ISP220, fall 2021: In-Class Project #8; 15 pts + 5 extra

Quarks, Spacetime, and the Big Bang

Thursday, September 30, 2021

Name: KEY Student # ____________

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1 Fields, 8 points

Some more field stuff. A reminder of how we represent vectors from a viewpoint in front or behind:

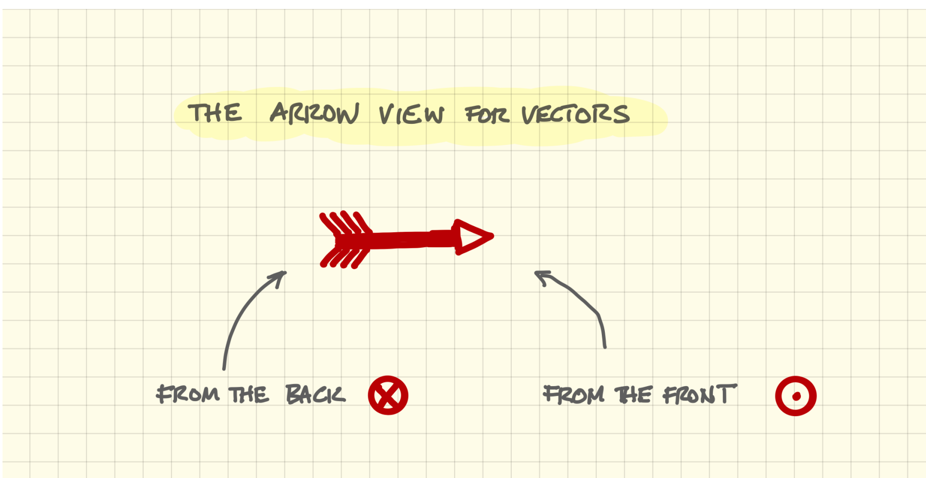

Figure 1: We indicate directions of vectors in a cartoon-ish way based on an image of an arrow.

For what follows you might find the videos of the field demonstrations shown in class useful. You can find them on the D2L page:

https://d2l.msu.edu/d2l/le/content/1490073/viewContent/10981927/View

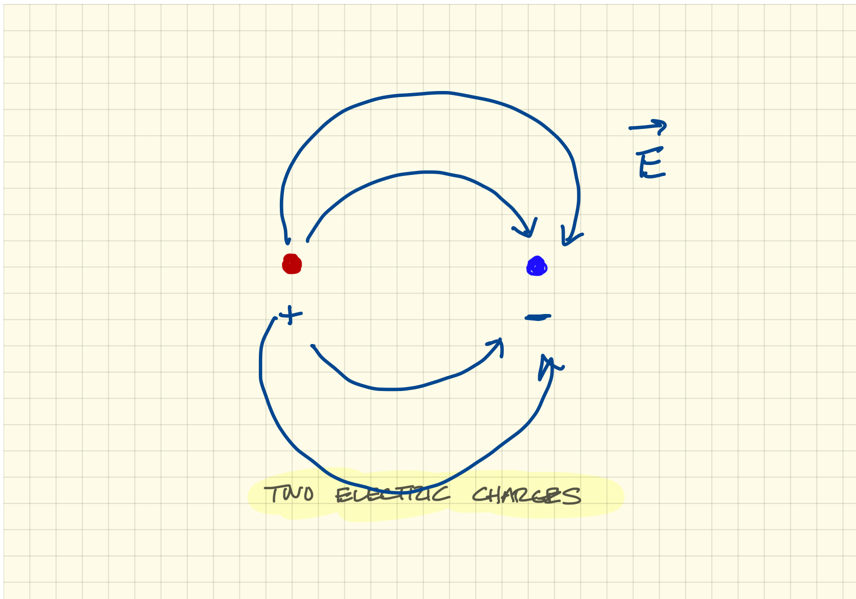

Figure 2: The left is a positive point charge and the right is a negative point charge. They are near to one another. Draw the electric field lines that this combination would produce. (1 point)

