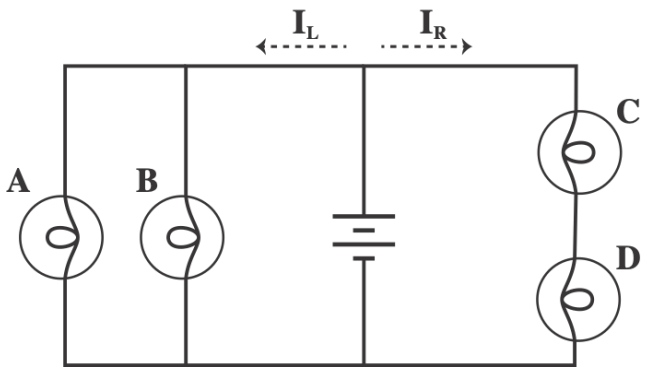
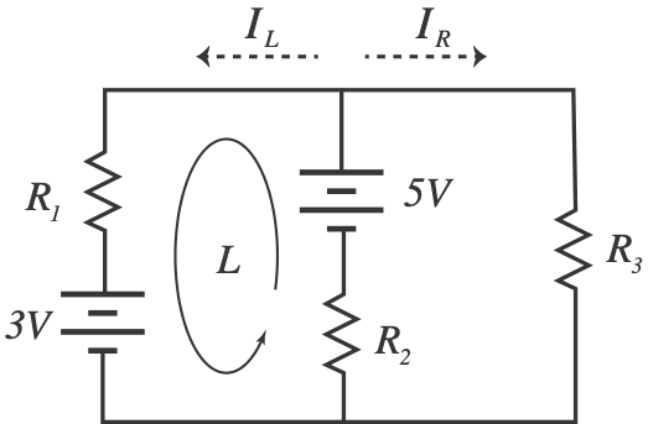
I. **Multiple Choice** [60 pts] Bubble in the most correct answer on your bubble sheet and circle on this page.

1. [5 pts] In the circuit at right the current from the battery splits and travels into the left and right arms of the circuit (I_L & I_R). Describe the currents and relative brightness (power) of the four identical lightbulbs in this circuit.



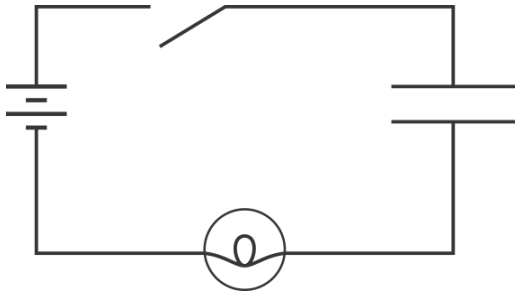
A. The current in the left branch is equal to the current in the right branch, so A & B are the same brightness and twice as bright as C & D.
B. The current in the left branch is twice the current in the right branch, so all the bulbs are the same brightness.
C. The current in the left branch is 4 times the current in the right branch. A & B are the same brightness and 4 times as bright as C & D.
D. There is not enough information given to determine the currents and relative brightnesses.

2. [5 pts] The circuit below is being analyzed using Kirchhoff's Loop rule. For the loop *L* indicated, what is the correct equation?

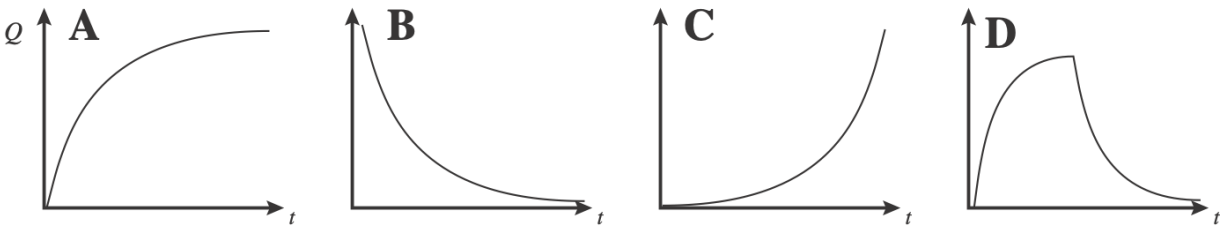


A. $5V - I_L R_1 - 3V - (I_L + I_R)R_2 = 0$
B. $5V - I_L R_1 + 3V - I_L R_2 = 0$
C. $5V - I_L R_1 + 3V - I_R R_2 = 0$
D. $5V - I_L R_1 - 3V - I_R(R_2 + R_3) = 0$

