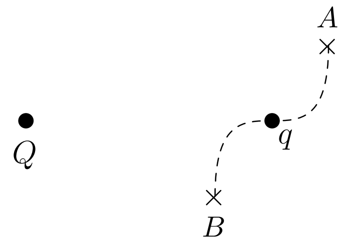
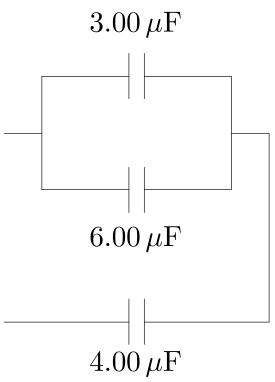
1. The point charge Q below is stationary. The electric potential energy U of the system is $-37\,\mathrm{nJ}$ if point charge q is at A. As q moves from A to B, the work done on q (by the electric field of Q) is $+23\,\mathrm{nJ}$. What is U when q is at B? *[2]*



$$\Delta U = U_B - U_A = -(\text{Work done by } \vec{E}_Q) = -23\,\mathrm{nJ}$$

$$U_B = U_A + \Delta U = (-37\,\mathrm{nJ}) + (-23\,\mathrm{nJ}) = -60\,\mathrm{nJ}$$

2. When the capacitors below are fully charged, the $6.00\,\mu\mathrm{F}$-capacitor has a charge of $36.0\,\mu\mathrm{C}$. What is the charge of $4.00\,\mu\mathrm{F}$-capacitor? *[2]*



$$Q_{3.00\,\mu\mathrm{F}} = \frac{3.00\,\mu\mathrm{F}}{6.00\,\mu\mathrm{F}} Q_{6.00\,\mu\mathrm{F}} = 18.0\,\mu\mathrm{C}$$

$$Q_{4.00\,\mu\mathrm{F}} = Q_{3.00\,\mu\mathrm{F}} + Q_{6.00\,\mu\mathrm{F}} = (18.0\,\mu\mathrm{C}) + (36.0\,\mu\mathrm{C}) = 54.0\,\mu\mathrm{C}$$

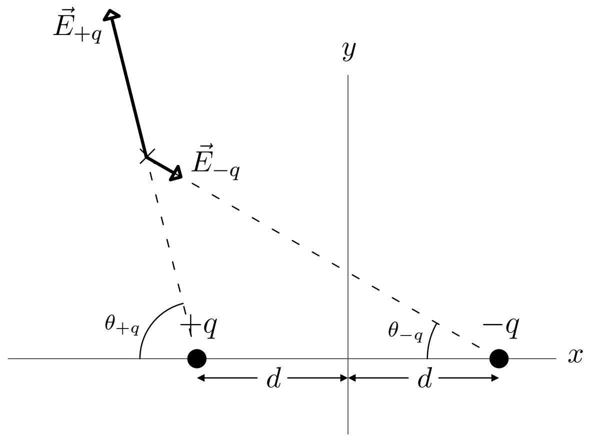
3. In the diagram below, $q = 0.10\,\text{nC}$ and $d = 3.0\,\text{cm}$. Find the *x-component* E_x of the *net* electric field at the point with coordinates $(-4.0\,\text{cm}, +4.0\,\text{cm})$. *[4]*

$$r_{+q} = \sqrt{17.0}\,\text{cm}$$

$$r_{-q} = \sqrt{65.0}\,\text{cm}$$

$$\cos\theta_{+q} = \frac{1.0}{\sqrt{17.0}}$$

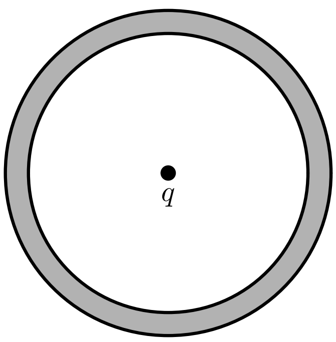
$$\cos\theta_{-q} = \frac{7.0}{\sqrt{65.0}}$$



$$E_x = -|\vec{E}_{+q}|\cos\theta_{+q} + |\vec{E}_{-q}|\cos\theta_{-q}$$

$$= -8.2\,\text{N/C}$$

4. A point charge $q = 2.40\,\text{nC}$ is at the center of a spherical conducting shell (inner radius of $1.00\,\text{cm}$, outer radius of $1.20\,\text{cm}$). The electric field $4.00\,\text{cm}$ from the *center* of the shell has a magnitude of $5.00\,\text{kV/m}$ and points radially inward. Find the surface charge density on the *outer* surface of the shell. (Justify your choice of sign.) *[3]*

