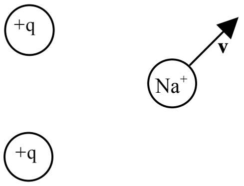
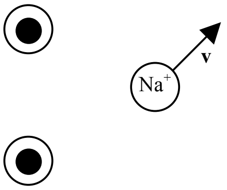
1) A sodium ion (12 protons, 12 neutrons, 11 electrons, Na^+) travels in the direction shown. In case i, on the left, the ion is in the presence of two unknown plus charges. In case ii, on the right, the ion is in the presence of two neutral, current-carrying wires (current coming out of the page, as shown).

i)

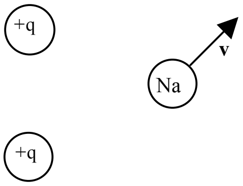


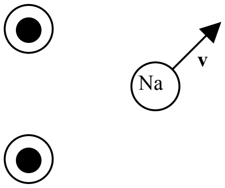
ii)



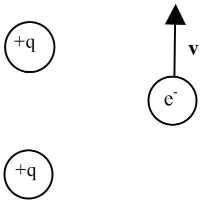
a) Determine the direction of the net force on the sodium ion for each case above. Show your work so it is clear how you arrive at your final force vector. Also be certain it is clear which of your vectors is the net force, if you draw more than one vector.

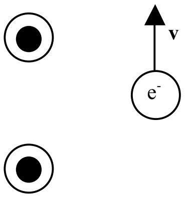
b) Suppose we replace the sodium ion with a sodium atom (12 protons, 12 neutrons, 12 electrons, Na). Which of the net force arrows would change? Why? Draw new net force vectors for the sodium atom on both images below.





c) Suppose we replace the sodium ion with a free electron. Further, suppose this electron travels directly upwards. Draw new net force vectors for the electron on both images below. Explain how you arrived at your answer.

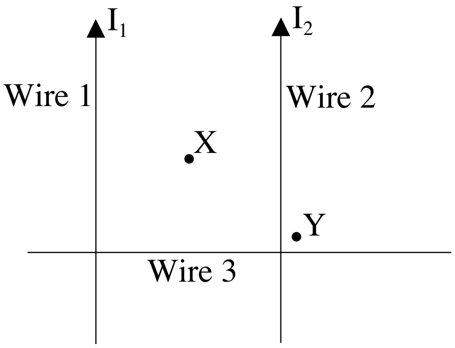




$E=kq/r^2$ $E=-\Delta V/\Delta r$ $PE=qV$ or $-pE\cos\theta$ $F=qE$ $F=-\Delta(PE)/\Delta r$

$B_{wire}=\mu_0 I/2\pi r$ (RHR1) $PE=-mB\cos\theta$ $F=qvB\sin\theta$ (RHR2) $q=1.6x10^{-19}c$

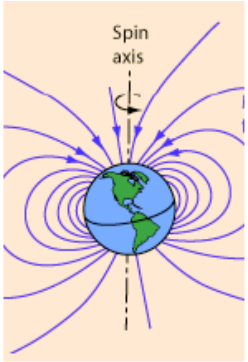
2. There are three wires carrying current. The direction of the currents for wires 1 & 2 are as shown in the drawing to the right. The current in wire 1, I_1, is smaller than the current in wire 2 (**$I_1 < I_2$**).
   At ***Point X***, the magnetic field is zero (**$B = 0$**).
   Note: Point X is ***equidistant*** to all three wires.



   a. Determine the **direction** of the current in wire 3 (**I_3**). **Explain**

   b. Determine the **direction** the **magnetic field** at point **Y**. **Explain**

