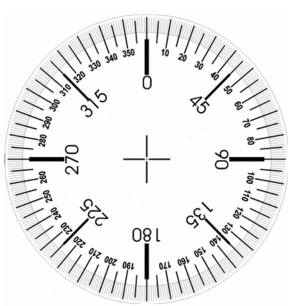
Electromagnetism and Light Course
HW08 – Building and testing a galvanometer

1) INTRODUCTION
Watch lecture 7b, which is also available as a .pdf at
http://kestrel.nmt.edu/~rsonnenf/phys571/handouts/lecture8.pdf.

2) BUILD THE GALVANOMETER
Build a galvanometer according to the instructions in the lecture. Important points of the construction are also summarized below:

a) Use a toilet paper tube.
b) Cut a 2 cm slot in the middle of the tube and fold the cardboard in so as to make a "platform" for the compass you were provided in your kit.
c) Some scotch tape or electric tape may be useful to stabilize the platform. (You could also make a platform with a popsicle stick or small ruler, the goal is to mount the compass at a point near the long axis of the toilet paper tube.)
d) Print out the small degree scale attached below and adhere it to the platform. (Or print out the large one to help you estimate the rotations by eye). If you use the scale, the 90 and 270 degree ticks should be aligned with the long axis of the toilet paper tube.
e) Adhere the compass to the platform (and the degree scale if you use it) (double stick tape?)
f) Wind 20 windings of magnet wire around the TP tube to the left of the slot. Make sure to leave at least a foot of wire before you start winding so you have a lead to connect your battery to. The 20 windings should all fit within about 1 cm, as near as possible to the edge of the slot.
g) Use tape to secure the windings as needed so they don't unwind. The tape will not affect the magnetic or electrical properties of the device in any way.
h) Stretch the wire across the back of the tube behind the slot so you can put 20 more windings to the right of the slot. The windings can be either clockwise or counterclockwise, but be consistent on both sides of the slot. (If you switch direction the magnetic field will be quite different and, though the compass needle might move some, the results will make no sense.)
i) Make sure to leave another foot of free wire after finishing the windings to the right of the slot.
j) "Tin" the ends of the magnet wire, which will also remove the insulation. Touch a tip of the hot iron (with perhaps a small solder ball on it to conduct heat better) to the ends of the wire. Feed in fresh solder and move the solder tip back and forth about 1 cm. You should see the wire ends become clearly silver. Feel free to repeat if it does not work at first.
k) Attach the galvanometer to a slat of wood (as shown in the video). You could also attach it to an aluminum bar or any other heavy object that will tend to hold it down and keep it straight. (Don't attach it to iron or steel as they WILL affect the magnetic fields to be measured).
l) Drill six holes in the wood and stick the following resistors, 22, 47, 100, 220, 470 and 1000 Ohm. These values work well with this galvo design, so get something close to these if these values are not available.



3) CALIBRATE THE GALVANOMETER

a) Test your galvanometer and check that the compass needle rotates freely and remains pointed north as you turn the wooden base. (You may have to retape to the base if you didn't mount it level to begin with).
b) Orient the galvanometer so that the North arrow points at right angles to the long axis of the TP tube. If you mounted the degree scale properly, the North arrow should be pointing at the 0 or the 180 degree mark.
c) Your goal is to arrange your battery, a resistor, and your galvanometer in series. The next steps make sure you understand how to do that.
d) Attach a clip lead to the positive terminal of your 6 Volt battery and the other end to one of the 220 Ohm resistor.
e) Attach another lead to the other end of the resistor and the other end of that lead to the galvanometer.
f) Attach a third lead to the other end of the galvanometer, and thence back to the negative terminal of the battery.
g) As soon as you attach the lead, you should see a noticeable swing in the compass needle. If you don't, you either don't have a good electrical connection or your compass is stuck (or you oriented it wrong).
h) Measure and record your battery voltage [Vbat]. (It is nominally Vbat=6 V, but actually it's probably a bit different. Use the measured value).
I) Measure and record your resistor values [Rmeas] (I put nominal values below, correct them)
j) Calculate and record I-Ohmslaw for each resistor (I-Ohmslaw = Vbat / Rmeas)
k) Measure theta. (It should be small for large resistors and nearly 90 for the 22 Ohm)
l) Record tan(theta).
m) Calculate I-expt = 0.05 * tan(theta).