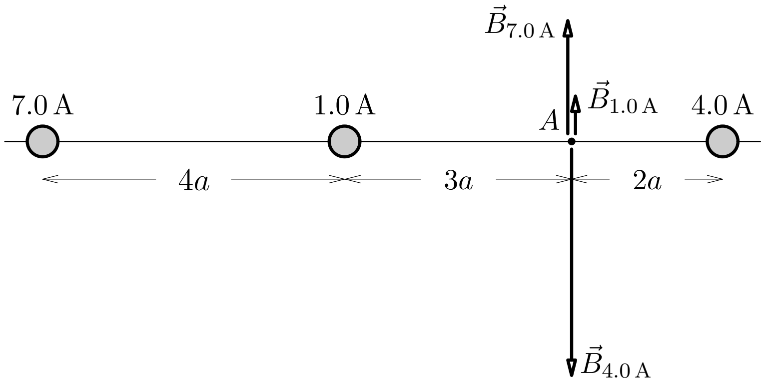


$$|Q_{\text{outside}}| = 4\pi\epsilon_0(4.00\,\text{cm})^2|\vec{E}| = 8.89\times10^{-10}\,\text{C}$$

$$|\sigma| = \frac{|Q_{\text{outside}}|}{4\pi(1.20\,\text{cm})^2} = 4.91\times10^{-7}\,\text{C/m}^2$$

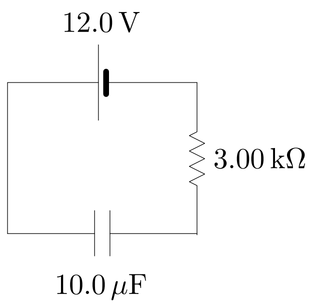
$$\sigma < 0 : \ \vec{E}\ \text{inward}$$

5. Three long straight parallel wires (seen end-on below) carry currents *out* of the page; $a = 2.50\,\text{cm}$. Find the magnitude of the *net* magnetic field $\vec{B}$ at A. *[3]*



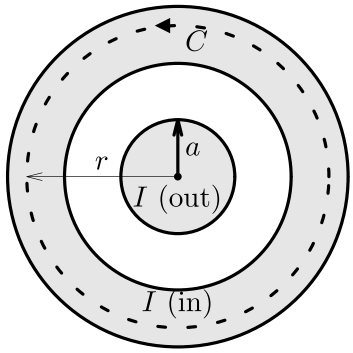
$$
\begin{aligned}
|\vec{B}| &= |\vec{B}_{4.0\,\text{A}}| - |\vec{B}_{7.0\,\text{A}}| - |\vec{B}_{1.0\,\text{A}}| \\
&= \frac{\mu_0}{2\pi}\left[\frac{4.0}{2a} - \frac{7.0}{7a} - \frac{1.0}{3a}\right] \\
&= 5.3 \times 10^{-6}\,\text{T}
\end{aligned}
$$

6. Find the *rate* at which energy is being gained by the capacitor below when the plate charge is $Q = 30.0\,\mu\text{C}$. *[3]*



$$
\begin{aligned}
I &= \left(\mathcal{E} - \frac{Q}{C}\right)\Big/ R = 3.0 \times 10^{-3}\,\text{mA} \\
\frac{dU}{dt} &= \mathcal{E} I - I^2 R \\
&= 9.0 \times 10^{-3}\,\text{W}
\end{aligned}
$$

