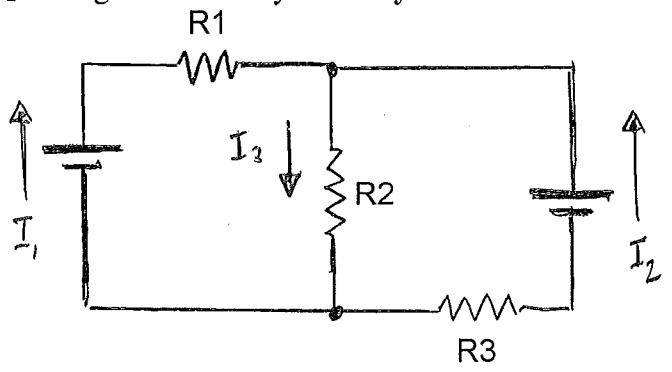
Physics 161 Midterm Exam III – Circuits and Magnetic Fields. 100 pts total.

NAME SOLUTIONS

Problem 1.

a) [15] In the circuit shown, each battery is 30V. Each resistor is 10 ohms. What are the currents I_1 and I_2 through each battery? **Show your work.**



$I_1 + I_2 = I_3$

so

$\mathcal{E} - I_1 R - (I_1 + I_2) R = 0$

$\mathcal{E} - (I_1 + I_2) R - I_2 R = 0$

subtract $\rightarrow$ $I_1 = I_2$

so

$\mathcal{E} - 3IR = 0$

$I = 1$ Ampere $= I_1 = I_2$

b) [10] How much power does each battery add to the circuit? **Show your work.**

$P = IV = I\mathcal{E} = 30\text{W}.$

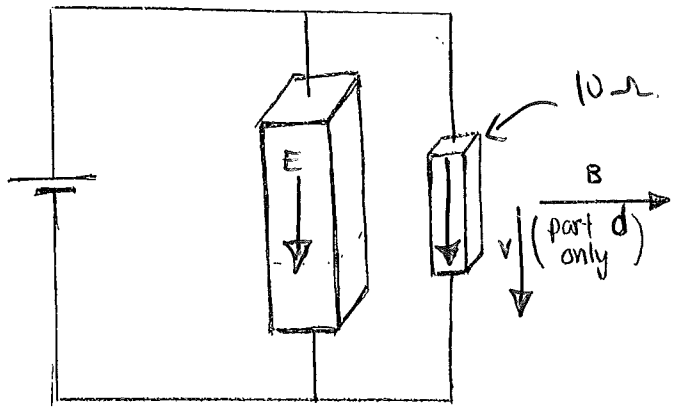
c) [5] How much power is dissipated in each resistor? **Show your work.**

R1: $P = I^2 R = 1^2 \cdot 10 = 10\text{W}$

R2: $P = I^2 R = 2^2 \cdot 10 = 40\text{W}$

R3: 10W

Problem 2. Two resistors are each made from the same resistive material, in the form of rectangular parallelepipeds as shown in the figure. The resistor on the left is twice as large in every dimension as the resistor on the right. The resistor on the right is 10 ohms.



a) [10] What is the resistance of the resistor on the left? **Show your work.**

$R = \rho\frac{L}{A}$ $\quad L' = 2L$ $\quad A' = 4A$ $\quad$ so $\quad R' = \rho\frac{2L}{4A} = \frac{1}{2}\rho\frac{L}{A} = \frac{1}{2}R = 5\Omega$

b) [10] The emf of the battery is 10V; the resistor on the right is 1 cm long and 2 mm on each short side. What is the electric field direction and magnitude in each resistor, in V/m? **Show your work.**

$E_L = \frac{10V}{2cm} = 500\frac{V}{m}$ down.

$E_R = \frac{10V}{1cm} = 1000\frac{V}{m}$ down.

c) [10] What is the current through the battery? **Show your work.**

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10} + \frac{1}{5} = \frac{3}{10}$ $\quad R_{eq} = \frac{10}{3}$ $\quad V = IR$ so

$I = 3A.$

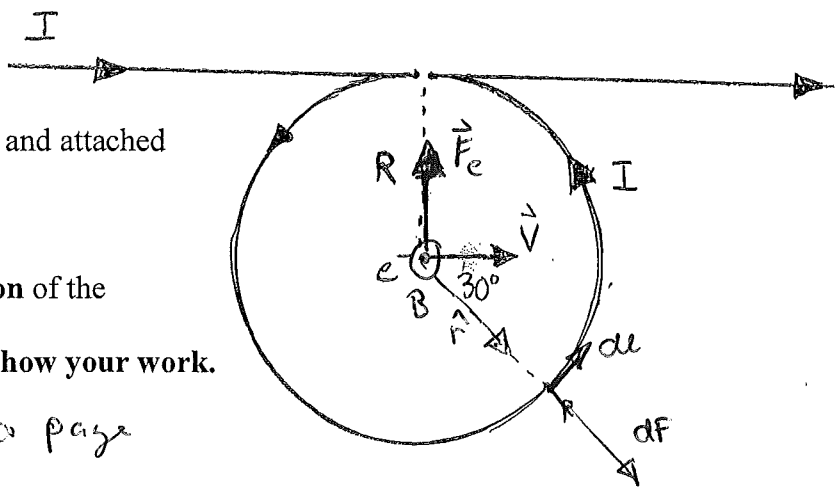
d) [5] Now, a strong magnetic field is applied in the direction shown. In the exact middle of the resistor, it is found that there is a small potential difference between two faces (the Hall voltage). If the current carriers in the resistors are positively charged, which face is positive and which negative?

$\vec{v}\times\vec{B}$ out of page. Front face +

For which resistor is the Hall voltage larger, or is the Hall voltage the same? **Show your work / use back.**

$qE_H = qv_d B$ Drift velocity $\propto E$ so Hall FIELD is 2x larger in 10Ω R.

BUT Hall Voltage $= \int E\cdot dl = E\cdot l$ so Hall Voltage is SAME.



Problem 3. A very long straight wire is cut and attached to a circular wire loop as shown.
A current I runs through the wire and loop.

a) [10] What is the magnitude **and direction** of the magnetic field in the center of the loop?
Give your answer in terms of I, R, π, μ_0. **Show your work.**

From wire: $B = \frac{\mu_0 I}{2\pi R}$ into page

From loop: $B = \frac{\mu_0 I}{2R}$ out of page $(a=R, z=0)$

total $B = \frac{\mu_0 I}{2R}\left(1 - \frac{1}{\pi}\right)$ out of page

b) [10] An electron at the center of loop has velocity v as shown, parallel to the wire. What is the magnitude **and direction** of the magnetic force on the electron? Give your answer in terms of I, R, π, μ_0, v, and the electron charge –e. **Show your work.**

$\vec{F} = q\vec{v}\times\vec{B}$ $\quad F = qvB = -evB$

$|F| = \frac{ev\mu_0 I}{2R}\left(1 - \frac{1}{\pi}\right)$ upward

c) [10] At the instant the electron is moving through the center of the loop, what is the magnitude **and direction** of the magnetic field **caused by the electron** at point p? Give your answer in terms of R, π, μ_0, v and the electron charge –e. **Show your work.**

$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{R^2}$ → out of page $\quad |\vec{v}\times\hat{r}| = v\sin 30°$

$|B| = \frac{\mu_0 e}{4\pi}\frac{v}{R^2}\cdot\frac{1}{2}$.

d) [5] Does the electron exert any magnetic force on a small part dl of the wire at p? If so, in what direction?

yes. $d\vec{l}\times\vec{B}$ is away from the center of the loop.