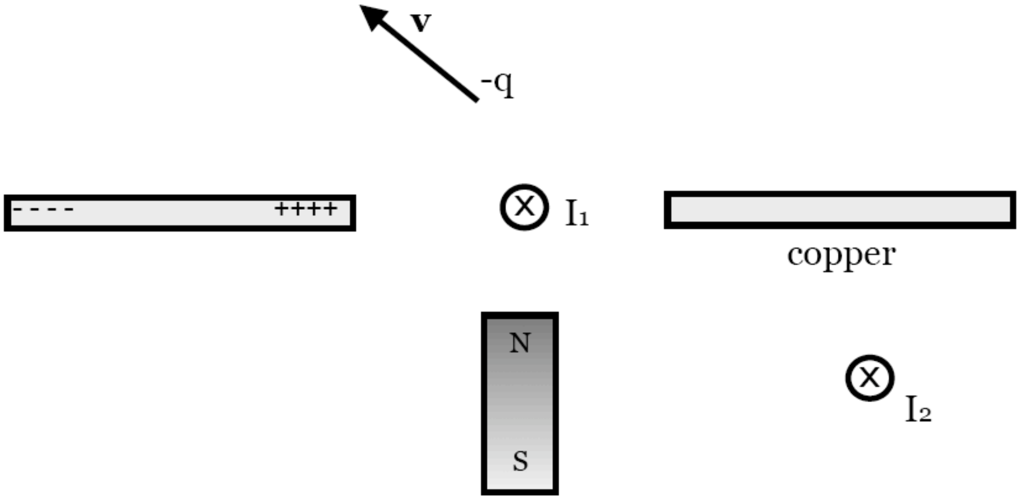
3. Cosmic rays (atomic nuclei stripped bare of their electorns) would continuously bombard Earth's surface if most of them were not deflected by Earth's magnetic field. Given that Earth is, to an excellent approximation, a magnetic dipole, the intensity of cosmic rays bombarding Earth's surface is greatest at which spot? Explain your answer using the magnetic field and force model.



a) North pole
b) Halfway between equator and north pole
c) Equator
d) South pole
e) even everywhere

$E=kq/r^2$ $E=-\Delta V/\Delta r$ $PE=qV$ or $-pE\cos\theta$ $F=qE$ $F=-\Delta(PE)/\Delta r$
$B_{wire}=\mu_0 I/2\pi r$ (RHR1) $PE=-mB\cos\theta$ $F=qvB\sin\theta$ (RHR2) $q=1.6\times10^{-19}$c

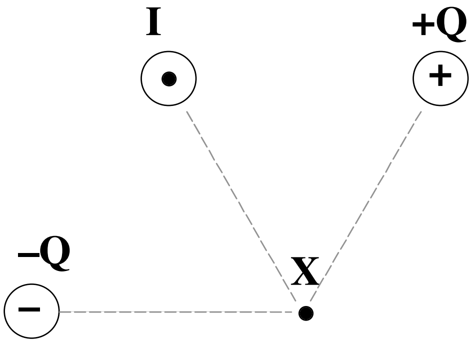
4. A charged rod, a moving charge, a neutral copper rod, a current in wire 2, and a bar magnet are arranged around a current carrying wire (wire 1) as shown.



Wire 1 is fixed in place. The rest are free to move or turn. Consider the interaction between wire one and each of the objects placed near it (you may ignore the effects of the objects on eachother). For each, will it stay where it is, mover toward away from the wire, move in some other direction, or rotate clockwise or counter clockwise? Justify your choice.

a. Neutral copper rod:
b. Insulating rod:
c. Bar magnet:
d. Current in wire 2:
e. Moving charge.

$E=kq/r^2$	$E=-\Delta V/\Delta r$	$PE=qV$ or $-pE\cos\theta$	$F=qE$	$F=-\Delta(PE)/\Delta r$
$B_{wire}=\mu_0 I/2\pi r$ (RHR1)		$PE=-mB\cos\theta$	$F=qvB\sin\theta$ (RHR2)	$q=1.6\text{x}10^{-19}$c



5. In the accompanying image, there are two stationary charges (+Q & –Q) and one wire with current (I). All are equal-distance from point X. At point X, draw the electrical field and the magnetic field due to these charges and current. Show your work.

$E=kq/r^2$	$E=-\Delta V/\Delta r$	$PE=qV$ or $-pE\cos\theta$	$F=qE$	$F=-\Delta(PE)/\Delta r$
$B_{wire}=\mu_0 I/2\pi r$ (RHR1)		$PE=-mB\cos\theta$	$F=qvB\sin\theta$ (RHR2)	$q=1.6\text{x}10^{-19}\text{c}$