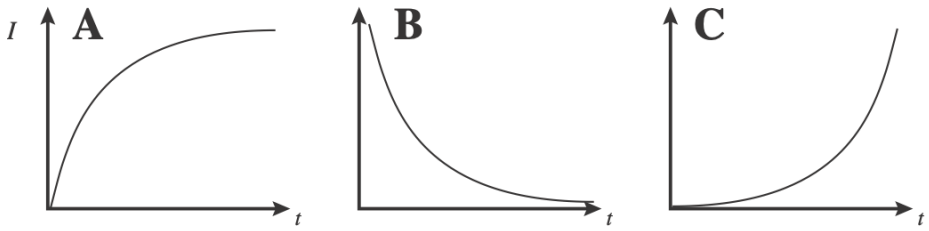
Both problems 3 & 4 correspond to the following circuit with a battery, a capacitor, and light bulb. Initially the switch is open and the capacitor is uncharged.



3. [5 pts] After the switch is closed, which of the following graphs depicts the charge on the capacitor Q vs. time? A

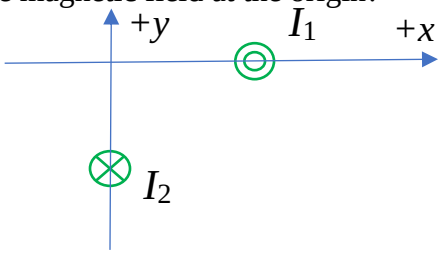


4. [5 pts] After the switch is closed, which of the following graphs depicts the current through the light bulb vs. time? B



D) zero current

5. [5 pts] Two current carrying wires of I_1=1.5 A and I_2= 2.0 are situated as shown. I_1 is at x= 3.0 m and I_2 is at y= -2.25 m. What is the magnitude of the magnetic field at the origin?



A. 1.1 x10^{-7} T
B. 1.5 x10^{-7} T
C. 2.0 x10^{-7} T
D. 2.2 x10^{-6} T
E. None of these are correct

6. [5 pts] What is the direction of the magnetic field at point P due to the current I which is out of the page?

A.
B.
C. 
D. 

7. [5 pts] A 3.0 A current carrying wire is in a magnetic field of 2.0 T. The current is perpendicular to the magnetic field. If the force on the wire is 12.0 N, what is the length of the wire?
A. 2.0 cm
B. 4.0 cm
C. 1.5 m
D. 2.0 m
E. not enough information

8. [5 pts] A system loses 300 J of heat and then expands, doing 500 J of work on the surroundings. What is the total change in thermal (internal) energy of the system?
A. -800 J
B. -200 J
C. -100 J
D. 200 J
E. none of these

9. [5 pts] An engine does 500 J of work and emits 1500 J of heat as waste. What is the efficiency of this engine?
A. 33%
B. 25%
C. 50 %
D. 13 %
E. none of these

10. [5 pts] If in one day you eat 2000 kcal of food and decide to walk; for how long can you do so using only the calories from food? Assume the body consumes 380 W as you walk.
    A. 22 hrs
    B. 15.4 hrs
    C. 6.1 hrs
    D. All day long
    E. Not enough information

11. [5 pts] Which system has the lowest average kinetic energy per molecule?

