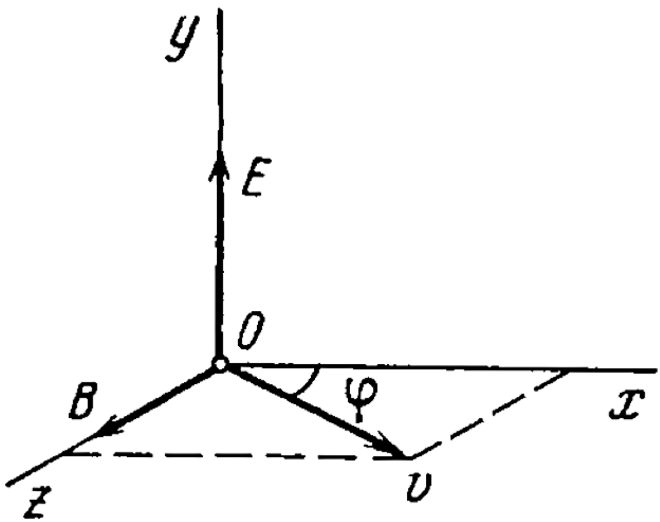
17. A narrow beam of identical ions with specific charge q/m, possessing different velocities, enters the region of space, where there are unifrom parallel electric and marnetic fields the strength E and induction B, at the point O (see Fig). The beam direction coincides with the x axis at the point O. A plane screen oriented at right angles to the x axis is located at a distance l from the point O. Find the equation of the trace that the ions leave on the screen. Demonstrate that at $x < \ < l$ it is the equaction of a parabola.



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18. A non-relativistic protons beam passes without diviation through the region of space where there are unifrom transverse mutually perpendicular electric and magnetic fields with $E = 120kV/m$ and $B = 50mT$. Then the beam strikes a grounded target. Find the force with which the beam acts on the target if the beam current is equal to $I = 0.80mA$.

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19. Non-relativistic protons move rectinearly in the region of space where there are unifrom mutually perpendicular electric and magnetic fields with

$E = 4.0 kV / m$ and $B = 50 mT$. The trajectory of the protons lies in the plates xz (Fig) and forms an angle $\varphi = 30^{\circ}$ with the x axis. Find teh pithc of the helical trajectory along which the protons will move after the electric field is swiched off.

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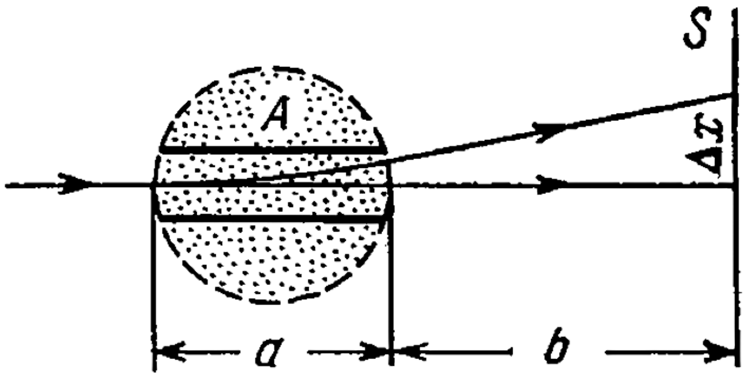
20. A beam of non-relatitivistic chagred particles moves without deviation through the region of space A (fig) where there are transerve mutually perpendicular electric and magnetic fields with streght E and induction B. When the magnetic field is swichted off, the trace of the beam on the screen S shifts by $\Delta \pi$. Knowing the distances a and b, find the spefic charge q/m of the particles.



