PHY3054 - Exam 2 - Solutions - Fall 1996 - Selman Hershfield

1. Light bulbs B and F are only connected at one end so they are off (no current flowing through them). Light bulbs D and E are short circuited and hence are also off. To see this, note that we can go between the two ends of bulbs D and E via wires, which we are assuming have no resistance. Consequently, both ends are at the same electrical potential and $I = 0$. Resistors A and C are in parallel and hence have the same voltage drop. The current is also the same because they have the same resistance: $I = V/R$. $\Rightarrow$ The answer is **dimmest (BDEF),(AC) brightest**.

2. Since bulbs D and E are short circuited, the voltage drop across bulb C (or A) is 6V. There is no voltage drop across B because there is no current through it. Thus, if we go from P2 to P1, we find that the net voltage change is $V_{P1} - V_{P2} = \mathbf{6V}$.

3. Compute the effective resistance of the top and bottom branches and then add them in parallel.

$$\begin{aligned} R \text{ of Top Branch} &= 9\Omega + 2\Omega = 11\Omega \\ R \text{ of Bottom Branch} &= \left(\frac{1}{1} + \frac{1}{2}\right)^{-1} \Omega + 2\Omega = \frac{8}{3}\Omega \\ \Rightarrow R_{eff} &= \left(\frac{1}{11} + \frac{1}{2.667}\right)^{-1} \Omega \approx \mathbf{2\Omega} \end{aligned}$$

4. R_1, R_2, and R_3 are in parallel and hence have the same voltage drop (2 V). The effective resistance of R_1, R_2, and R_3 in parallel is 0.818Ω. $\Rightarrow$ The net current through them is $2V/0.818\Omega = 2.445A$. This is also the net current through R_2 and R_5 combined. Since the effective resistance of R_2 and R_5 in parallel is 1.429Ω, the voltage across each of them is $(2.445A)(1.429\Omega) = 3.494V$. The current through R_5 is $3.494V/5\Omega \approx \mathbf{0.7A}$.

5. Let I be defined as the current flowing clockwise in the circuit. Going clockwise from point A computing the voltage changes,

$$-4I + 8 - 2 - 7I - 1 - 8I - 2I + 5 = 0,$$

gives $I \approx$ **0.5 A clockwise**.

6. Let I_1 be the current from B to A, and let I_2 be the current from B to C. Apply the loop rule and then solve for I_1 and I_2.

Loop rule in left loop going counterclockwise starting at A:

$$\begin{aligned} 9 - I_1 - 9I_1 - (I_1 + I_2) + 3 - 8I_1 &= 0 \\ -19I_1 - I_2 + 12 &= 0 \end{aligned}$$

Loop rule in right loop going clockwise starting at B:

$$\begin{aligned} -5I_2 + 7 - 7I_2 - I_2 - (I_1 + I_2) + 3 &= 0 \\ -14I_2 - I_1 + 10 &= 0 \end{aligned}$$

Solving these two simultaneous equations yields $I_1 \approx 0.60A$ and $I_2 \approx 0.67A$. The current from E to B is $I_1 + I_2 = 1.27A \approx$ **1.3 A**.

7. To get the voltage drop $V_D - V_F$ start at F and go to D computing the change in the voltage:
$$V_D - V_F = -9\Omega \times I_1 + 1\Omega \times I_2 - 4.73V \approx \mathbf{-4.9V}.$$

8. Compute the effective capacitance of the top and bottom branches and then add the two branches in parallel.
$$\begin{aligned} C \text{ of Top Branch} &= \left(\frac{1}{7}+\frac{1}{1}\right)^{-1} \mu F = 0.875\mu F \\ C \text{ of Bottom Branch} &= \left(\frac{1}{1}+\frac{1}{9}+\frac{1}{4}\right)^{-1} \mu F \approx 0.735\mu F \\ \Rightarrow C_{eff} &= 0.875\mu F + 0.735\mu F \approx \mathbf{1.6\mu F} \end{aligned}$$

9. The voltage drop across C_4 is 2 V. Because $C_3 = C_4$ and the two capacitors are in series (same charge), the voltage drop across C_3 is also 2 V. Thus, the net voltage drop across C_3 and C_4 is 4 V. This is also the voltage drop across C_1 and C_2 in parallel, which has an effective capacitance of $2.55\mu F$. $\Rightarrow$ The charge on C_2 is $(2.55\mu F)(4V) \approx \mathbf{10\mu F}$.