    A. System at 200 K
    B. System at 200^{o}C
    C. System at 200^{o}F
    D. would need to know the mass and number of molecules to answer this

12. [5 pts] Ice at a temperature of 0^{o}C gains thermal energy at a rate of 30 W from the air at 20^{o}C. What is the change in entropy per second of the air alone? Assume the ice and air do not change temperature during your measurement.
    A. -1.2 J/K per second
    B. -0.10 J/K per second
    C. -0.32 J/K per second
    D. -1.5 J/K per second
    E. Need more information

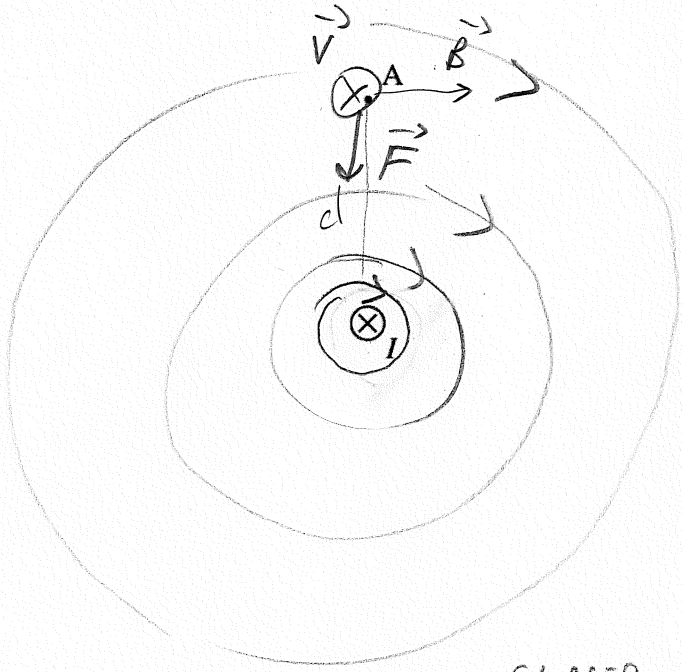
SOLN

II. **Lecture Free Response** [20 pts] Show work or explain reasoning where requested.

A long straight wire carrying a 1 Amp current is arranged so it is oriented so the current is traveling into the page, as shown below, with a reference location A 2.0 cm above it.

a) [5 pts] On the diagram at right, draw the Magnetic Field Lines. (Draw at least 3 lines)

USE RHR TO FIND FIELD LINES



b) [5 pts] At the position A, determine the strength and direction of the Magnetic Field.

USE $B = \frac{\mu_0 I}{2\pi d}$, TO THE RIGHT

$= \frac{(4\pi \times 10^{-7} \frac{T\cdot m}{A})(1A)}{2\pi(2\times10^{-2}m)}$

$\boxed{B = 10^{-5} T}$

c) [5 pts] If a positive charge of 1.0 μC (Hint: $1\mu C = 1 \times 10^{-6} C$) is moving into the page at point A with a velocity of 1.0 m/s, determine the direction and magnitude of the Magnetic Force on the charge.

FIELD LINES CLOSER WHERE B LARGER

POSITIVE CHARGE, USING RHR, F IS TOWARD THE CURRENT I.

$F = qvB = (10^{-6} C)(1 m/s)(10^{-5} T)$

$\boxed{F = 10^{-11} N}$

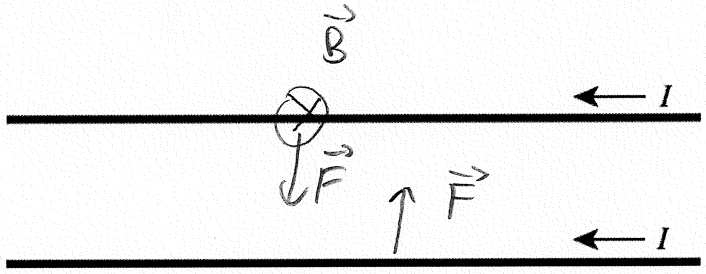
SOLN

d) [5 pts] We now change our perspective on the wire, so it appears horizontal with the current traveling to the left, and place an identical wire 2.0 cm above it. This results in a new configuration where there are two parallel current carrying wires, both with 1.0 Amp, 2.0 cm apart. Indicate on the diagram and describe in words the direction of the force on each wire; and calculate the force per unit length (F/L) on each wire.

