

HW #5 Solutions

Ch. 19

Q5) The outlets in a double outlet are connected in parallel. Both outlets deliver the same potential difference of 120 VAC and they operate independently. A lamp plugged into one outlet can be turned on and off without affecting a TV plugged into the other outlet.

Q12) I will accept either answer on this question. If used to supply energy, the terminal voltage can never exceed the emf. The terminal or output voltage is given by $V_{term} = \mathcal{E} - Ir$, which implies that the terminal voltage is always less than or equal to the emf. However, if the battery is rechargeable, and it is being recharged by connection to a source of higher voltage than the emf, then the voltage at the terminals must be larger than the emf to drive current through the battery in the opposite direction. Tricky!

By the way, when I assigned this question I thought the answer was NO, but a student pointed out that YES was a good answer too, and the solutions manual agreed with the student. Don't worry. I will not ask this kind of tricky/subtle question on the exam.

Q16) Outside in barefeet you have much better electrical contact with the ground than if you are inside with thick soles on a dry floor. So if you are exposed to a high voltage, more current will go through you when outside and barefoot.

P3) 12 V is the emf of the battery. The terminal voltage is 8.4 V, so the voltage drop across the internal resistance is $12\text{ V} - 8.4\text{ V} = 3.6\text{ V}$. Since I is 75 A, then from $V = IR$, we get that $R = 3.6\text{ V}/75\text{ A} = 0.048\ \Omega$.

P7) The effective resistance of the two resistors in parallel is $2200\ \Omega + 650\ \Omega = 2850\ \Omega$. The current is $I = V/R = 12\text{ V}/2850\ \Omega = 0.0042\text{ A}$. The voltage across the 2200 Ω resistor is $V = IR = 0.0042 \times 2200 = 9.3\text{ V}$.

P17) The 820 Ω resistor and the 680 Ω are in parallel, so the effective resistance is 372 ohms $\left(\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} \right)$. These two resistors are in series with the 470 ohm resistor, so the resistance of the whole circuit is $470 + 372 = 842$ ohms. The current leaving the supply is $I = V/R = 12\text{ V}/842\ \Omega = 0.0143\text{ A}$. From the current you can find that the voltage drop across the 470 ohm resistor is $V = IR = 0.0143\text{ A} \times 470\ \Omega = 6.7\text{ V}$. The voltage across the other two resistors must be $12\text{ V} - 6.7\text{ V} = 5.3\text{ V}$. You could also get this from $V = IR = 0.0143\text{ A} \times 372\ \Omega$.

P18) The resistance of a 75 W bulb can be found using $P = V^2/R$. $R = V^2/P = (110\text{ V})^2/75\text{ W} = 161\ \Omega$. Similarly, the resistance of the 40 W bulb is 303 Ω . The resistance of the two in parallel is 105 ohms.

P19) a) This question is hard to answer qualitatively without actually doing the numbers, but let's try. When the switch is closed, it reduces the resistance of the parallel part of the circuit. This leads to a larger current, which will cause the voltage drop across R1 to increase. Since the total voltage is fixed, the voltage across the parallel part of the circuit must decrease.

b) In a we said that the current through R1 increases. We also said that the voltage drop across the parallel combination decreases. That means that the current through R3 and R4 must decrease. Of course the current through R2 increases.

c) This one is easy. Since the total current increases, the power output increases.

d) Before closing: 125 in parallel with 125 gives 62.5 ohms. This in series with 125 gives 187.5 ohms. Since V is 22 V, the total current is $I = V/R = 22 \text{ V}/187.5 \Omega = 0.117 \text{ A}$. This is the current in R1. The current splits evenly between R3 and R4, so each has a current of 0.059 A.

After closing: The three resistors in parallel give a resistance of 41.7 ohms. The total resistance is $41.7 + 125 = 166.7$ ohms, so the total current is 0.132 amps. This is the current in R1. The currents in R2, R3, and R4 are one third of this value or 0.044 amps.

P22) The key to this problem is first figuring out what is going on. Imagine turning up the voltage. The power of each resistor will increase, but the power of each resistor will be different. At some voltage the power of one of the resistors will reach 0.5 W, and that is the maximum voltage.