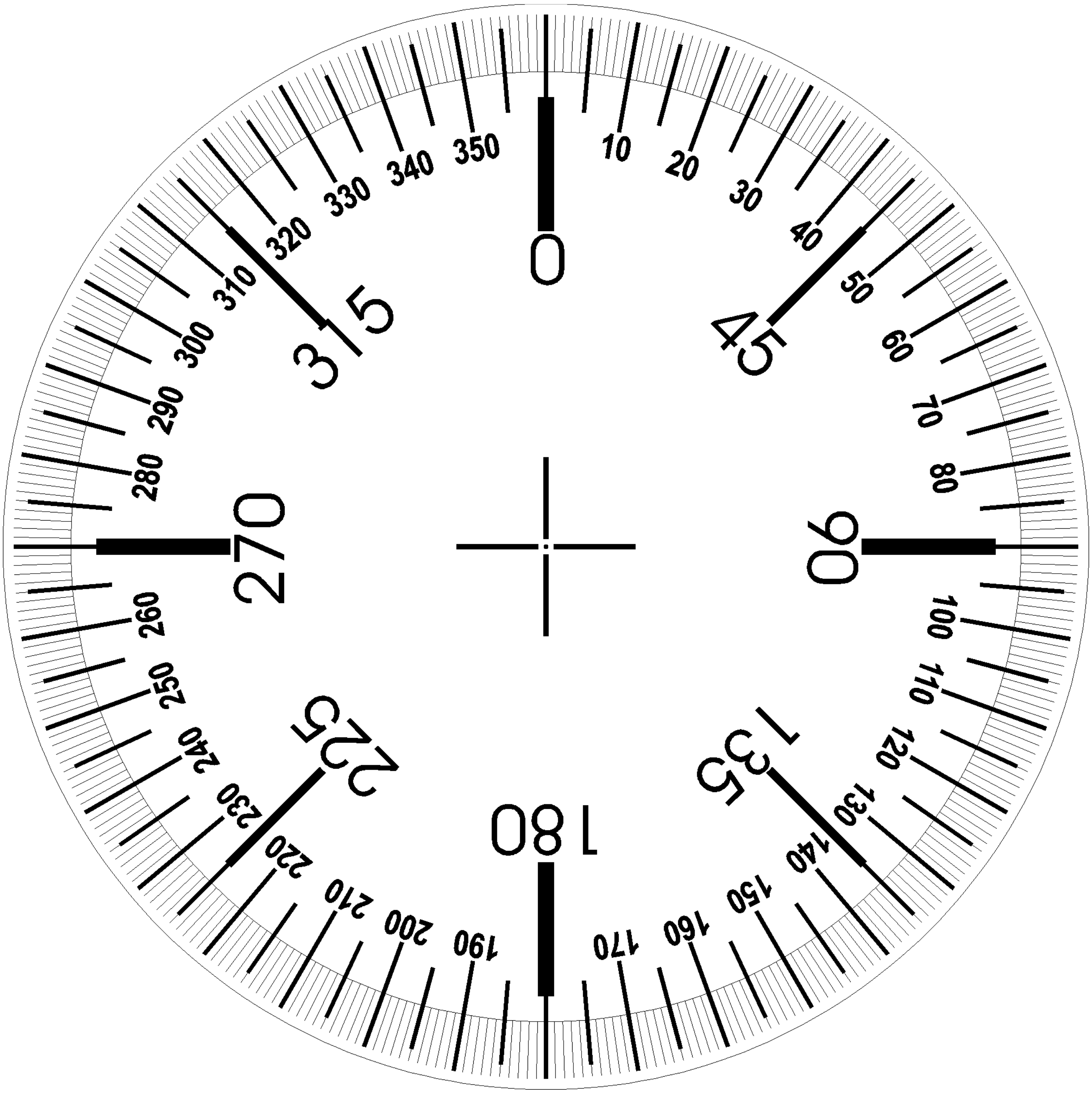
R (Ohms)	I-Ohmslaw	Theta	tan(theta)	I-expt
22				
47				
100				
220				
470				
1000				

4) DATA ANALYSIS
I got the value of 0.05 for my galvanometer, but you can calibrate yours. Plot I-Ohmslaw vs tan(theta). Use fitting software (Excel?) to give you the slope of the line. (Or do it with pencil and paper and a ruler!). What is your slope? (Now you have a calibrated galvanometer!)

5) MAGNETIC FIELD
The magnetic field in your galvanometer has a magnitude of B=mu0*n*I. For the 1000 Ohm resistor, estimate the magnetic field you created in your TP tube. Hint. It is very very small. You made a sensitive instrument!

6) FEEDBACK

Was this lab interesting? Do you think you might be able to use parts of it? How could it be improved? Let me know.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K) Upload a photo

Build a homopolar motor using the supplies in your kit.

Upload a video of your motor spinning. If you have trouble with videos, you may upload photos of your completed motor.

2) You would like to be comfortable explaining how this motor works to your class, so please do that here by answering parts a, b, c, and d.

a) Draw a sketch of your actual wire loop and indicate approximate dimensions in centimeters.

b) Indicate for the orientation of your battery what the direction of current flow is. Show a couple of magnetic field lines where they intersect the wire and show the direction of magnetic field at these lines (assume your battery was North Pole upward). Show on your sketch the result of the cross product and explain why the motor turns, and in which direction. If you are able, sketch the current, the field and the force using different colors of ink.

c) Draw a second sketch. It is same as the first except that you turn your magnet upside down (South pole up). Show the current, B-field and force and which direction the motor spins now.

d) Let us estimate the amount of force and torque that your motor generates. Please note – this is very rough. You will be ESTIMATING. You are only trying to get an answer within a factor of 10 so pleas do not stress about how complicated it is to do these calculations precisely. Estimating is an important skill. The magnets in your kit are Neodymium/Iron/Boron (NIB). If you check this table: https://en.wikipedia.org/wiki/Rare-earth_magnet you will see that the magnetic field at the surface of the magnet is roughly one Tesla. (20,000 X the Earth's field!).   If you look at page 24 of Lecture 3 you will see that magnetic field falls off as roughly the cube of distance. Given the characteristic dimension of the magnet as about one centimeter, we will assume the field is one Tesla there.

I) Using an inverse cube law, how far should you be for the field to be only 0.1 Tesla?
II) How far will you need to be for the field to be about 0.01 Tesla? (The answer is roughly 4 cm – calculate this distance to two decimal places)
III) Estimate what length of wire is subject to the 0.1 Tesla field and calculate the force exerted on that wire. You will need to know the current put out by your AA battery. It is about 5 Amperes.
IV) Estimate what length of wire is subject to the 0.01 Tesla field and calculate that contribution to the force.
V) To calculate the torque, multiply the force you got by the wire's distance *from the rotation axis of the motor* (that is, a vertical line through the center of the battery). What is your torque estimate?