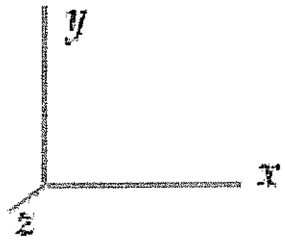
Physics 1520, Spring 2013 — Name: Key

Quiz 4, Form: A — 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 ($+z$) $\odot$
- into the page ($-z$) $\otimes$

Section 1. Multiple Choice

1. Which of Kirchhoff's Laws is a result of Conservation of Mass (or alternatively Conservation of Charge)?
   (a) Kirchhoff's Junction Law (also called Kirchhoff's Current Law or Current Rule)
   (b) Kirchhoff's Loop Law (also called Kirchhoff's Voltage Law or Loop Rule
   (c) Neither of the above.
   (d) Both of the above.

2. When an ion channel opens in a cell wall, monovalent (charge $+e$) ions flow through the channel at a rate of 2.7×10^7 ions/s. What is the current through the channel?
   (a) 2.7×10^7 A
   (b) 5.93×10^{-27} A
   (c) 1.69×10^{-12} A
   (d) 5.93×10^{-13} A
   (e) 4.32×10^{-12} A

$$\left(2.7\times10^{7}\ \frac{\text{ions}}{\text{s}}\right)\left(\frac{1.6\times10^{-19}\text{C}}{\text{ion}}\right) = 4.32\times10^{-12}\text{A}$$

Questions 3–4: Two wires of the same length and diameter are connected together in series as shown below. $\rho_1 = \frac{1}{2}\rho_2$. The current through wire 2 is I_2.

3. Compare the resistance of each wire.

   (a) $R_1 = R_2$
   (b) $R_1 = 2R_2$
   (c) $R_1 = 4R_2$
   (d) $R_1 = \frac{1}{2}R_2$
   (e) $R_1 = \frac{1}{4}R_2$

   $R = \rho\frac{L}{A}$ $R \propto \rho$ So $R_1 = \frac{1}{2}R_2$

4. Compare the current in each wire.

   (a) $I_1 = I_2$
   (b) $I_1 = \frac{1}{2}I_2$
   (c) $I_1 = 2I_2$
   (d) $I_1 = \frac{1}{4}I_2$
   (e) $I_1 = 4I_2$

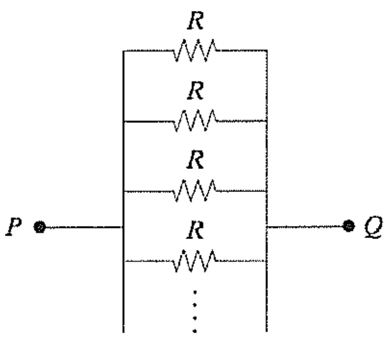
   $I_1 = I_2$ KCL (current Law)

5. A metal wire of resistance R is cut into two pieces of equal length. The two pieces of wire are then connected together side by side, in parallel. What is the resistance of the two connected wires?

   (a) R/4
   (b) R/2
   (c) R
   (d) 2R
   (e) 4R

   $\frac{1}{R_{eq}} = \frac{1}{R/2} + \frac{1}{R/2} = \frac{2}{R} + \frac{2}{R} = \frac{4}{R}$ $R_{eq} = \frac{R}{4}$

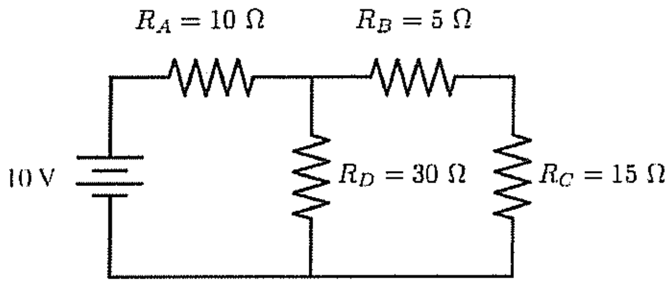
6. As more identical resistors R are added to the parallel circuit shown here, the total resistance between points P and Q



   (a) increases.
   (b) decreases.
   (c) remains the same.

   Adding resistors in parallel decreases resistance.

Questions 7–9: Consider the circuit shown below.