7. In the coaxial cable shown in cross-section below, the central cylindrical conductor (radius a) and the outer coaxial conducting tube (inner radius b, outer radius c) carry equal currents $I = 12.0\,\text{A}$ in opposite directions. The current densities are uniform; $a = 1.5\,\text{mm}$, $b = 3.0\,\text{mm}$ and $c = 4.5\,\text{mm}$. Find the magnitude of the magnetic field 4.0 mm from the central axis. *[4]*



Using amperian loop C,

$$|\vec{B}| = \frac{\mu_0}{2\pi r}\Big[I - (I_{\text{tube}}\text{ inside } C)\Big]$$

$$J_{\text{tube}} = \frac{I}{\pi(c^2 - b^2)} = 3.4 \times 10^5\,\text{A/m}^2$$

$$I_{\text{tube}}\text{ inside } C = J_{\text{tube}}\,\pi(r^2 - b^2) = 7.5\,\text{A}$$

$$|\vec{B}| = 2.3 \times 10^{-4}\,\text{T}$$

8. A very long insulating cylinder (of radius 4.00 cm) has a uniform charge on its outer surface; the surface charge density is $-35.0\,\mu\text{C/m}^2$. Find the potential difference $V_A - V_B$, where A is a point on the outer surface and B is a point 12.0 cm from the central axis. *[4]*

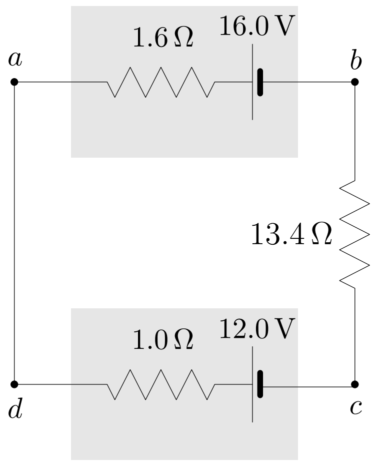
$$V_A - V_B = +\int_{4\,\text{cm}}^{12\,\text{cm}} \frac{2k\lambda}{r}dr$$

$$= 2k\lambda \ln 3$$

$$\lambda = 2\pi(4.00\,\text{cm})\sigma = -8.80 \times 10^{-6}\,\text{C/m}$$

$$V_A - V_B = -1.7 \times 10^5\,\text{V}$$

9. Find the voltage $V_a - V_c$ in the circuit below. *[3]*

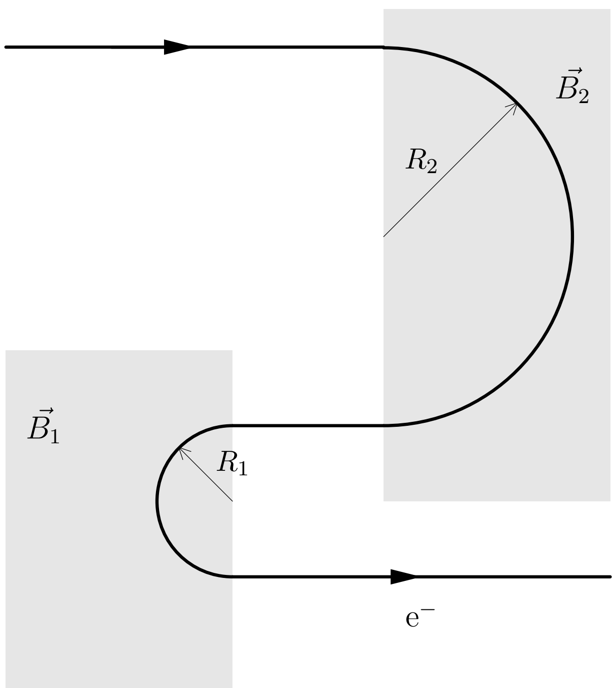


Loop rule (I counter-clockwise):

$$16.0\,\mathrm{V} - I(1.6\,\Omega) - I(1.0\,\Omega) - 12.0\,\mathrm{V} - I(13.4\,\Omega) = 0 \quad \Longrightarrow \quad I = 0.25\,\mathrm{A}$$

$$\begin{aligned} V_a - V_c &= 12.0\,\mathrm{V} + I(1.0\,\Omega) \\ &= 12.25\,\mathrm{V} \end{aligned}$$

