Problems — Please show *all* working; give only *one* solution

1.

A proton moves in a region of uniform electric and magnetic fields: $\vec{E} = (75.0\,\mathrm{N/C})\hat{\imath}$ and $\vec{B} = (0.200\,\mathrm{T})\hat{\imath} + (0.300\,\mathrm{T})\hat{\jmath} + (0.400\,\mathrm{T})\hat{k}$. Find the components of the proton's acceleration $\vec{a}$ when its velocity $\vec{v} = (0.200\,\mathrm{km/s})\,\hat{\imath}$. *[3]*

Using $\vec{v}\times\vec{B} = v\hat{\imath}\times\vec{B} == +vB_y\,\hat{k} - vB_z\hat{\jmath}$ and $\vec{F} = (+e)(\vec{E} + \vec{v}\times\vec{B})$,

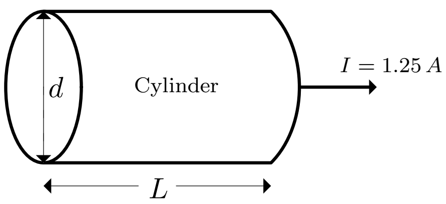
$$a_x = \frac{e}{m_\mathrm{p}}\,|\vec{E}| = 7.19\times 10^9\ \mathrm{m/s},$$

$$a_y = \frac{e}{m_\mathrm{p}}(-vB_z) = -7.66\times 10^9\ \mathrm{m/s},$$

$$a_z = \frac{e}{m_\mathrm{p}}vB_y = 5.75\times 10^9\ \mathrm{m/s}.$$

2.

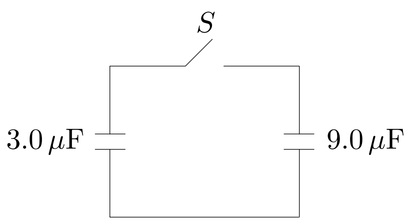
The cylindrical conductor below (of length $L = 10.0\,\mathrm{cm}$ and diameter $d = 1.50\,\mathrm{mm}$) has a resistivity of $2.82\times 10^{-8}\,\Omega\cdot\mathrm{m}$. Find the magnitude $|\vec{E}|$ of the uniform electric field responsible for the current $I = 1.25\,\mathrm{A}$ through the conductor. *[2]*



$$|\vec{E}| = \rho\,\frac{I}{\pi d^2/4} = 1.99\times 10^{-2}\ \mathrm{V/m}$$

3.

Before the switch S below is closed, the charge on the $3.0\,\mu\mathrm{F}$ capacitor is $0.36\,\mathrm{mC}$ and the $9.0\,\mu\mathrm{F}$ capacitor is uncharged. Find the energy U stored in the $3.0\,\mu\mathrm{F}$ capacitor long after the switch is closed. *[2]*

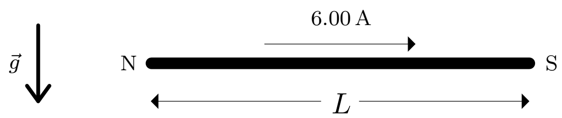


$$V_\mathrm{eq} = \frac{Q_\mathrm{eq}}{C_\mathrm{eq}} = \frac{360\,\mu\mathrm{C}}{12.0\,\mu\mathrm{F}} = 30.0\,\mathrm{V} \qquad \text{[Capacitors in parallel]}$$

$$U_{3\mu\mathrm{F}} = \tfrac{1}{2}CV_\mathrm{eq}^2 = \tfrac{1}{2}(3.0\,\mu\mathrm{F})V_\mathrm{eq}^2 = 1.35\times 10^{-3}\ \mathrm{J}$$

4.

A horizontal straight wire (mass $m = 20.0\,\mathrm{g}$, length $L = 2.50\,\mathrm{m}$) carries a $6.00\,\mathrm{A}$ current from north (N) to south (S). Find the magnitude and direction of the smallest uniform magnetic field $\vec{B}$ which will support the wire against gravity. *[3]*

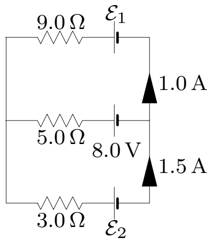


Direction of $\vec{B}$: To the east (or into the page)

$$|\vec{B}| = \frac{mg}{IL} = 1.3\times 10^{-2}\ \mathrm{T}$$

5.

Find the emf $\mathcal{E}_2$ in the circuit below. *[3]*



$I_{5.0\,\Omega} = 0.5\,\text{A}$ to the left

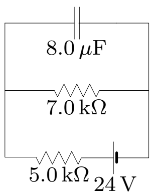
Kirchhoff's loop rule for the lower loop:

$-(1.5\,\text{A})(3.0\,\Omega) - \mathcal{E}_2 + 8.0\,\text{V} - (0.5\,\text{A})(5.0\,\Omega) = 0$

$\Longrightarrow \quad \mathcal{E}_2 = 1.0\,\text{V}$

6.