$R_{BC} = 20\ \Omega$

$\frac{1}{R_{DBC}} = \frac{1}{30} + \frac{1}{20} = \frac{5}{60}$

$R_{DBC} = \frac{60\ \Omega}{5} = 12\ \Omega$

$R_{ABCD} = 10\ \Omega + 12\ \Omega = 22\ \Omega$

7. What is the equivalent resistance of the resistors?

   (a) 8.3 Ω
   (b) 12 Ω
   (c) 60 Ω
   (d) 28 Ω
   (e) 22 Ω

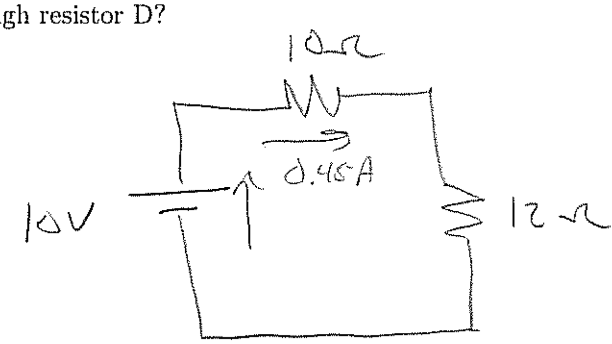
8. What is the current through the battery?

   (a) 1.0 A
   (b) 0.067 A
   (c) 0.33 A
   (d) 0.45 A
   (e) 0.83 A

$I = \frac{10\ V}{22\ \Omega} = 0.45\ A$

9. What is the current through resistor D?

   (a) 0.33 A
   (b) 0.15 A
   (c) 0.18 A
   (d) 0.20 A
   (e) 0.27 A

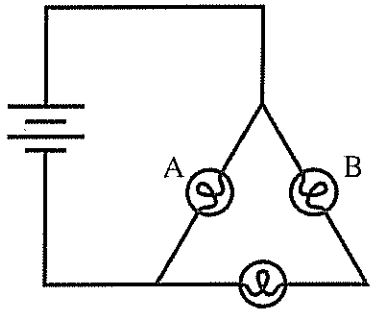


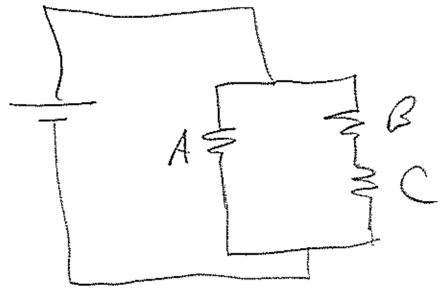
$\Delta V_A = (0.45\ A)(10\ \Omega) = 4.5\ V$

So $\Delta V_D = 10\ V - 4.5\ V = 5.5\ V$

$I_D = \frac{\Delta V_D}{R_D} = \frac{5.5\ V}{30\ \Omega} = 0.18\ A$

Questions 10–13: Consider the circuit shown below. Assume that the light bulbs are identical. Note that you may find it better to redraw the circuit in a more conventional fashion.





10. Which individual bulbs are connected in parallel (with each other)?
   - (a) A and B
   - (b) B and C
   - (c) A and C
   - (d) All three bulbs are connected in parallel with each other.
   - (e) None of the bulbs are connected in parallel.

Must be connected together at both ends.

11. Which individual bulbs are connected in series (with each other)?
   - (a) A and B
   - (b) B and C
   - (c) A and C
   - (d) All three bulbs are connected in ~~parallel~~ series.
   - (e) None of the bulbs are connected in ~~parallel~~ series.

No junction between them where current splits.

12. Rank the bulbs from brightest to dimmest.
   - (a) B=C>A
   - (b) B>C>A
   - (c) B>C=A
   - (d) A>B>C
   - (e) A>B=C

A has greater current and voltage.

B and C are identical so voltage will be the same.

13. If you unscrew bulb B and remove it from its socket, what happens to the brightness of bulb A?
   - (a) It increases.
   - (b) It decreases.
   - (c) It remains the same.

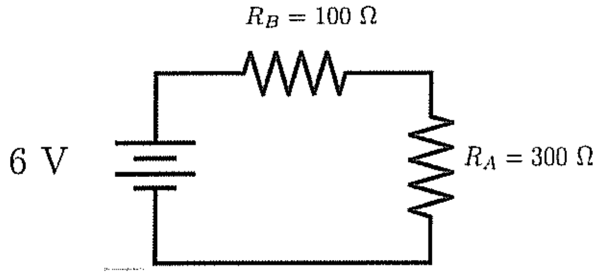
Voltage across A stays the same.

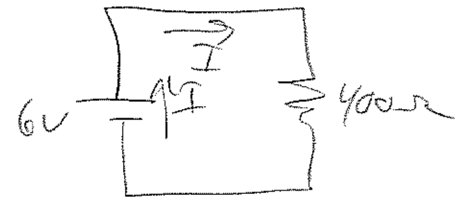
Since $\Delta V = IR$, I stays the same

So P stays the same.