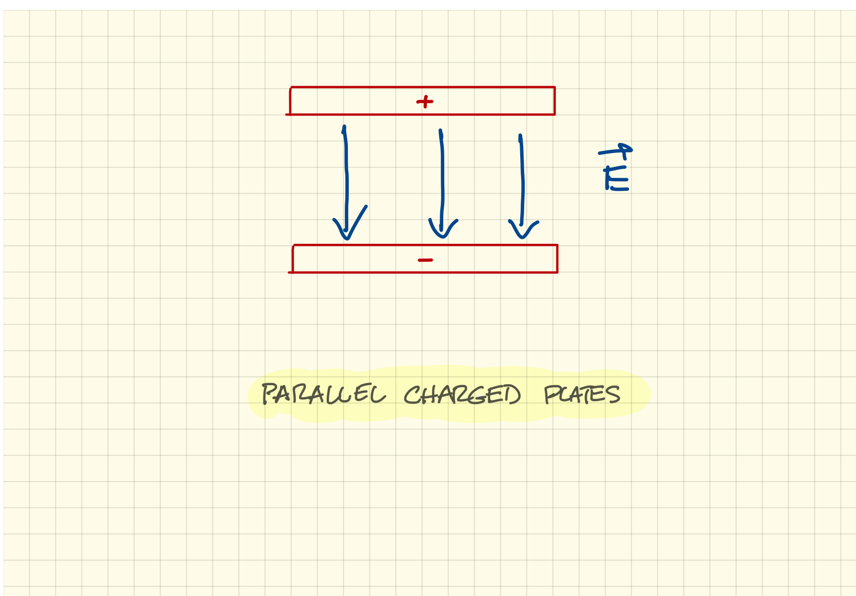

Figure 3: Draw the electric field lines between the charged plates. (1 point)

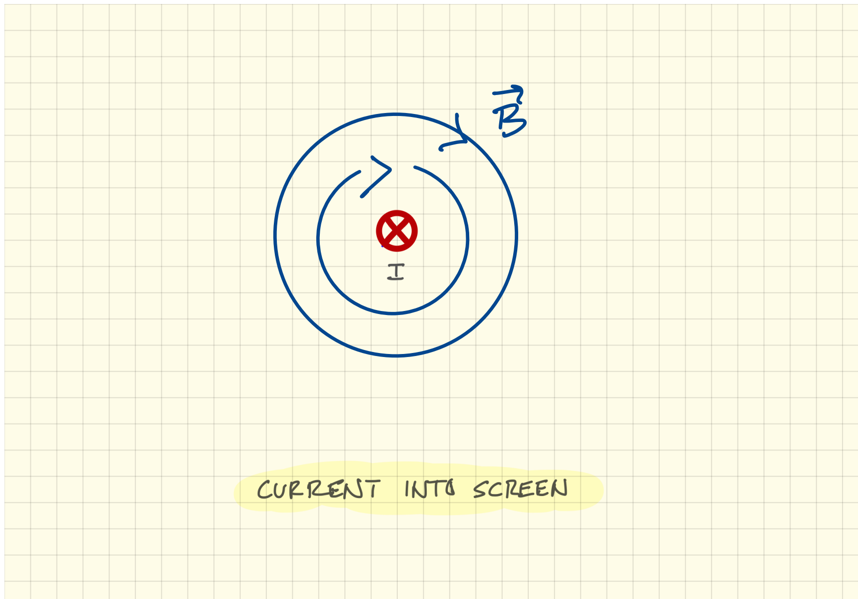

Figure 4: This is how the single current appeared on the video - the current is going into the screen. Draw in the magnetic field lines —the full circles— that resulted with directions correct. (You'll need your right hand.) (1 point)

