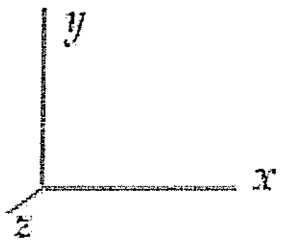
Physics 1520, Fall 2012

Quiz 4, Form: $\boxed{A}$

Name: Key

Date: ______

To specify directions, use the coordinate system shown below where $+x$ is to the right, $+y$ is toward the top of the page, and $+z$ is out of the page.



Note the following terminology for directions:

- to the right ($+x$)
- to the left ($-x$)
- upward or toward the top of the page ($+y$)
- downward or toward the top of the page ($-y$)
- out of the page ($+z$)
- into the page ($-z$)

Section 1. Multiple Choice

1. A coil of wire of total length 10 m has a resistance of 10 Ω. What is the resistance of a coil made from the same wire that has a length of 5 m?

   (a) 20 Ω

   (b) 2.5 Ω

   (c) 40 Ω

   (d) 5 Ω

   (e) It is the same, 10 Ω.

$R = \frac{\rho L}{A}$ so $R \propto L$

$\frac{1}{2}R \quad \frac{1}{2}L$

2. In an ionic solution, 5.8×10^{15} positive ions with charge $+2e$ pass to the left each second while 6.6×10^{15} negative ions with charge $-e$ pass to the right. What are the magnitude and direction of current in the solution?

   (a) 0.80 mA to the left

   (b) 1.06 mA to the right

   (c) 1.86 mA to the left

   (d) 1.98 mA to the right

   (e) 2.91 mA to the left

$\leftarrow \oplus\ +2e$

$I = (2e)(5.8\times10^{15}\text{ ions}) = 1.86\times10^{-3}\,A$ to the left

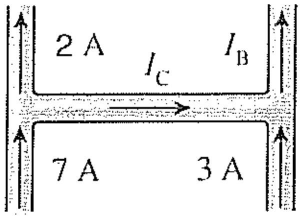
$\ominus\ -e \rightarrow$

$I = (e)(6.6\times10^{15}\text{ ions}) = 1.06\times10^{-3}\,A$ to the left

because conventional current is opposite electron current.

$$I_{net} = 1.86\times10^{-3}\,A + 1.06\times10^{-3}\,A = 2.92\times10^{-3}\,A$$

3. Currents ~~flowing~~ flow in connected wires are shown below.



What is I_B?

(a) 5 A
(b) 8 A
(c) 12 A
(d) 6 A
(e) 3 A

$\Sigma I_{in} = \Sigma I_{out}$

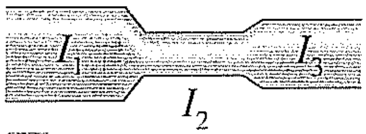
$7A = 2A + I_C$

$I_C = 5A$

$I_C + 3A = I_B$

$I_B = 5A + 3A$
$= 8A$

4. A side view of a wire of varying circular cross section is shown below.



Rank in order the currents flowing in the three sections.

(a) $I_1 > I_2 > I_3$
(b) $I_2 > I_3 > I_1$
(c) $I_1 = I_2 = I_3$
(d) $I_1 > I_3 > I_2$

$\Sigma I_{in} = \Sigma I_{out}$

$I_1 = I_2 = I_3$

5. Rank in order the speed of an electron in the three sections.

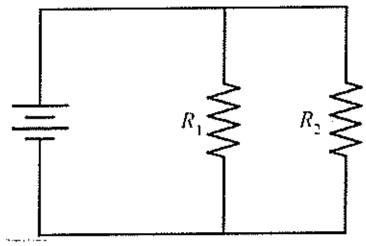
(a) $v_1 > v_2 > v_3$
(b) $v_2 > v_3 > v_1$
(c) $v_1 = v_2 = v_3$
(d) $v_1 > v_3 > v_2$

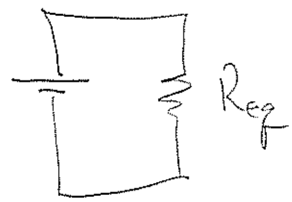
$v \propto \frac{1}{A}$

larger area has smaller drift speed, so smaller area has larger speed.

