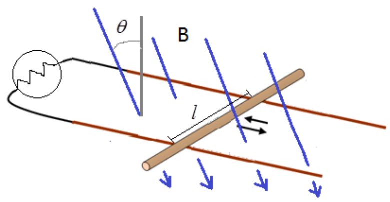
Homework 11: Motors/Generators due 6/8

Problem 1. A 10Ω light bulb is connected to the sliding bar via conducting rails. And the ℓ = 20cm bar is immersed in a 5T magnetic field, making an angle θ = 20° with the vertical.



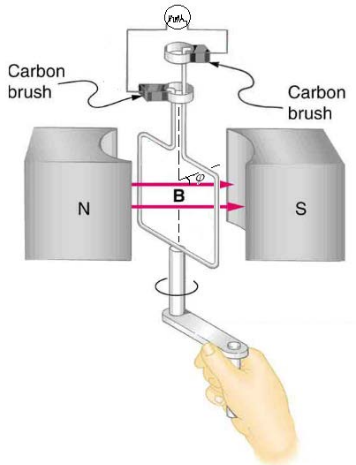
(a) How fast and in which direction must you move the bar if you want the current to circulate CCW with magnitude 2.5A?

(b) What force **F** must you exert (this is equal/opposite to the force the magnetic field exerts on the wire, $\mathbf{F}_B$)?

(c) Let's take a look at energy conservation. The power you exert should equal the power dissipated by the lightbulb. What power ($\mathbf{F}\cdot\mathbf{v}$) do you exert? What power (i^2R) does the lightbulb dissipate? Are these the same?

(d) And now let's take a look at the magnetic field's net power. Magnetic fields are supposed to do no net work (or power). And here the magnetic field seems to exert two different powers: one is $P_{emf} = I\xi_{effective}$ (basically IΔV from the circuits stuff we studied before) and the other is $P_{mechanical} = \mathbf{F}_B\cdot\mathbf{v}$. What are these powers? And what is the net power the magnetic field exerts? Is it zero?

Problem 2. Now our 10Ω light bulb is connected to an N = 75 square loop (side lengths ℓ = 20cm) being rotated in a 5T magnetic field, which presently makes a 20° angle w/r to the loop.



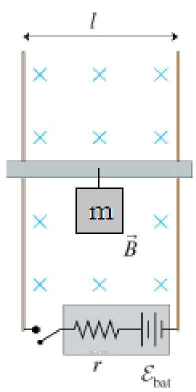
(a) What frequency of rotation, f, and in what direction (CW, CCW) must you rotate the loop if you want the current to pass rightwards through the lightbulb with magnitude 2.5A?

(b) What torque $\boldsymbol{\tau}$ must you exert (you need to calculate the $\mathbf{F}_B$ force on the front wire and back wire, then the torque each of these exerts about the central axis, and then sum to get the net torque, $\boldsymbol{\tau}_B$; your torque is equal/opposite to this)?

(c) Let's take a look at energy conservation. The power you exert should equal the power dissipated by the lightbulb. What power ($\boldsymbol{\tau}\cdot\boldsymbol{\omega}$) do you exert? What power (i^2R) does the lightbulb dissipate? Are these the same?

(d) And now let's take a look at the magnetic field's net power. Magnetic fields are supposed to do no net work (or power). And here the magnetic field seems to exert two different powers: one is $P_{emf} = I\xi_{effective}$ and the other is $P_{mechanical} = \boldsymbol{\tau}_B\cdot\boldsymbol{\omega}$. What are these powers? And what is the net power the magnetic field exerts? Is it zero?

Problem 3. A battery with internal resistance $r = 25\text{m}\Omega$, and potential difference ξ_{bat} is connected to an $\ell = 20\text{cm}$ slide rail supporting a weight of m = 50kg. And this is immersed in a magnetic field B = 2T.



(a) What force must the magnetic field exert on the bar to raise it at rate 2m/s (speed makes no difference in this calculation)?

