Oberlin College Physics 111, Spring 2024

Model Solutions to Second Exam

1. Teakettle. The rate of water evaporation is proportional to the power dissipated at the resistive element, namely i^2R. If i increases by a factor of 1.21, then power dissipation increases by a factor of $(1.21)^2 = 1.46$ (three significant figures), so the rate of water evaporation increases to (two significant figures)

$$1.46 \times (0.41 \text{ cup/min}) = 0.60 \text{ cup/min}.$$

⟦*Grading:* 2 points for "rate proportional to power"; 2 points for i^2R; 2 points for number; 2 points for two significant figures; 2 points for "cup/min" (either explicit or in text).⟧

2. Network circuit. Call the current up through the left battery i_L (this is our desired quantity), the current up through the right battery i_R. The loop rule applied to the left loop gives

$$13 \text{ V} - i_L(15\ \Omega) - (i_R + i_L)(22\ \Omega) = 0$$

while the loop rule applied to the right loop gives

$$25 \text{ V} - i_R(11\ \Omega) - (i_R + i_L)(22\ \Omega) = 0.$$

So we need to solve simultaneously

$$\begin{aligned} 13 \text{ V} - i_L(37\ \Omega) - i_R(22\ \Omega) &= 0 \\ 25 \text{ V} - i_L(22\ \Omega) - i_R(33\ \Omega) &= 0 \end{aligned}$$

To eliminate i_R multiply the top equation by 3, and the bottom equation by -2, then sum:

$$(3 \times 13 - 2 \times 25) \text{ V} - i_L(3 \times 37 - 2 \times 22)\ \Omega = 0$$

giving

$$i_L = \frac{(3 \times 13 - 2 \times 25)}{(3 \times 37 - 2 \times 22)} \text{ A} = \frac{-11}{67} \text{ A} = -0.16 \text{ A}.$$

Note the negative sign. The 25 V battery is so hefty that it actually forces current *down* through the 13 V battery.

⟦*Grading:* 2 points for starting off; 2 points for left loop equation; 2 points for right loop equation; 4 points for solution.⟧

3. Force on table wire. Because $\vec{F} = i\vec{L} \times \vec{B}$, where $\vec{L}$ is horizontal, the horizontal component of $\vec{B}$, parallel to $\vec{L}$, does not contribute to the force. The magnitude is $F = iLB_v = 0.474$ mN, and the direction (through right-hand rule) is horizontal, toward magnetic west (i.e. toward 7.60° south of west).

⟦*Grading:* 2 points for correct equation; 4 points for correct magnitude; 4 points for correct direction.⟧

4. Switched-on circuit. Immediately after the switch is closed, no current flows through the inductor.

(a) Current through the 10 Ω resistor is (30 V)/(30 Ω) = 1 A.

(b) So the voltage drop across the 10 Ω resistor is 10 V, whence the emf of the inductor is 10 V, whence $di/dt = \mathcal{E}/L = (10\text{ V})/(0.2\text{ mH}) = 50$ kA/s.

After a long time has passed, changes have stopped happening so the inductor has nothing to fight. It acts like a simple piece of wire.

(c) Current through the 10 Ω resistor is zero — it shunts through the simple piece of wire instead.

(d) $di/dt = 0$ — everything has settled down and is not changing with time.

⟦*Grading:* 3 points each for (a) and (b); 2 points each for (c) and (d).⟧