$V_2 > V_3 > V_1$

6. In the circuit shown below, the emf of the battery is 1.5 V, $R_1 = 10\ \Omega$ and $R_2 = 20\ \Omega$.





What is the current through the battery?

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(20)(10)}{30} = 6.67\Omega$$

(a) 0.15 A

(b) 0.075 A

(c) 0.05 A

(d) 0.225 A

(e) 0.125 A

$$\Delta V_R = IR$$

$$I = \frac{1.5V}{6.67\Omega} = \boxed{0.225\ A}$$

7. What is the voltage across R_2 in the previous question?

(a) 1.5 V

(b) 1.0 V

(c) 0.05 V

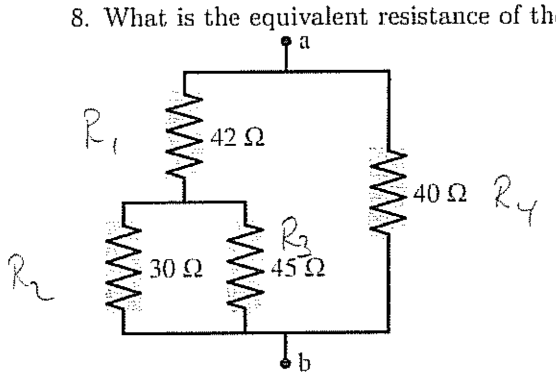
(d) 1.35 V

(e) 0.15 V

It is in parallel with the battery, so

$$\Delta V_2 = \Delta V_{bat}$$

8. What is the equivalent resistance of the resistors shown below?



$$R_{23} = \frac{R_2 R_3}{R_2 + R_3} = \frac{(30)(45)}{30+45}$$

$$= 18\Omega$$

$$R_1 + R_{23} = 42\Omega + 18\Omega = 60\Omega$$

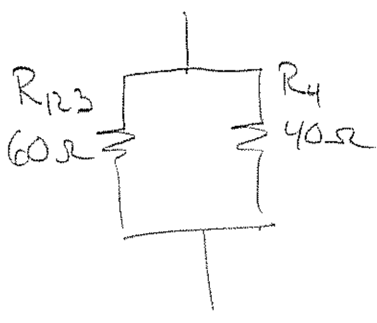
(a) 10 Ω

(b) 100 Ω

(c) 157 Ω

(d) 53 Ω

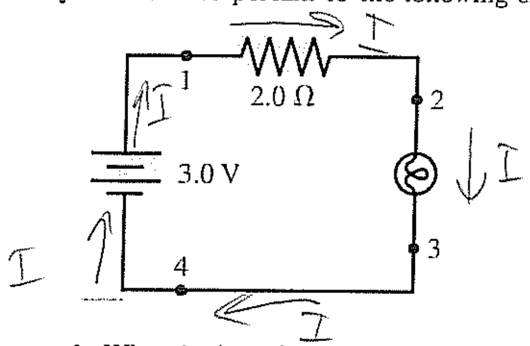
(e) 24 Ω

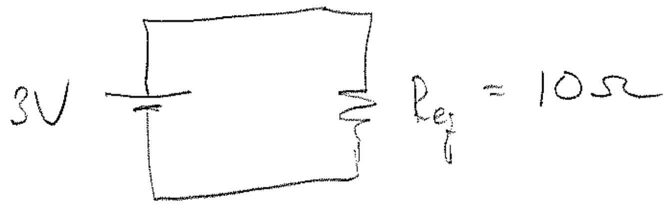


$$R_{eq} = \frac{(60)(40)}{60+40}$$

$$= \boxed{24\Omega}$$

Questions 9–13 pertain to the following circuit where the resistance of the light bulb is 8 Ω.