Connecting additional bulbs in parallel does not change brightness of original bulb

14. What is the voltage across the 300 Ω resistor?



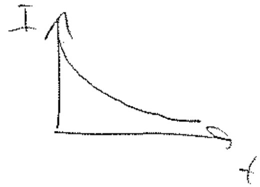


$I = \frac{6V}{400\Omega} = 0.015\ A$

$\Delta V_A = IR = (0.015A)(300\Omega) = 4.5V$

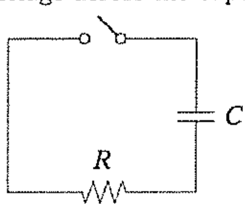
(a) 1.5 V
(b) 2.0 V
(c) 4.0 V
(d) 4.5 V
(e) 6.0 V

15. A resistor and an initially uncharged capacitor are connected in series to a battery, which is connected at t = 0. The current in the circuit



(a) is constant because the emf supplied by the battery is constant.
(b) increases exponentially in time.
(c) initially increases and then levels off to a constant value.
(d) decreases exponentially in time.
(e) There is no current because the electrons cannot flow through the gap in the capacitor.

16. A simple circuit consists of a resistor $R = 1200\ \Omega$ and a capacitor $C = 1$ mF. The capacitor is initially charged to a potential of 3 V when a switch, that is initially open, is closed. At what time is the voltage across the capacitor 2 V?



$\Delta V_c = \Delta V_{cmax} e^{-\frac{t}{RC}}$

$RC = (1200\Omega)(1.0 \times 10^{-3} F) = 1.2$

$2 = 3e^{-\frac{t}{1.2}}$

$\frac{2}{3} = e^{-\frac{t}{1.2}}$

$\ln\left(\frac{2}{3}\right) = -\frac{t}{1.2}$

$t = 0.49s$

(a) 1.2 s
(b) 0.80 s
(c) 0.49 s
(d) 0.40 s
(e) 0.37 s

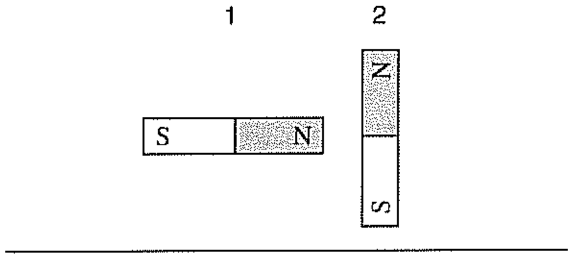
17. If you repeat the experiment exactly as before except with a resistor $R = 600\ \Omega$, then the capacitor will discharge

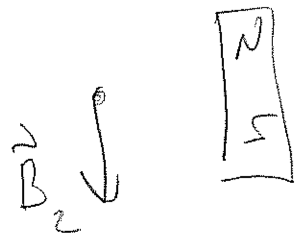
(a) faster than before (i.e. less time).
(b) slower than before (i.e. more time).
(c) in the same time as before.

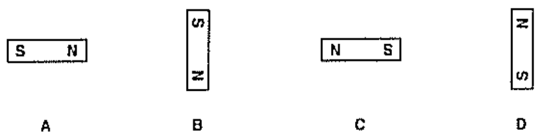
$\tau = RC$

so smaller R gives less τ.

18. Suppose that each magnet can spin about an axis through its center (but otherwise cannot move). You hold magnet 2 with your hand so that it cannot rotate. You then release magnet 1 from rest. Eventually it stops rotating and is at equilibrium. What will be the orientation of magnet 1?



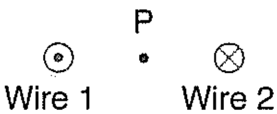


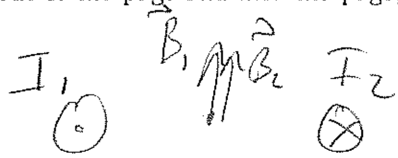


(a) A
(b) B
(c) C
(d) D

Magnet 1 aligns with $\vec{B}$ due to magnet 2.

19. Two wires carry equal and opposite currents, out of the page and into the page, as shown below. At point P, the net magnetic field is

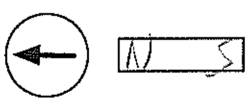




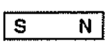
(a) in the $+y$ direction.
(b) in the $-y$ direction.
(c) in the $+z$ direction.
(d) in the $-z$ direction.
(e) zero.

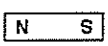
So $\vec{B}_{net}$ is ↑

20. A compass and bar magnet are shown below. Use the compass to label the poles of the bar magnet.



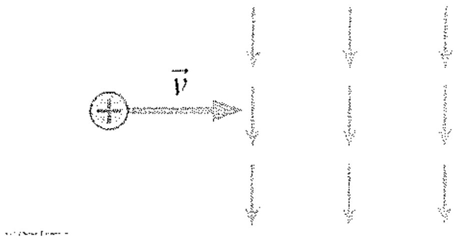
Which image below shows the correct labels for the bar magnet?

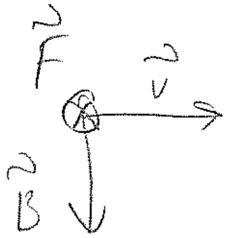
(a) 

(b) 

Compass points away from N pole, in dir. of $\vec{B}$.