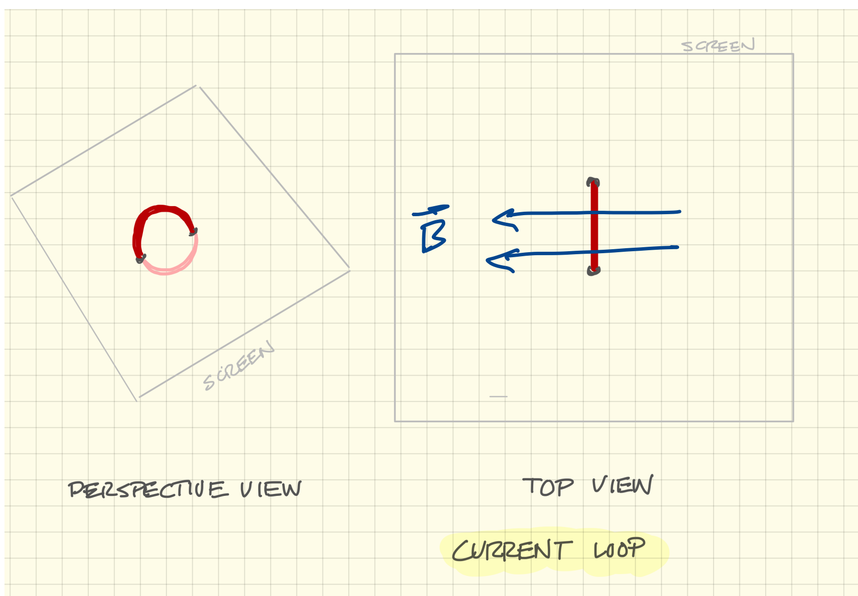

Figure 5: Left is a perspective view of the screen showing a current loop piercing the screen. The right is what you saw in class. Draw in the magnetic field lines assuming that the current is flowing bottom to top. (1 point)

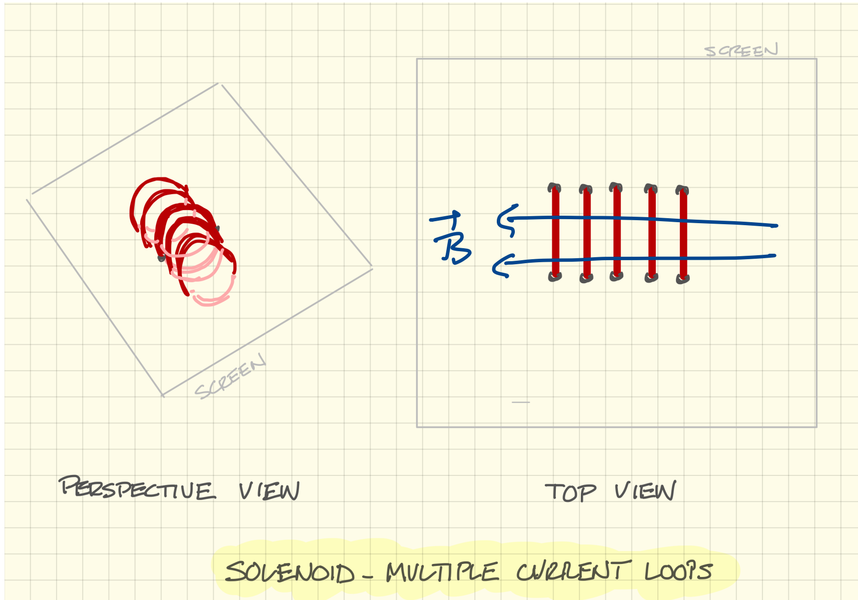

Figure 6: Left is a perspective view of the screen showing many aligned current loops piercing the screen. The right is what you see in class. Draw in the magnetic field lines without worrying about direction. (1 point)