So here is the solution: The equivalent resistance of the two resistors in parallel is 1200 ohms. This is in series with 1800 ohms, so the resistance of the entire network is 3000 ohms. If V is the voltage applied to the network, then the total current is $I = V/3000$, and this is the current through the 1800 ohm resistor. The power of the 1800 ohm resistor is then $P = I^2R = (V/3000)^2 \cdot 1800$. The voltage across the other two resistors is $V = IR = (V/3000) \cdot 1200$, so the power of the 2100 ohm resistor is $P = V^2/R =$

$$\frac{\left(\frac{V}{3000} \cdot 1200\right)^2}{2100}, \text{ and the power for the 2800 ohm resistor is } \frac{\left(\frac{V}{3000} \cdot 1200\right)^2}{2800}.$$

Simplifying these expressions gives $P_{1800} = V^2 \cdot 0.0002$, $P_{2100} = V^2 \cdot 0.000076$, and $P_{2800} = V^2 \cdot 0.000057$. Thus the 1800 ohm resistor has the highest power and will reach 0.5 W first.

Solving the power expression for V and setting $P = 0.5 \text{ W}$ gives

$$V = \sqrt{P/0.0002} = \sqrt{(0.5)/(0.0002)} = 50 \text{ V}.$$

Eric pointed out that this problem can be done with quite a bit less work if one notices that the power of the 1800 ohm resistor must be greater than the power of the 1200 ohm parallel combination because the currents are the same and $P = I^2R$. Since the power of the parallel combination must be greater than the power of either resistor in the combination, the power must be greatest in the 1800 ohm resistor. This saves calculating the power for the other two resistors.

AP1) Each charge produces an electric field at P. The resultant field at P is the vector sum. The magnitude of the field due to each charge is $E = \frac{kQ}{r^2} = 1170 \frac{N}{C}$, where I have used $r = 0.13$ m. The field due to the positive charge points to the right and the field due to the negative charge points to the right, so the vector sum is just $1170 + 1170 = 2340$ N/C to the right (away from Q1).

AP2) The potential at A is the sum of the potentials due to Q1 and Q2. The potential due to a point charge is kQ/r , so we have

$$a) \quad V_{atA} = \frac{9 \times 10^9 \cdot 2.2 \times 10^{-9}}{0.12} + \frac{9 \times 10^9 \cdot (-2.2 \times 10^{-9})}{0.14} = 165 - 141 = 24V.$$

$$b) \quad V_{atB} = \frac{9 \times 10^9 \cdot 2.2 \times 10^{-9}}{0.14} + \frac{9 \times 10^9 \cdot (-2.2 \times 10^{-9})}{0.12} = 141 - 165 = -24V$$

c) Using $E = \Delta V/d = 48 \text{ V}/0.02\text{m} = 2400 \text{ V/m} = 2400 \text{ N/C}$. Notice that I am not worrying about the minus signs because I only want to know the magnitude of E. The direction is from high potential to low potential and thus is from A to B.

Alternatively, I could use $E_x = -\Delta V_{A \rightarrow B}/\Delta x$. In that case,

$\Delta V_{A \rightarrow B} = V_B - V_A = -24V - (24V) = -48 \text{ V}$, and $E_x = -(-48 \text{ V})/0.02 \text{ m} = +2400 \text{ V/m}$. In this case the + sign tells us that the field points in the positive x-direction, namely from A to B.

AP3)

a) $E = \Delta V/d = 32,100 \text{ V}/0.012 \text{ m} = 2,675,000 \text{ V/m}$, just below the breakdown voltage of air.

$$b) \quad Q = CV = \frac{\epsilon_0 A}{d} V = \frac{8.85 \times 10^{-12} (0.18)^2}{.012} (32,100) = 0.77 \mu\text{C}$$

c) Sorry, there was no way to answer this question. I meant to say that the top plate was connected to the positive terminal of the power supply. Then the field points down, and since it is a positive particle it will hit the bottom plate.

d) The particle travels 15 cm horizontally at a constant speed in the horizontal direction of $1.55 \times 10^7 \text{ m/s}$ so the time of travel is $0.15 \text{ m}/1.55 \times 10^7 \text{ m/s} = 9.7 \times 10^{-9} \text{ s}$.

During this time the particle moves $0.12 \text{ cm}/2 = 0.006 \text{ m}$ in the vertical direction.

Assuming the field is uniform, the acceleration is uniform and we can use $y = \frac{1}{2}at^2$ to find a. Note that $v_{oy} = 0$. The result is $a = 1.28 \times 10^{14} \text{ m/s}^2$. Using $F=ma$ and $F=qE$ we can find $m = qE/a = 1.6 \times 10^{-19} \cdot 2,675,000/1.28 \times 10^{14} = 6.7 \times 10^{-27} \text{ kg}$.