21. When the positively charged ion below first enters the region of uniform magnetic field shown by the set of arrows, the magnetic force on the ion is:





(a) in the $+y$ direction.

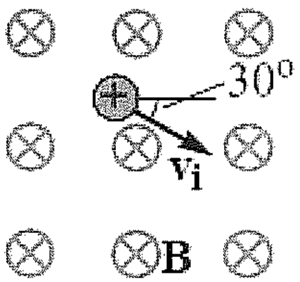
(b) in the $-y$ direction.

(c) in the $+z$ direction.

(d) in the $-z$ direction.

(e) zero.

22. The particle in the figure below has a charge of 3.00×10^{-6} C and a speed of 2.00×10^{3} m/s. It is in a uniform magnetic field, directed into the page, of 5.00×10^{-2} T. As the figure shows, the initial velocity of the particle is directed at 30° below the positive x-axis. What is the magnitude of the magnetic force acting on the particle?



$\theta = 90°$

$F = |q| v B \sin \theta$

$= (3 \times 10^{-6} C)(2 \times 10^{3} \frac{m}{s})(5 \times 10^{-2} T)$

$= 3 \times 10^{-4} N$

(a) 1.5×10^{-4} T

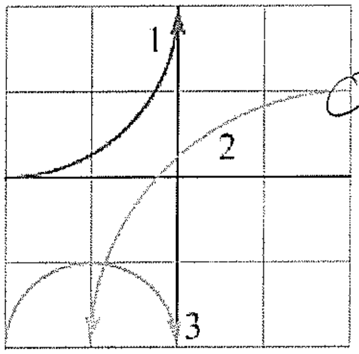
(b) 2.6×10^{-4} T

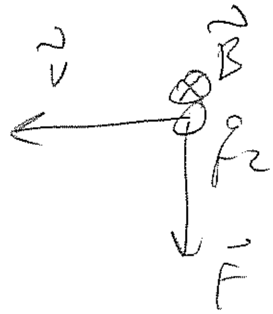
(c) 3×10^{-4} T

(d) 0.12 T

(e) zero

Questions 23–24: The figure below shows the paths followed by three charged particles through a region of uniform magnetic field that is directed perpendicular to the page. All three particles are ions with charge $+e$ or $-e$. *Particle 2 has a positive charge.*





23. In what direction is the magnetic field in the region?

    (a) $+z$ direction
    (b) $-z$ direction

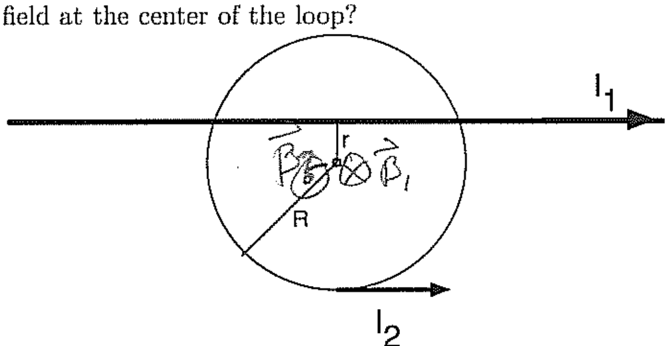
24. Which particle has the *least* mass?

    (a) particle 1
    (b) particle 2
    (c) particle 3

$R = \frac{mv}{|q|B}$ so $R \propto m$

less m, smaller R.

25. A long wire crosses the face of a wire loop as shown below. The loop carries a current of 2 A counter-clockwise. The long wire carries a current of 1 A to the right. The long wire is $r = 0.01$ m from the center of the loop, and the loop has a radius $R = 0.03$ m. What is the magnitude of the net magnetic field at the center of the loop?



$\vec{B}_1$ $\vec{B}_2$

At center, ⊗ ⊙

$B_1 = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7})(1A)}{2\pi(0.01m)}$

$= 2 \times 10^{-5}\,T$ $\quad B_{1z} = -2 \times 10^{-5}\,T$

$B_2 = \frac{\mu_0 I}{2R} = \frac{(4\pi \times 10^{-7})(2A)}{2(0.03m)}$

$= 4.2 \times 10^{-5}\,T$ $\quad B_{2z} = +4.2 \times 10^{-5}\,T$

   (a) 6.4×10^{-5} T
   (b) 2.0×10^{-5} T
   (c) 4.2×10^{-5} T
   (d) 6.2×10^{-5} T
   (e) 2.2×10^{-5} T

$B_{net\,z} = B_{1z} + B_{2z}$

$= -2 \times 10^{-5}\,T + 4.2 \times 10^{-5}\,T$

$= 2.2 \times 10^{-5}\,T$