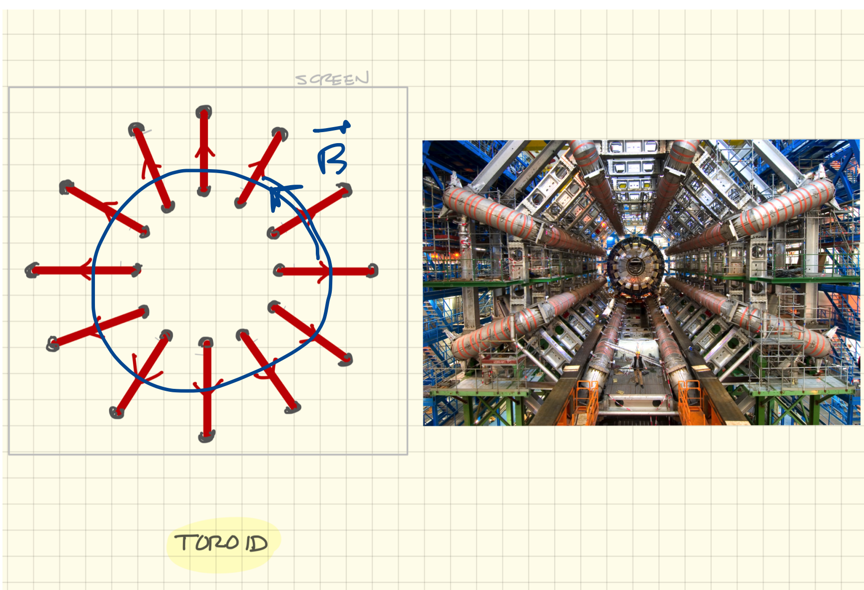

Figure 7: This is what you saw in class for a toroid—loops of current wrapped around a circle. Draw in the magnetic field lines without worrying about direction. The figure on the right is the large superconducting toroid magnet that surrounds the ATLAS detector. (1 points)

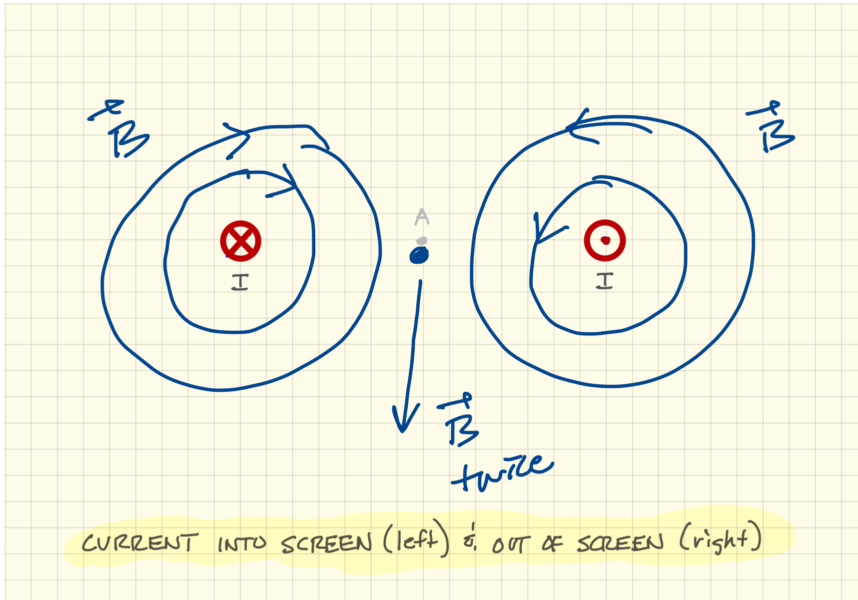

Figure 8: Here we have two currents, one flowing into the paper (left) and the other coming out at you (right). Draw in a few magnetic field lines —the full circles—with directions and indicate what the combined field would roughly be at point A, precisely between them. (1 points)

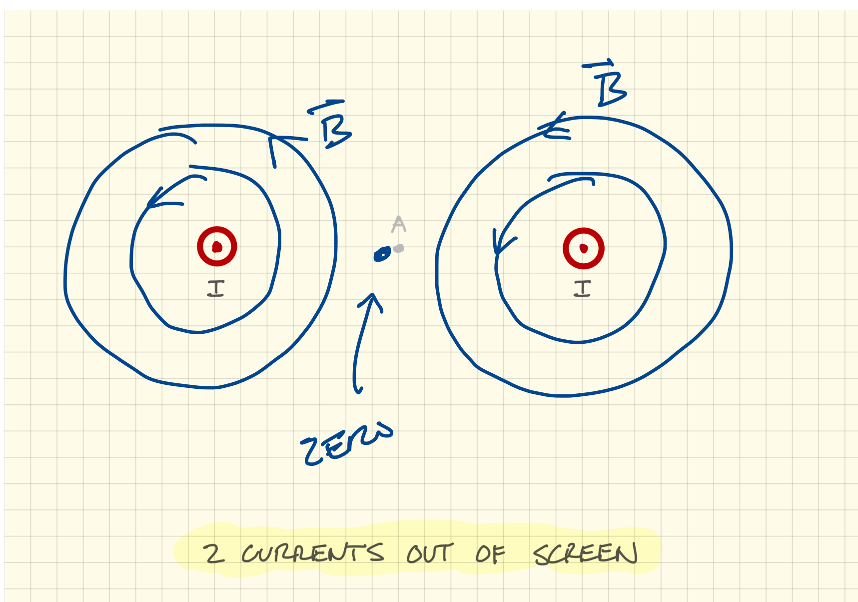

Figure 9: Here we have two currents, both of which are flowing out at you. Draw in a few magnetic field lines —the full circles— with directions and indicate what the combined field would roughly be at point A, precisely between them. (1 points)