10. The grey rectangles below are regions of *uniform* magnetic field $\vec{B}_1$ and $\vec{B}_2$ *perpendicular* to the plane of the page; $|\vec{B}_2| = 1.5\,\mathrm{T}$. The path of an electron of constant speed v is shown; $R_2 = 2.5R_1$. Find the direction and magnitude of $\vec{B}_1$. *[3]*



$$\frac{R_2}{R_1} = \frac{|\vec{B}_1|}{|\vec{B}_2|}$$

$$|\vec{B}_1| = \frac{R_2}{R_1}|\vec{B}_2| = 3.75\,\mathrm{T}$$

$\vec{B}_1$ out of the page

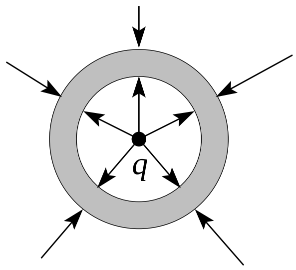
1. A positive point charge q is placed at the centre of a conducting shperical shell. The electric field lines are as shown in the figure. If Q is the net charge on the shell, then

   (a) $\boxed{Q < 0, \text{ with } |Q| > q}$.

   (b) $Q < 0$, with $|Q| < q$.

   (c) $Q < 0$, with $|Q| = q$.

   (d) $Q = 0$.



2. An electron with initial velocity along the positive x-direction passes straight through a region of uniform electric and magnetic fields. The electric field is in the negative y-direction. So, the magnetic field must be such that,

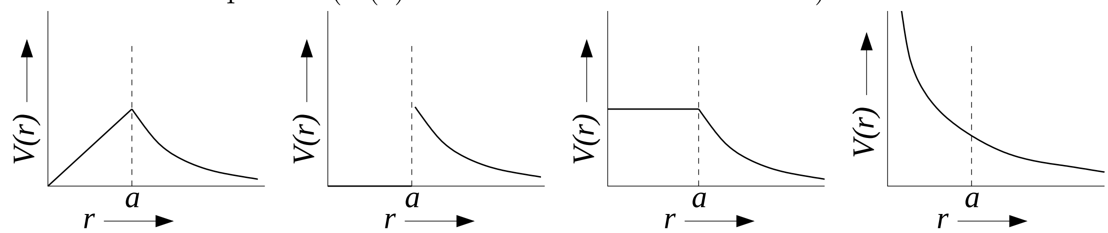
   (a) $B_y = 0$, and $B_z > 0$.

   (b) $\boxed{B_y = 0, \text{ and } B_z < 0}$.

   (c) $B_y > 0$, and $B_z < 0$.

   (d) $B_y < 0$, and $B_z = 0$.

3. A conducting sphere of radius a has a positive charge. Which one of the following figures best represents the variation of electric potential $V(r)$ as a function of distance r from the centre of the sphere? ($V(r)$ is taken to be zero at $r \to \infty$).



(a) (b) (c) (d)

$\boxed{\text{Ans: c}}$

4. Two point charges, q_1 and q_2, initially a distance d apart are released from rest. They will move in such a way that their potential energy

   (a) always increases as they move.

   (b) $\boxed{\text{always decreases as they move}}$.

   (c) increases if they have same sign and decreases if they have opposite signs.

   (d) decreases if they have same sign and increases if they have opposite signs.

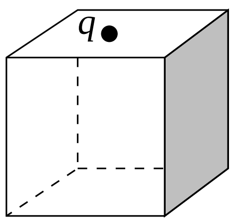
5. A point charge is placed at the centre of the top face of the cubical surface shown in the figure. If Φ_0 is the electric flux through the bottom face of the cube, the electric flux through the shaded face of the cube is

   (a) Φ_0.

   (b) $\frac{q}{\varepsilon_0} - \Phi_0$.

   (c) $\frac{1}{5}\left(\frac{q}{2\varepsilon_0} - \Phi_0\right)$.

   (d) $\boxed{\frac{1}{4}\left(\frac{q}{2\varepsilon_0} - \Phi_0\right)}$.