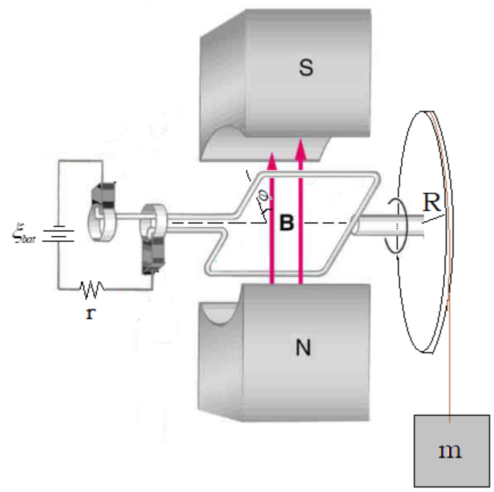
(b) What current must be flowing through the bar to engender this force? Is the battery hooked up to make the current flow in the proper direction to produce the desired upwards force?

(c) What must ξ_{bat} be to give rise to this current?

(d) Now let's take a look at energy (power) conservation again. What is the power supplied by the battery? What is the power absorbed by the resistor? What is the mechanical power absorbed by the weight ($P_{mechanical} = dPE_g/dt = mg \cdot dh/dt = mgv$)? Does the power supplied equal the power absorbed?

(e) And now let's check that the magnetic field does no net work (power). The magnetic field exerts two powers, again. It exerts a mechanical power $P_{mechanical} = \mathbf{F}_B \cdot \mathbf{v}$, and also $P_{backemf} = I \cdot \xi_{effective}$. Do these two add up to zero?

Problem 4. Now consider a different, more economical motor. So say we go back to our N = 75 turns, ℓ = 20cm square loop, immersed in magnetic field B = 5T, and presently making 20° angle with the loop. Let's also take the internal resistance of our battery to be r = 25mΩ. And finally, let's say that we're trying to use our battery to generate a torque sufficient to lift this m = 50kg mass via pulley with radius R = 5cm.



(a) What torque must the magnetic field exert on the loop to raise the bar at an angular rate ω = 2rad/s (angular velocity makes no difference in this calculation)?

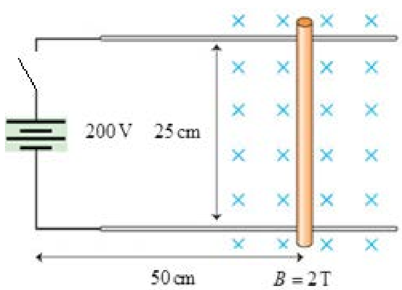
(b) What current must be flowing through the loop to engender this torque? Is the battery hooked up to make the current flow in the proper direction, to produce the desired CCW torque?

(c) What must ξ_{bat} be to give rise to this current?

(d) Now let's take a look at energy (power) conservation again. What is the power supplied by the battery? What is the power absorbed by the resistor? What is the mechanical power absorbed by the weight ($P_{mechanical} = dPE_g/dt = mgv = mg\omega R$)? Does the power supplied equal the power absorbed?

(e) And now let's check that the magnetic field does no net work (power). The magnetic field exerts two powers, again. It exerts a mechanical power $P_{mechanical} = \boldsymbol{\tau}_B \cdot \boldsymbol{\omega}$, and also $P_{backemf} = I \cdot \xi_{effective}$. Do these two add up to zero?

Problem 5. A device called a *railgun* uses the magnetic force on currents to launch projectiles at very high speeds. An idealized model of a railgun is illustrated in the figure. A power supply is connected to two conducting rails. A segment of copper wire (the projectile), in a region of uniform magnetic field, slides freely on the rails. The wire has a 0.28mΩ resistance and a mass of 75kg.



(a) What will be the force on the segment at t = 0, when the switch is closed?

(b) What will be its terminal velocity?