- USING RHR FIND $\vec{B}$ FROM ONE I AT THE OTHER.
- THEN FIND $\vec{F}$ USING RHR, AND IT IS TOWARD OTHER CURRENT.
- USING N'S 3rd LAW THE TWO ARE ATTRACTED TO EACH OTHER

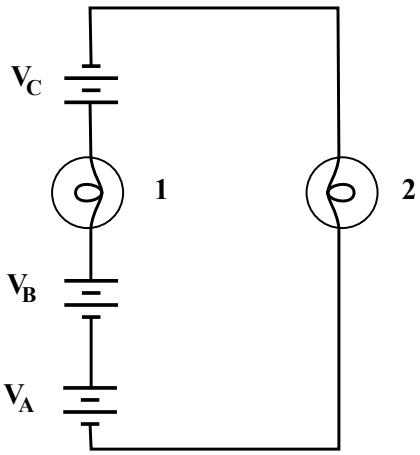
$F = ILB$

$$\frac{F}{I} = IB = \frac{I\mu_0 I}{2\pi d} = \frac{\mu_0 I^2}{2\pi d} = \boxed{10^{-5} N = \frac{F}{L}}$$



III. **Tutorial Free Response** [20 pts]: Show work or explain reasoning where requested.

For parts a) and b) use the circuit below: The bulbs are all identical and the batteries are all identical as well, with a potential difference of $V_A=V_B=V_C=\mathcal{E}$.



a) [5 pts] Rank the brightness of bulbs 1 and 2. If a bulb has zero brightness state so explicitly. Explain your answer.

Bulb 1 = Bulb 2

Since the bulbs are in series and the same, both the current and the potential across each will be the same, so the brightness will be the same.

Aside: The potential is not zero across either bulb since the sum of the batteries potential differences is not zero.

b) [5 pts] What is the potential difference across bulb 2? Answer should be in terms of $\mathcal{E}$. Explain your answer.

Using Kirchoff's loop rule we find

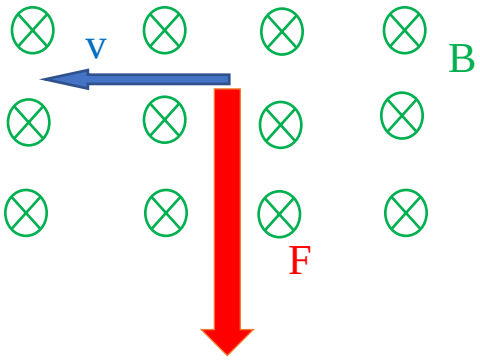
$V_A+V_B-IR-V_C-IR=0$

Solve for I to get:

$I= \mathcal{E}/2R$

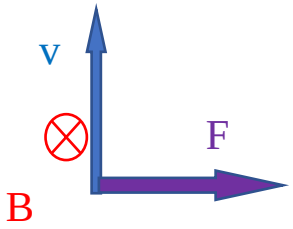
So $V=I\,R= (\mathcal{E}/2R)\,R= \mathcal{E}/2$

c) [5 pts] A positively charged particle is moving to the left in a magnetic field (into the page) as shown to the right. What is the direction of the force on the particle? Draw in the diagram and explain.



Using the right hand rule, we find the force is down the page. It is perpendicular to both v and B.

d) [5 pts] A negatively charged particle experiences a force to the right. What is the direction of the magnetic field if the velocity is pointed up? Draw in the diagram and explain.



Using the right hand rule the B field is into the page. Since it is a negative charge, it is opposite the force on a positive charge using F=qvB.

In fact, there are a range of possible answers for B, as long as it is perpendicular to F and pointed into the page, the exact angle relative to v does not matter.