10. **Done correctly.**

11. Use the sign convention that B into page is negative, and B out of the page is positive.
$$\begin{aligned} B \text{ at P due to } I_1 &= \frac{-\mu_o(6A)}{0.03m} = -200\mu_o \\ B \text{ at P due to } I_2 &= \frac{\mu_o(4A)}{0.01m} = 400\mu_o \\ B \text{ at P due to } I_3 &= \frac{-\mu_o(2A)}{0.01m} = -200\mu_o \\ B \text{ total at P} &= B_1 + B_2 + B_3 = \mathbf{0T} \end{aligned}$$

12. Wire A is attracted to B and repelled from C; however, attraction to B is stronger because B is closer. **F on A to the right.** Wire B is attracted to B and repelled from C. **F on B to the left.** Wire C is repelled from both A and B. **F on C to the right.**

13. Placing your fingers in the direction of B and your thumb in the direction of I, the **force on the wire is out of the page**. The two sides of the rectangular loop produce equal and opposite forces, which cancel. The segment of the rectangular loop closest to the wire is attracted to the wire (F up), and the segment furthest from the wire is repelled (F down). The attractive force is greater since that segment is closer. **The force on the loop is up.**

14. Using the right hand rule for a wire with current flowing, the force on the right side of the loop is up, and the force on the left side of the loop is down. Consequently, the loop is rotating **counterclockwise**. To get the magnetic moment, wrap your fingers in the direction of the current flow and your thumb points in the direction of the magnetic moment (**down**). The magnetic moment is trying to align with the magnetic field.

15. To make the particle move in a circle, the magnetic force must be pointing radially inwards. The magnetic field direction consistent with the motion shown in the figure is B in I is out of the page, and **B in II is into the page**. Since the force is perpendicular to the velocity, no work is done, and the velocity remains constant. From the force equation,

$$F = \frac{mv^2}{r} = qvB,$$

we can see that the magnetic field is inversely proportional to the radius. **The magnitude of B in II is larger than B in I**.

16. To determine the direction of the magnetic field for a straight wire, put your thumb in the direction of the current and wrap your fingers around the wire. Your fingers then give the direction of the current. $\Rightarrow$ The top wire with current into the page produces a magnetic field at 270^o at P. The right wire with current out of the page produces a magnetic field at 180^o at P. The middle with current into the page produces a field at 315^o at P. This magnetic field is slightly smaller than the other two. Drawing a vector diagram to add the three vectors will indicate that 250 degrees is probably correct.

    To actually be sure, one must add the three vectors.

	x-component	y-component
B due to top wire	0	$-\mu_o I/(2\pi \times 1\text{m})$
B due to middle wire	$\cos(45)\ \mu_o I/(2\pi \times \sqrt{2}\text{m})$	$-\sin(45)\ \mu_o I/(2\pi \times \sqrt{2}\text{m})$
B due to right wire	$-\mu_o I/(2\pi \times 1\text{m})$	0
B net	$-0.5\mu_o I/(2\pi \times 1\text{m})$	$-1.5\mu_o I/(2\pi \times 1\text{m})$

    The tangent of the direction angle is $(-1.5)/(-0.5) = 3$, which means the angle is 71.6 or $71.6 + 180 = 251.6$. From the above discussion, we can see that $251.6 \approx$ **250 degrees** is the correct answer.

17. The time constant is RC. The largest capacitance is made with capacitors in parallel ($2\mu F$). The largest resistance is made with resistors in series ($2k\Omega$). Consequently, the largest time constant is $RC = (2 \times 10^{-6}F)(2 \times 10^{3}\Omega) = 4 \times 10^{-3}s =$ **4ms**.

18. The left loop produces a magnetic field going out of the page at the right loop. Since this field is decreasing, the induced current produces a flux out of the page. $\Rightarrow$ The induced current is going **counterclockwise in Fig. 14.1**.

    The magnetic field is going into the page at the loop in Fig. 14.2. Since the loop is moving away from the wire, the flux is decreasing into the page. The induced current produces a flux into the page. $\Rightarrow$ The induced current is going **clockwise in Fig. 14.2**.

19. In case (a) if the magnetic field is pointing north and the space shuttle is moving east, then the tether with is pointing radially outwards will be positively charged far from the earth and negatively charged closer to the earth. The magnitude of the motional emf is $vBL =$ **8000 V in (a)**. For case (b) the shuttle is moving parallel to the earth's

magnetic field. Since v and B are parallel, there is no force on the electrons in the wire and consequently no induced voltage: **0V in (b)**.

20. Since the loop is rotating either clockwise or counterclockwise, choose one of the possibilities and see if it makes sense. Suppose the loop is rotating clockwise. Then the flux going up through the loop will be increasing, and to oppose this change in flux, the induced current will produce a flux going down through the loop. This would correspond to a current flowing in the opposite direction as the one in the figure. Consequently, we guessed wrong, and **the loop is rotating counterclockwise**. The magnetic flux is proportional to the magnetic field perpendicular to the loop, which is zero in this case. **The flux is zero.**