Find the plate charge on the $8.0\,\mu$F capacitor below when it is *fully* charged. *[2]*



$$I_{7.0\text{k}\Omega} = I_{5.0\text{k}\Omega} = \frac{24\,\text{V}}{5.0\,\text{k}\Omega + 7.0\,\text{k}\Omega} = 2.0 \times 10^{-3}\,\text{A}$$

$Q = C\,V_{7.0\text{k}\Omega} = 1.1 \times 10^{-4}\,\text{C}$

Questions   Please choose the *best* answer

1.

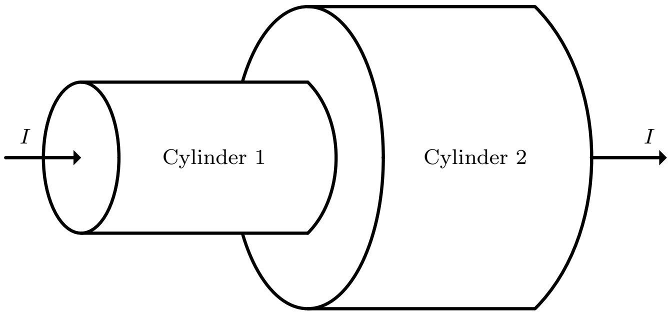
Below, current I flows through cylinders 1 and 2, which are made of the same conducting material but have different radii: $r_2 = 2r_1$. If the drift speed in cylinder 1 is v_d, then the drift speed in cylinder 2 is:

a) v_d

b) $v_d/2$

c) $v_d/3$

d) $v_d/4$



2.

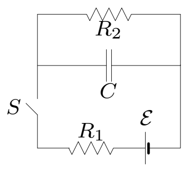
When the switch S below is closed, the *initial* current in resistor R_2 is:

a) 0

b) $\mathcal{E}/R_1$

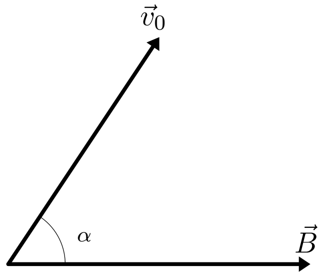
c) $\mathcal{E}/R_2$

d) $\mathcal{E}/(R_1 + R_2)$



3.

A point charge enters a uniform magnetic field $\vec{B}$ with velocity $\vec{v}_0$ at an angle α to $\vec{B}$. The ***pitch*** of the helix on which the charge then moves is proportional to:



a) v_0

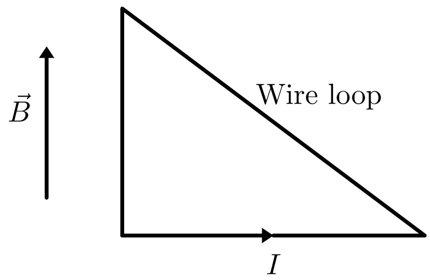
b) $v_0 \sin\alpha$

c) $v_0 \cos\alpha$

d) $v_0 \tan\alpha$

4.

The closed wire loop below (carrying current I) is in a uniform magnetic field $\vec{B}$. With the direction of $\vec{B}$ as shown, the net force on the loop is:



a) into the page

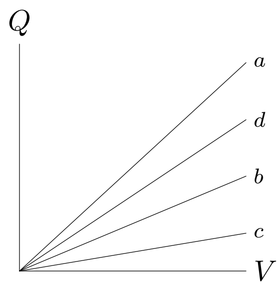
b) out of the page

c) to the right

d) zero

5.

Charge Q versus voltage V is plotted below for capacitors a, b, c and d. The correct ranking of capacitances is:



a) $C_a > C_b > C_c > C_d$

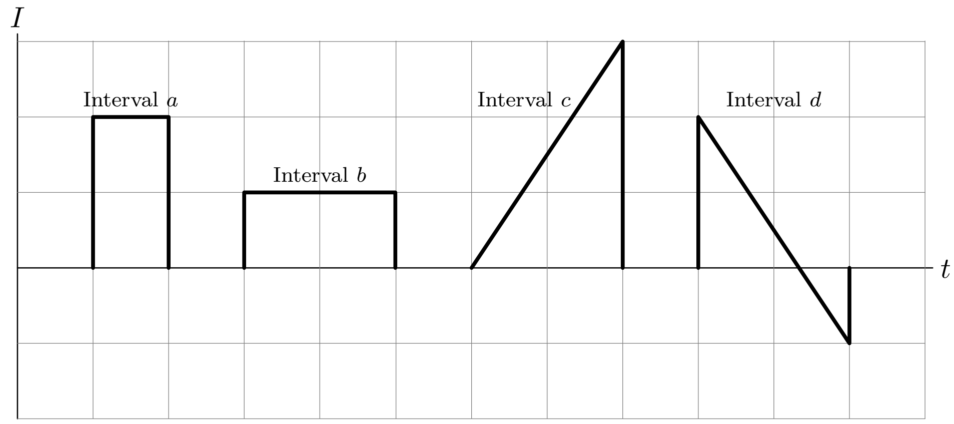
b) $C_b > C_c > C_d > C_a$

c) $C_a > C_d > C_b > C_c$

d) $C_c > C_b > C_d > C_a$

6.

Below, the current I through a surface S_c is plotted versus time t. The time interval in which the net charge crossing S_c is largest is:



a) a

b) b

c) c

d) d