PHYS 4310 Sample problems (In class Midterm Exam)

February 26, 2018

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YOU HAVE 85 MINUTES TO COMPLETE THIS TEST

1. A copper rod of length, h, mass, m, and electric resistance, R, slides with negligible friction on metal rails that have negligible electric resistance (see Fig. 1). The rails are connected on the right with a wire of negligible electric resistance, and a magnetic compass is placed under this wire. There is a uniform magnetic field, $\vec{B}$, pointing out of the page that fills the entire region.

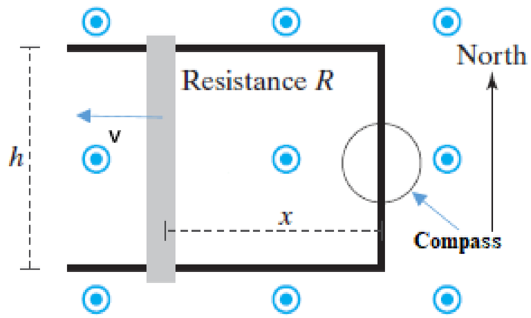


Figure 1: A rod sliding on u-shaped wire in a uniform magnetic field.

(a) If the rod moves to the left at a speed v, what is the magnitude and direction of the current in the circuit? Which direction would the compass deflect?

(b) What is the magnetic force on the bar?

(c) If the rod starts out with speed, v_0, at time, $t = 0$, and is left to slide, what is its speed at a later time, t.

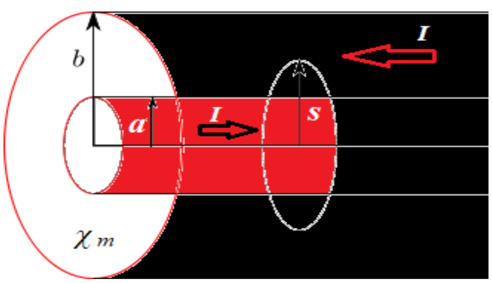
(d) The initial kinetic energy of the bar was, of course,

$$KE_i = \frac{1}{2}mv_0. \tag{1}$$

Show that the energy delivered to the resistor is exactly equal to this initial kinetic energy.

2. Griffiths Problem 7.14 (*remember the demo I showed you in class*)

3. A coaxial cable consists of two very long cylinders separated by linear insulating material of magnetic susceptibility, χ_m. A current I flows down the inner conductor and returns along the outer one, in each case the current distributes itself uniformly over over the volume (inner cylinder) and over the surface (outer cylinder).



(a) Find the magnetic field in the regions $s < a, a < s < b$, and $s > b$

(b) Determine the magnetization and the bound currents.

(c) Using the free and the bound currents find the magnetic fields in the regions $s < a, a < s < b$, and $s > b$.

(d) Find the magnetic energy stored in a section of length l.

4. To find the net force on the "northern" hemisphere of a uniformly charged solid sphere of radius, R, and charge Q using the Maxwell's stress tensor

$$\vec{F} = \oint_S \overleftrightarrow{T} \cdot d\vec{a}, \tag{2}$$

we considered two surfaces shown in Fig.2

(a) Using Gauss's law, find the electric field inside.