6. A parallel-plate capacitor is connected to a battery. Let E and Q be the magnitudes of the electric field between the plates and the plate-charge respectively. If the plate-separation is increased while it is still connected to a battery,

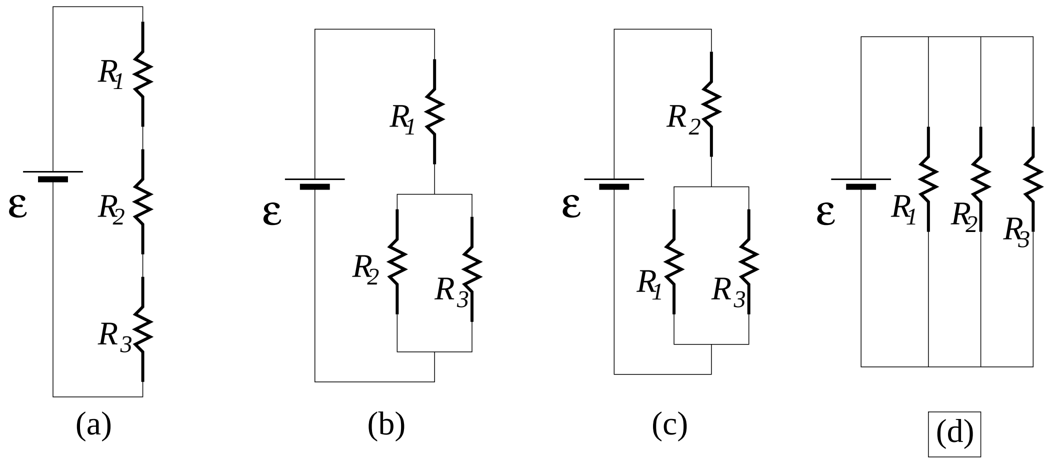
   (a) E will increase, but Q will decrease.

   (b) E will decrease, but Q will increase.

   (c) both E and Q will decrease.

   (d) E will remain the same but Q will decrease.

7. In the four different circuits shown, all the resistors are identical as well as the sources of emf. In which circuit is the power dissipated by the resistor R_1 greatest?



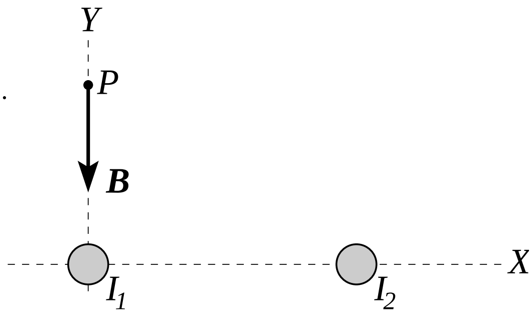
8. In the figure shown, the two long parallel wires carrying currents are perpendicular to the plane of paper. The net magnetic field at the point P is in the negative y-direction. Then

   (a) I_1 is out of the plane and I_2 is into the plane.

   (b) I_1 is out of the plane and I_2 is out of the plane.

   (c) I_1 is into the plane and I_2 is out of the plane.

   (d) I_1 is into the plane and I_2 is into the plane.



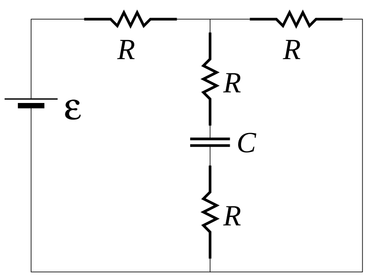
9. In the circuit shown, all the resistors are identical. What is the charge on the capacitor when the steady state has reached?

   (a) $Q = C\mathcal{E}$.

   (b) $Q = C\mathcal{E}/2$.

   (c) $Q = C\mathcal{E}/3$.

   (d) $Q = C\mathcal{E}/4$.



10. Two long identical solenoids have lengths that are very large compared to their diameters. They carry equal currents in the same direction. Let B be the magnitude of the magnetic field inside each of the solenoids. If they are joined together at one end, the magnitude of the magnetic field inside them will be

    (a) $2B$.

    (b) B.

    (c) $B/2$.

    (d) zero.