9. What is the voltage across the light bulb?

   (a) 2.25 V
   (b) 0.6 V
   (c) 2.4 V
   (d) 0.375 V
   (e) 0.75 V

$I = \frac{3V}{10\Omega} = 0.3A$

$\Delta V_{bulb} = IR$
$= (0.3A)(8\Omega) = 2.4V$

10. At which point is the current the greatest?

   (a) 1
   (b) 2
   (c) 3
   (d) 4
   (e) None of the above; it's the same at all of these points.

$\Sigma I_{in} = \Sigma I_{out}$

current is not "lost" in flowing from pt. 1 to pt. 4.

11. If the 2 Ω resistor is also a light bulb, which bulb will be brightest?

   (a) 2 Ω bulb
   (b) 8 Ω bulb
   (c) Neither; they will have the same brightness.

$P = I\Delta V = I(IR) = I^2R$

I is the same so larger R has more P.

12. What is the direction of conventional current at point 4?

   (a) to the right
   (b) to the left

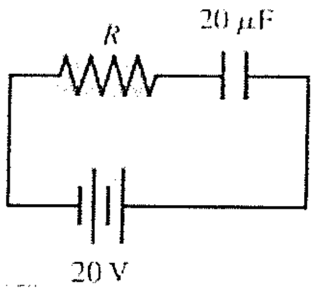
I leaves + terminal and flows into − terminal of battery.

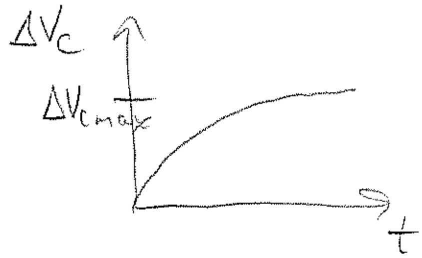
13. In what direction will electrons flow at point 4?

   (a) to the right
   (b) to the left

Electrons flow opposite conventional current.

14. Suppose that the capacitor in the circuit below starts out uncharged. At $t = 0$, a wire is connected from the capacitor to the battery, thus completing the circuit.





$\Delta V_{C_{max}} = \Delta V_{bat}$
$= 20\,V.$

After a very long time, what will be the charge (Q_{max}) on the capacitor?

(a) 1×10^{-6} C
(b) 1×10^{-4} C
(c) 4×10^{-6} C
(d) 4×10^{-4} C
(e) zero

$Q = C\,\Delta V$
$= (20 \times 10^{-6} F)(20 V)$
$= 4 \times 10^{-4}\ C$

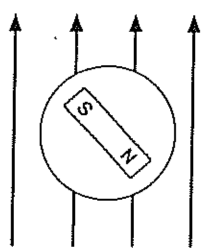
15. If you double the resistance and repeat the experiment, the time constant τ that characterizes how long it takes to charge the capacitor will be

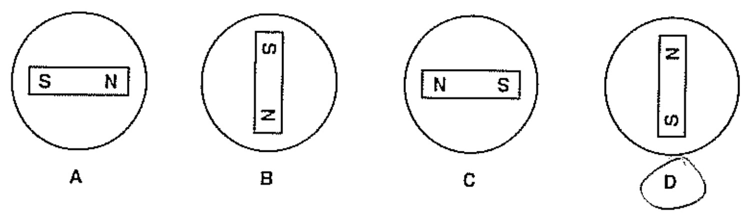
(a) twice as long.
(b) half as long.
(c) the same.

$\tau = RC$
so $\tau \propto R$

16. A dipole (such as a compass needle) is in the orientation shown below when suddenly a magnetic field is created (by a source not shown) in the $+y$ direction. The picture shows the situation at $t = 0$. If there is damping, the compass needle will eventually stop rotating and will be at rest in equilibrium. What will be the orientation of the compass needle after it reaches equilibrium?