(b) Evaluate the contribution of the force resulting from second surface

$$\vec{F}_1 = \int_{S_2} \overleftrightarrow{T} \cdot d\vec{a}. \tag{3}$$

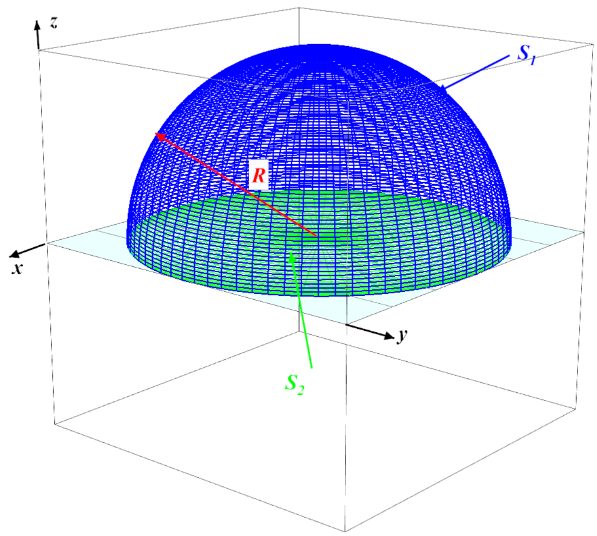
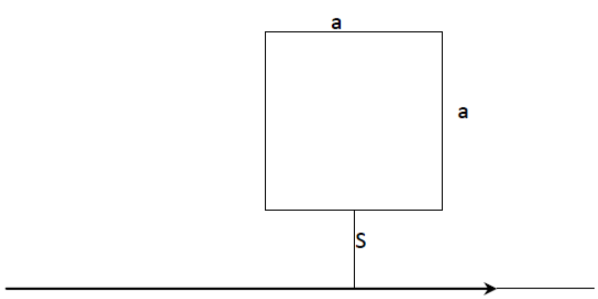


Figure 2: The two surfaces S_1 and S_2.

5. A square loop of wire (side a) lies on a table, a distance s from a very long straight wire, which carries a current, I, as shown in the figure below.

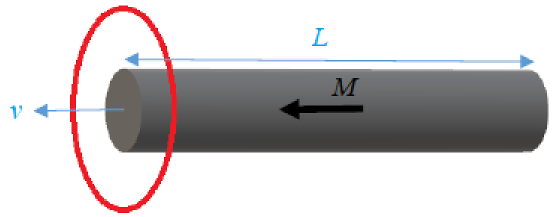


(a) Find the flux of $\vec{B}$ though the loop.

(b) If someone now pulls the loop directly away from the wire, at speed v, what emf is generated? In what direction (clockwise or counterclockwise does the current flow?

(c) What if the loop is pulled to the right at speed v, instead of away?

6. A long cylindrical magnet of length, L, and radius, a, carries a uniform magnetization, M, parallel to its axis. It passes with a constant velocity v through a circular conducting ring of slightly larger radius, b.



(a) Plot a qualitative graph for the magnetic flux as a function of time.

(b) Plot the emf induced as function of time.

(c) Determine the direction of the induced current.

7. In Fig . 3 there is a solenoidal coil with radius, b. A thin conducting ring of radius, a, (i.e. $a < b$) is sitting under the solenoid. The solenoid is connected to a switched-off power supply. You suddenly turned the switch on.

(a) If the ring has a resistance, R, what would be the magnitude and direction of the induced current in the ring? Both the axial and radial components of the magnetic field of the solenoid can be approximated to be a constant.

(b) Find the approximate magnitude and the direction of the magnetic force on the ring.

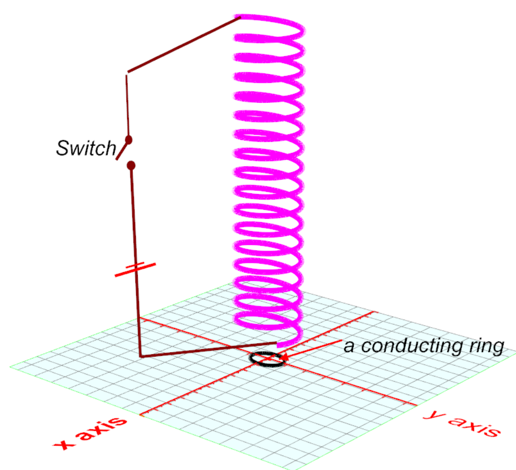


Figure 3: A solenoidal, a ring sitting at the bottom of the solenoid. The two ends of the solenoid are connected to a power suply with a switch.

8. A perfectly conducting spherical shell of radius a rotates about the z axis with angular velocity ω, in a uniform magnetic field, $\vec{B} = B_0\hat{z}$.

(a) An emf will develop between the north pole and the equator. Explain qualitatively how this emf is developed.

