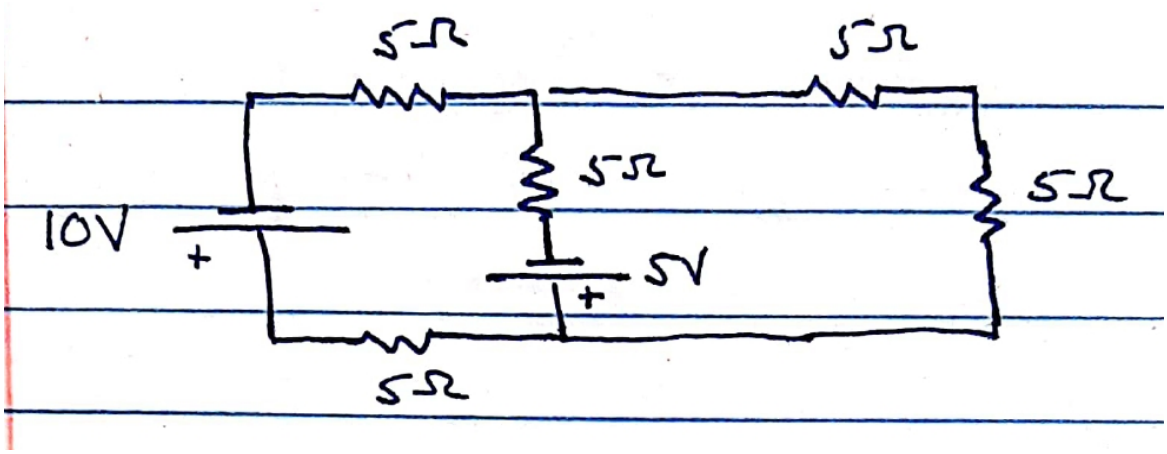
Physics 1320: Homework #10
Due Friday, 4/8/2022

Magnetic Forces

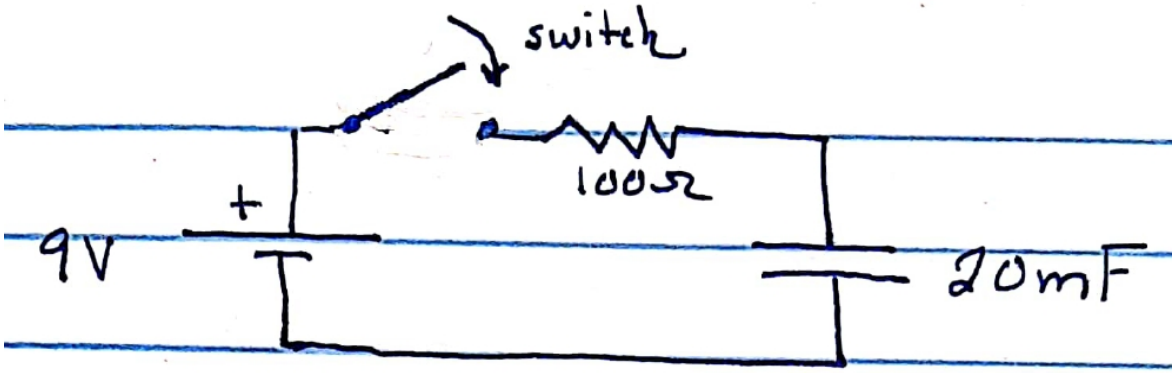
Please read Chapter 27 in your textbook. Pass in solutions to the seven problems below. The first problem finishes up Kirchoff's laws, and the second problem provides a chance for you to look at a time-dependent circuit.

Comment on notation: I will do my best to refer to the magnetic dipole moment as $\vec{m}$, even though your textbook prefers to denote the magentic dipole moment as $\vec{\mu}$, substituting the Greek letter μ for m. We are abandoning your textbook because the symbol μ is used for magnetic permeability, and it is quite confusing to use the same symbol for two different quantities, particularly when the two are actually related to one another.

1. Consider the two-loop circuit sketched below. Find the current passing through each battery, and calculate the rate at which energy is delivered to the circuit by the two batteries.