B

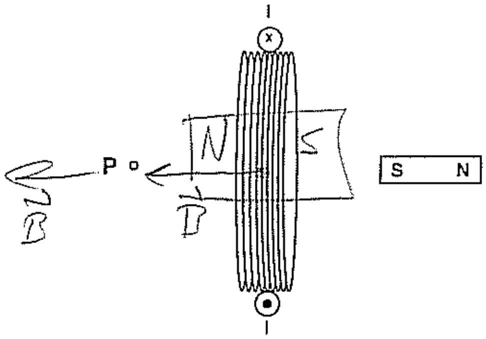




(a) A
(b) B
(c) C
(d) D

17. A side view of a current-carrying coil is shown below. Current flows into the page at the top of the coil and out of the page at the bottom of the coil.

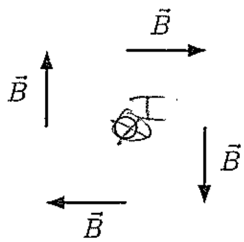
Coil acts as a dipole, and the S poles repel.



Will the bar magnet and coil attract or repel?

(a) attract
(b) repel
(c) Neither; they will not exert a force on each other.

18. The end-view of a current-carrying wire is shown below, along with the magnetic field at locations equidistant from the wire.

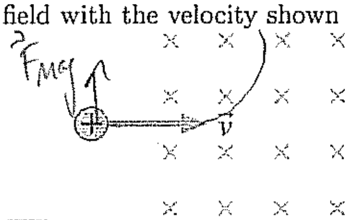


Right-hand rule.

What is the direction of the current in the wire?

(a) to the right ($+x$)
(b) to the left ($-x$)
(c) upward, toward the top of the page ($+y$)
(d) out of the page ($+z$)
(e) into the page ($-z$)

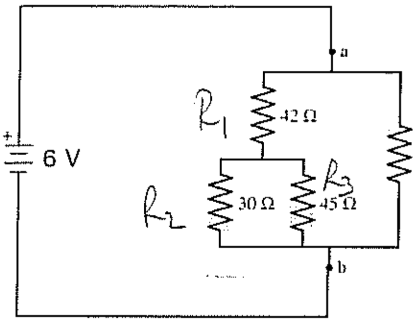
19. At a certain instant, an ion with a charge +1 (times 1.6×10^{-19} C) is in a region of uniform magnetic field with the velocity shown below.



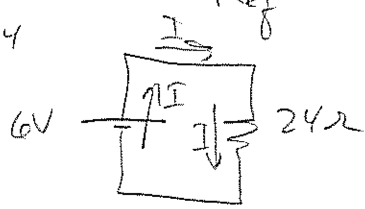
The ion will travel

(a) with a constant speed along a parabola that curves upward.
(b) with a constant speed along a parabola that curves downward.
(c) in uniform circular motion, counter-clockwise.
(d) in uniform circular motion, clockwise.
(e) in a straight line to the right with constant speed.

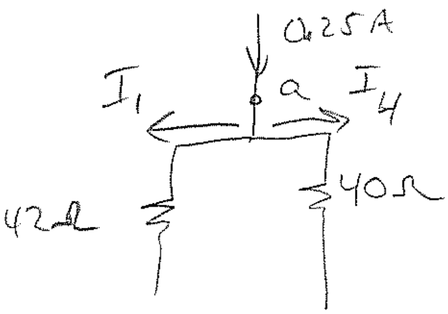
20. In the circuit below, what is the current through the 42 Ω resistor? (Note that it is the same circuit as in Question #8.)