2 Energy and Electron Volts, 7 points

Just like Figure 3 we have two parallel metal plates separated by a distance x with an electric charge on them as shown in Figure 10

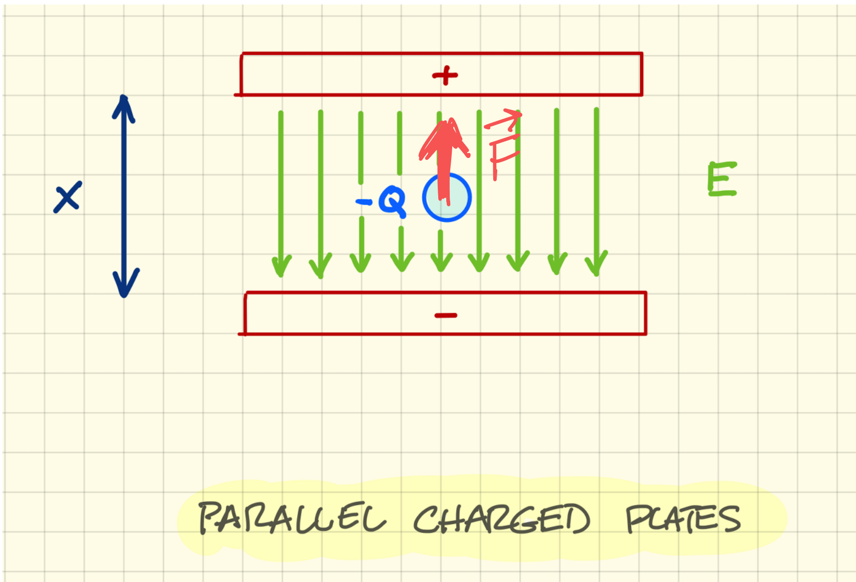

Figure 10: A negative charge in an electric field.

Answer (1 point): **Draw the force that Q feels as a bold arrow pointing from the charge.**

Let's invent some fake numbers here to simplify calculations. Define:

- $Q = 5$ Coulombs (remember, fake units...that's a really large electric charge!)
- $x = 2$ meters
- $V = 100$ Volts is voltage across the plates

For a parallel plate arrangement, the voltage and electric field are related by the spacing between the plates like this:

$$V = Ex.$$

So, remember that the units of electric field can be Volts per meter and Joules per Coulomb which is another way of saying:

$$1 \text{ V/m} = 1 \text{ J/C}$$

.

Answer (1 point): So, what is the electric field of this configuration in both units

$V = Ex$
$E = V/x = 100/2 = 50$

$E =$ 50 V/m, J/C

That electric charge, $-Q$ feels potential energy in that electric field of U. From the relationship in the text:

Answer (1 point): What is that energy in Joules?

$U = QV = (5)(100)$

$U =$ 500 J

Answer (1 point): If the distance between the plates had been twice as big, what would the energy be?

V would be twice as big

$U =$ 1000 J

Now let's use real numbers for a question. Your grandparents' TV set.

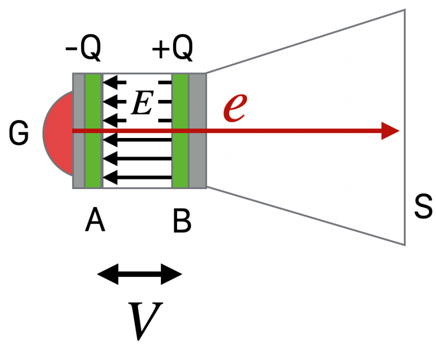

Figure 11: Here's an old-timey TV set. Electrons are "boiled" off of a cathode at G and enter the region between A and B, where they are accelerated in the electric field created between the two plates in a grid. They then strike the screen at S and you see Howdy Doody in black and white.