(b) Calculate the magnitude of this emf.

9. Griffiths Problem 7.29

10. Two coils are wound around a Ferromagnetic material as shown in Fig. 5. The Ferromagnetic material allows to create same flux, Φ, through every winding in both coils. The "primary" winding has N_P turns and the secondary winding has N_S turns. If the current, I_P, in the primary winding is changing, show that the emf in the secondary winding is given by

$$\varepsilon_S = \frac{N_S}{N_P}\varepsilon_P, \tag{4}$$

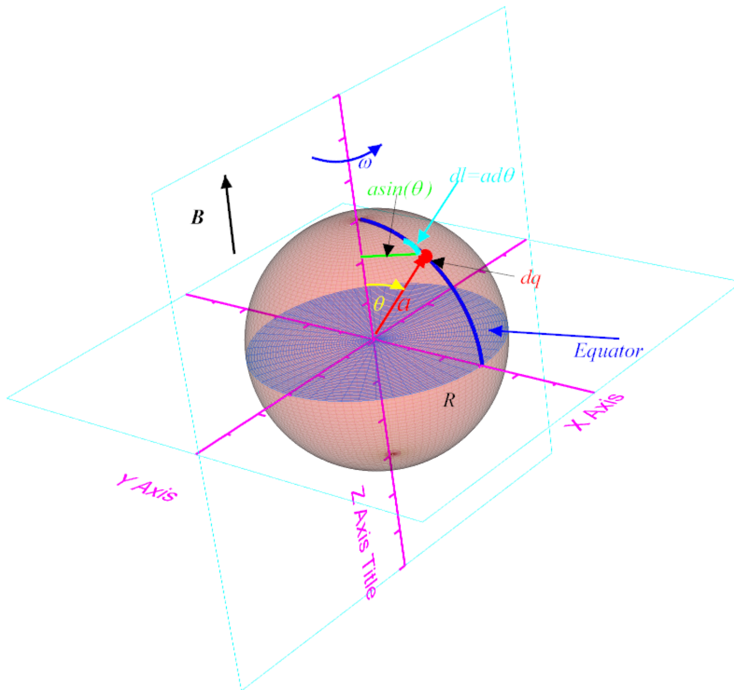


Figure 4: A conducting spherical shell spinning about the z-axis in a region of magnetic field.

where ε_P is the (back) emf which is equal to the source voltage supplying the changing current, I_P, in the primary.Suppose this transformer takes an input AC voltage of Amplitude, ε_P, and delivers an output voltage of Amplitude, ε_S, which is determined by the turns ratio ($\varepsilon_S/\varepsilon_P = N_S/N_P$). If $N_S > N_P$, the output voltage is greater than the input voltage.

(a) Why does not this violate conservation of energy?

(b) In ideal transformer the same flux passes through all turns of the primary and of the secondary as shown in Fig. 5. Show that in this case, $M^2 = L_P L_S$, where M is the mutual inductance of the coils, and, L_P, L_S are their individual self-inductances

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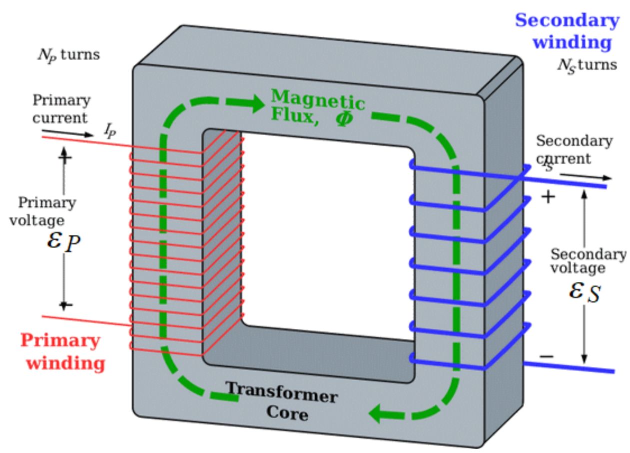

Figure 5: An ideal transformer.