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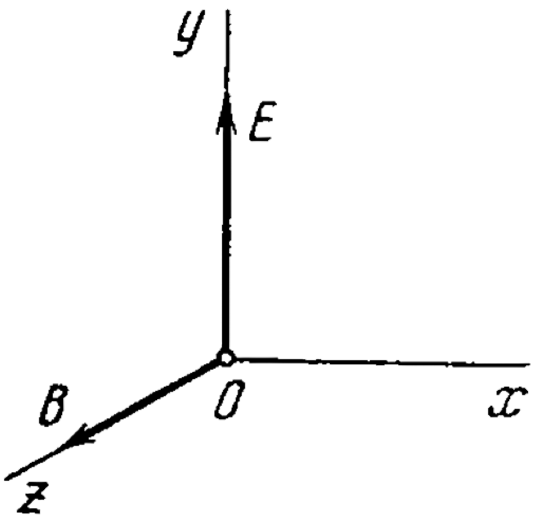
21. A particle with specific charge q/m moves in the region of space where there are unifrom mutually perpendicular electric and magnetic fields with strength E and induction B (fig). At the moment $t=0$ the particle was located at the point O and had zero velocity.

For the non-relativistic case find:

(a) the law of motion $x(f)$ and $y(t)$ of the particle, the shape of the trajectory,

(b) the lenght of the segment of the trajectory between two nearest points at which the velocity of the particle turns into zero,

(c) the mean value of the particle's velocity vector projections on the x axis (the drift velocity).



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22. A sytem consists of a long cylindrical anode of radius a and a coxial cylindrical cylindrical cathode of radius $b(b < a)$. A filament located along the axis of the system carries a heating current I producing a magnetic field in the surrounding space. FInd the least potentilal differnce between the cathode and anode at which the therimal electrons leaving the cathode without intital velcity start reaching the anode.

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23. Magentron is a device consisting of a filament of radius a and coaxial cylindrical anode of radius b which are located in a unifrom magnetic field parallel to the filament. An accelerating potential differnece V is applied between the filament and the anode. Find the value of magnetic induction at which the electrons leaving the filamnent with zero velocity reach the anode.

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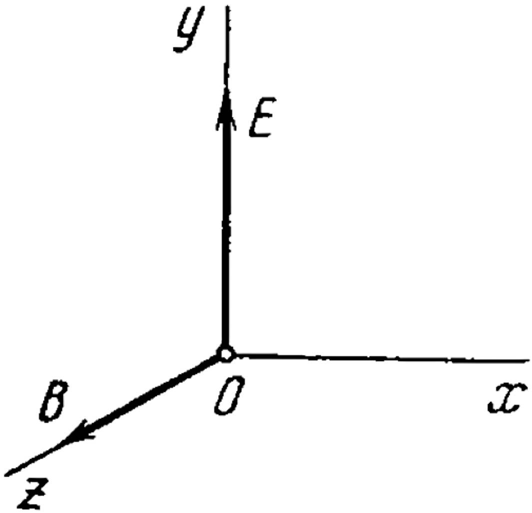
24. A charged particle with specfic charge q/m starts moving in the region of space where there are unifrom mutually perpendicular electric and magnitude fields. The magentic field is constant and has an induction B while the strength of the electric field varies with time as $E = E_m \cos \omega t$, where $\omega = qB/m$. For the non-relativistic case find the law of motion $x(t)$ and $y(t)$ of the particle if at the moment $t = 0$ it was located at the point O (see Fig). What is the appoximate shape of the trajectory of the particle?



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25. The cyclontron's oscillator frequency is equlal to $v = 10 MHz$. Find the effective voltage applied across the does of that cyclotron if the distance between the neighbouring trajecroies of protons is not less than $\Delta r = 1.0 cm$, with the trajectory radius being equal to $r = 0.5 m$.

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26. Protons are accelerated in a cyclotron so that the maximum curvature radius of their trajectory is equal to $r = 50 cm$. Find:

(a) the kinetic energy of the protons when the acceleration is completed if the magnetic induction in the cyclotron is $B = 1.0 T$,

(b) the minimum frequency of the cycloroton's oscillator at which the kinetic energy of the protons amounts to $T = 20 MeV$ by the end of accelearation.

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27. Singly charged ions He^{+} are accelerated in a cyclotron so that their maximum orbital radiys is $r = 60cm$. The frequency of a cyclotron's oscillator is equal to $v = 10.0MHz$, the effective accelearating volatage across the deos is $V = 50kV$. Neglecting the gap between the does, find:

(a) the total time of acceleration of the ion,

(b) the appoximate distance covered by the ion in the process of its acceleration.