The voltage in the acceleration region is

$$V = 20,000 \text{ V}$$

Answer (1 point): What is the voltage expressed in J/C? (Trick question.)

$V =$ 20,000 J/C

The kinetic energy in Joules that each electron acquires is

$$U = QV$$

Answer (1 point): How much energy is that in Joules?

$U = QV = (1.6\times10^{-19}\ C)(20{,}000\ J/C)$

$= 3.2\times10^{-15}\ J$

$KE =$ 3.2×10^{-15} J

Remember that energies expressed in electron volts are a familiar-looking conversion:

$$1\text{ eV} = 1.6\times10^{-19}\text{ J}$$

Answer (1 point): What is the energy of each electron in electron volts?

$(3.2\times10^{-15}\ J)\left(\frac{1\ eV}{1.6\times10^{-19}\ J}\right) = 20{,}000\ eV$

$KE =$ 20,000 eV $= 20\ keV$

3 A Dipole Beam Magnet

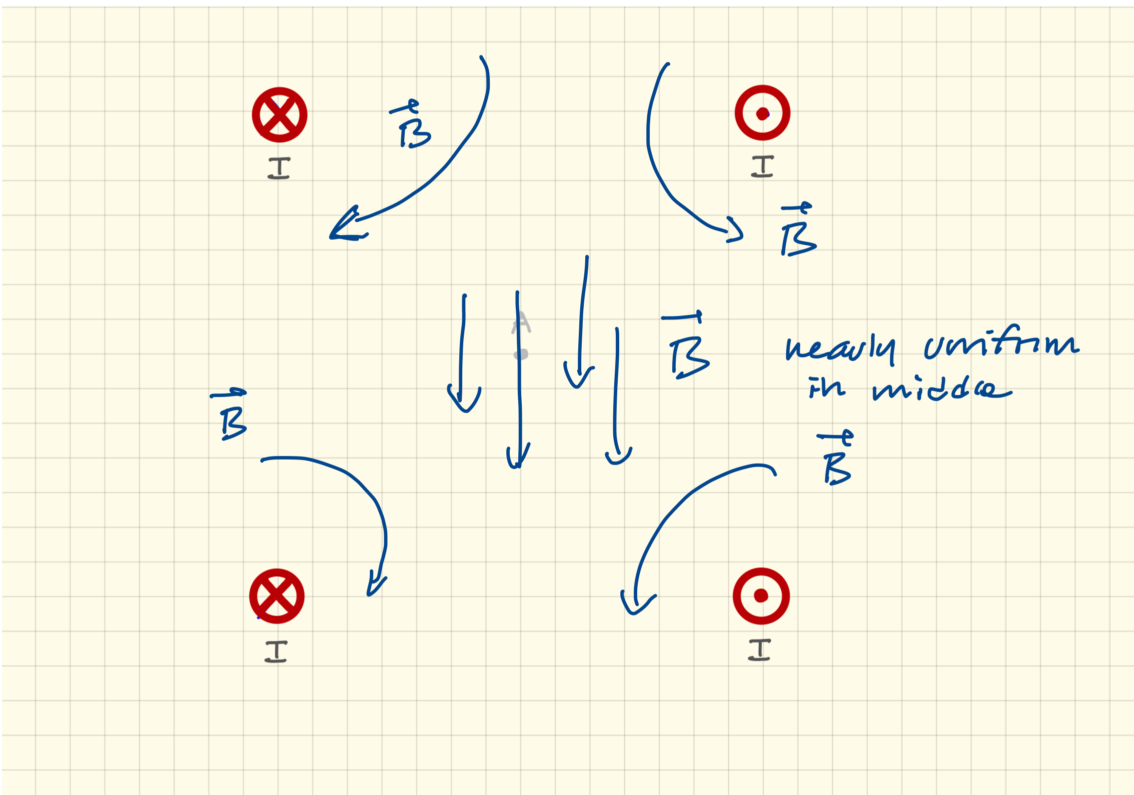

Figure 12: Now there are four currents into and out of the paper as before. Draw in a few magnetic field lines —the full circles— with directions and indicate what the combined field would roughly be at point A, precisely in the center of the collection. This is how a dipole beam magnet works. (5 points)