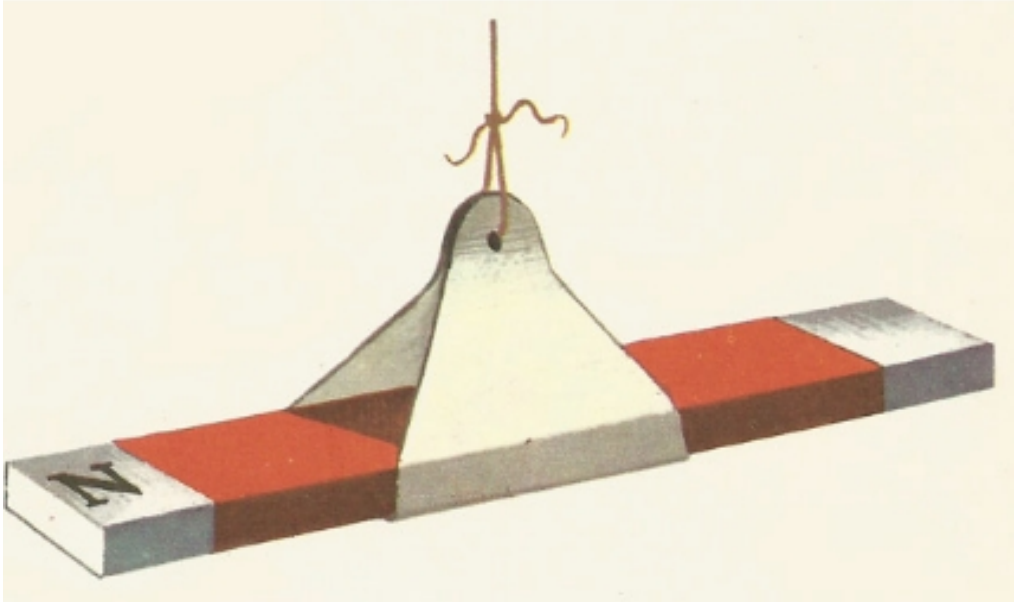


2. An ideal battery (no resistance) for which $V = 9$ Volts is placed in series with a 100 Ω resistor and a 20 mF capacitor in a closed loop circuit, as shown in the figure below. What is the RC time constant? The switch is closed at time $t = 0$. What will be the current in the circuit just after the switch is closed? What is the current in the circuit a long time after the switch is closed? Use DESMOS to make a graph of the current in amperes versus the time in seconds, from $t = 0$ to $t = 5RC$.

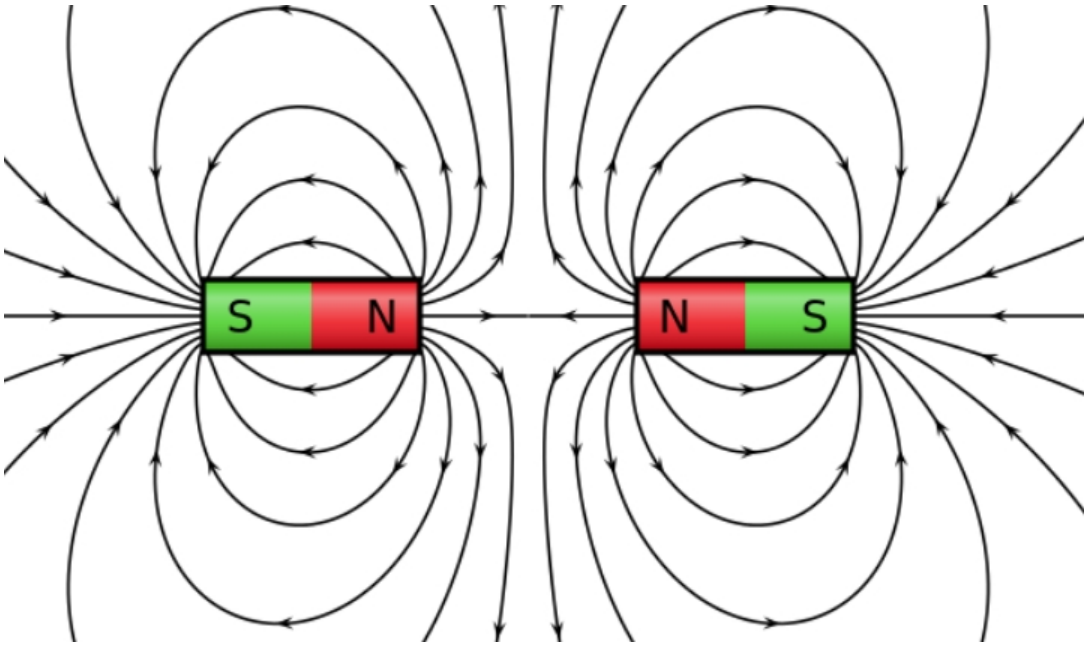


3. The N and S pole faces of a bent cylinder magnet form are separated from one another by a small gap, forming the magnetic analogue of a parallel plate capacitor. Positive magnetic charge is uniformly distributed on the north pole face and negative magnetic charge is uniformly distributed on the south pole face. If the magnetic field B in the gap is 0.2 Tesla, what is the magnetic surface charge density on each of the two pole faces? If the radius of the pole faces is 4.0 cm, what is the force of attraction between them?

4. A thin bar magnet is suspended by a string attached to its midpoint. The magnetic charge at the pole face marked N is 5×10^3 Cm/s, and the magnetic charge on the pole face marked S is -5×10^3 Cm/s. The ends are separated by a distance of 20 cm. What is the magnetic dipole moment m of the bar magnet? If the Earth's magnetic field at this location has a strength of 0.5 Gauss in a north/south direction, what is the torque exerted on the bar magnet if $\vec{m}$ points northeast/southwest?



5. The N pole faces of two cylindrical neodynium magnets having a radius of 0.5 cm and a length of 20 cm are brought together so that their faces are parallel and there is a small gap between them. The magnetic surface charge density on each pole face is 2×10^6 $\mathrm{Cm^{-1}s^{-1}}$. (a) What is the force between the magnets in the limit in which the gap goes to zero? Assume that the magnets are much longer than shown in the figure below, so that you only need to concern yourself with the repulsion between N and N. (b) What is the force between the magnets when they are separated by 0.5 m? At this separation you can approximate the four pole faces as point-charges.



6. How slow does a proton have to be traveling so that it will undergo circular motion while remaining between the pole faces of the magnetic shown in problem 3? What is the frequency of the orbit with a radius of 3.5 cm?

7. A positively charged krypton ion (+1) is accelerated from rest through a potential difference of 1 kV, after which it coasts at a constant velocity along the z axis. When it passes between the pole faces of a magnet where $\vec{B} = 0.2$ Tesla in the x direction, it is deflected, and after emerging from the magnet it continues on in a new direction. (a) What is the cyclotron frequency for a krypton ion in an 0.2 Tesla field? (b) What is the angle of deflection as measured from the z axis if the ion is subjected to the magnetic field for a time of 2.0 μs? (c) How far does it travel when it is between the pole faces?