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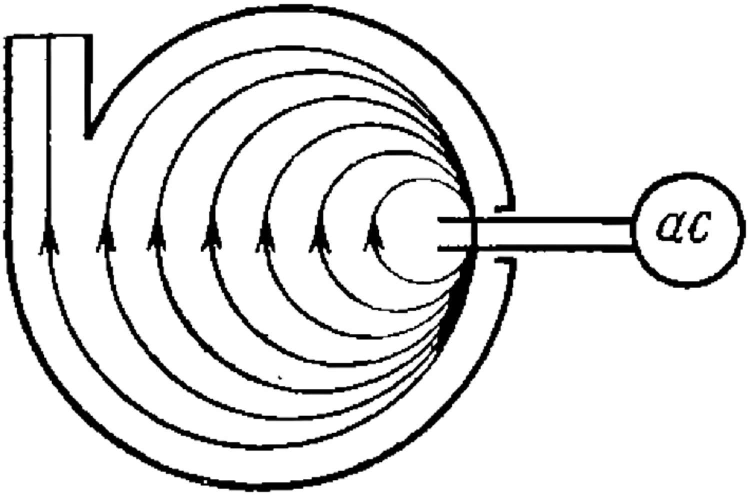
28. since the period fo revolution of electrons in a unifrom magnetic field rapidly increases with the growth of energy, a cyclotron in unsuitable for their accelearation. This drawback is rectified in a microton (Fig) in which a change ΔT in the period of revolution of an electron is made multipile with the period of acclerating field T_0. How many times has an electron to cross the accerating gap of a microtron to acquire an energy $W = 4.6 MeV$ if $\Delta T = T_0$ the magnetic induction is equal to $B = 107 mT$, and the frequency of accelerating field to $v = 3000 MHz$?



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29. The ill effects associated with the variatiion of the period of revolution of the particle in a cyclotron due to the increase of its energy are eleminated by slow monitoring (modulating) the frequency of accelerting field. According to what law $\omega(t)$ should this frequencecy by mointored if the masgnetic induction is equal to B and the particle acquires an energy ΔW per revolution ? The charge of the particle is q and its mass is m.

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30. A particle with specific charge q/m is located inside a round solenoid at a distance r from its axis. With the current swichted into the winding, the magnetic induction of the field generated by the solenoid amounts to B. Find the velocity of the particle and the curvature radius of its trajectory,n assuming that during the increase of current flowing in the solenoid the particle shifts by a negligible distance.

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31. In a betatron the magnetic flux across an equilibrium orbit of radius $r = 25cm$ grows during the acceleration time at paractically constant rate $\Phi = 5.0Wb/s$. In the process, the electrons acquire an energy $W = 25MeV$. Find the number of revolutions made by the electron during the acedeleration time and the corresponding distance covered by it.

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32. Demonstarate that electrons move in a betatron along a round orbit of constant radius provided the magnetic induction on the orbit of constant radius provided the magnetic induction on the orbit is equal to half the mean value of that indide the orbit (the betatron condition).

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33. Using the betatron condition, find the radius of a round orbit of an electron if the magnetic induction is known as a function of distance r from the axis of the field. Examine this problem for the specfic case $B = B_0 - \alpha r^2$, where B_0 and a are positive constants.

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34. Using the betatron condition, demonstarate that the strength of the eddy-current field has the extremum magnitude on an equiolibrium orbit.

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35. In a betatron the magnetic flux across an equilibrium orbit of radius $r = 20cm$ varies during a time interval $\Delta t = 1.0ms$ at practically constant rate from zero to $B = 0.40T$. Find the energy acquired by the electron per revolution.

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36. The magnetic induction in betatron on an equlibrium orbit of radius r varies during the acceleration time at paractically constant rate from zero to B. Assuming the initial velocity of the electron to be equal to zero, find:

(a) the energy acquired by the electron during the acceleration time,

(b) the corresponding distance covered by the electron if the accelearation time is equal to Δt.

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