$R_{eq} = 24\Omega$ (see #8)

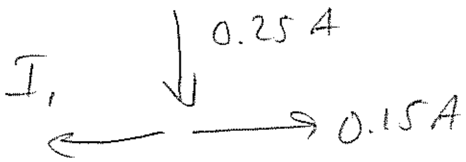


$I = \frac{6V}{24\Omega} = 0.25A$



ΔV across 40Ω resistor is 6V because it is in parallel with the battery. So

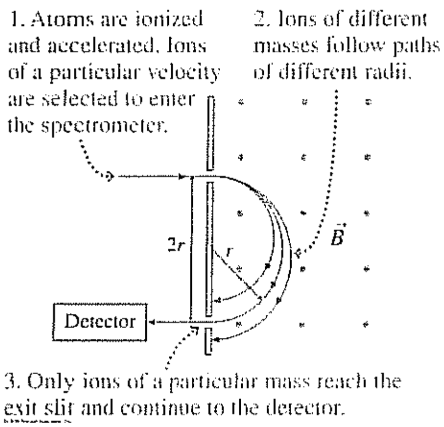
$$I_4 = \frac{6V}{40\Omega} = 0.15A.$$



Thus current through R_1 must be $0.25A - 0.15A = \boxed{0.1A}$

Questions 21-22:

21. A mass spectrometer similar to the one in the figure below is designed to separate protein fragments. The fragments are ionized by removing a single electron and then enter a 0.60 T uniform magnetic field at a speed of 2.4×10^5 m/s. If the distance between the points where the ion enters and exits the magnetic field is 0.501 m, what is the mass of the ion?



$R_{circle} = \frac{1}{2}(0.501\,m) = 0.2505\,m$

$R = \frac{mv}{qB}$

$m = \frac{qBR}{v}$

$m = \frac{(1.6\times10^{-19}C)(0.6T)(0.2505m)}{2.4\times10^{5}\frac{m}{s}} = 1.0\times10^{-25}\,kg.$

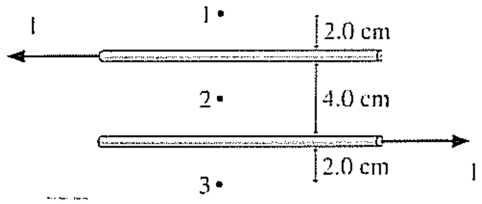
22. How many times more massive is this ion than a single proton? ($m_p = 1.67 \times 10^{-27}$ kg)

$M = \frac{1.0\times10^{-25}kg}{1.67\times10^{-27}kg}\ m_p$

$\boxed{m = 60\,m_p}$

Questions 23-24:

23. Two wires carry a current $I = 2$ A in the directions shown below.



(a) At which point (1, 2, or 3) is the magnetic field the greatest (in magnitude)? State your reasoning. For full credit, you must have the correct answer with correct reasoning.

$I_A \leftarrow$

$\rightarrow I_B$

At Point 1: $\otimes B_A$ and $\odot B_B$ so net B is $|B_B - B_A|$ and is in $-z$ dir.

At Pt. 2: $\odot B_A$ and $\odot B_B$ so net B is $|B_B + B_A|$ and is in $+z$ dir.

At Pt. 3: $\odot B_A$ and $\otimes B_B$ and net B is $|B_B - B_A|$ and is in $-z$ dir.

hus, B at t. 2 is greatest ince $\vec{B}_A$ and $\vec{B}_B$ are n the same direction.

24. What is the net magnetic field at point 3? Give both the magnitude and the direction.

$$B_{wire} = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{4\pi \times 10^{-7}}{2\pi}\frac{I}{r} = (2\times 10^{-7})\frac{I}{r}$$

$$B_{A_z} = +2\times 10^{-7}\left(\frac{2\,A}{0.06m}\right) = +6.67\times 10^{-6}\,T$$

$$B_{B_z} = -(2\times 10^{-7})\left(\frac{2\,A}{0.02m}\right) = -2\times 10^{-5}\,T$$

$$B_{net_z} = B_{Az} + B_{Bz}$$
$$= 6.67\times 10^{-6}\,T + -2\times 10^{-5}\,T = \boxed{-1.33\times 10^{-5}\,T}$$

B_{net_z} is in the $-z$ dir as indicated by the sign.