PHY2054 General Physics II

Prof. Douglas H. Laurence

(Substituting for Prof. David Judd)

Exam 4

Take-Home, Fall 2019

Name: ______________________________

Instructions:

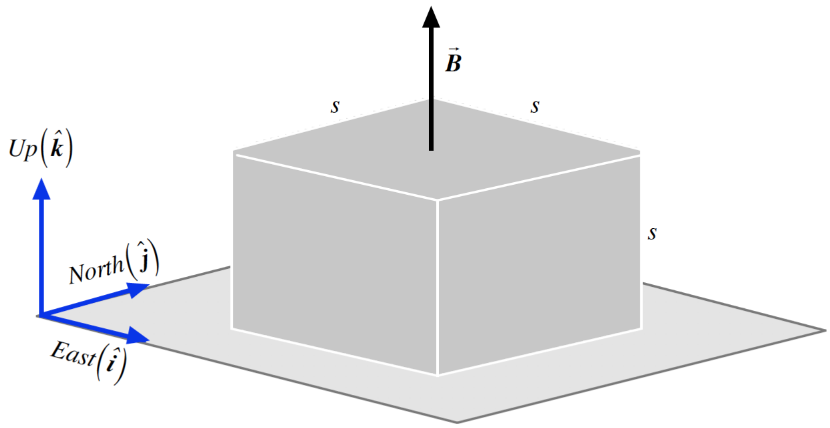
This exam is composed of **3 free-response problems**, each question worth 25 points. To receive a perfect score (75 points) on the exam, not only must your answers be correct, but you **must show all work**; the final answer isn't as important as the logic you use to attain that final answer. **This does not apply to any multiple-choice questions, however; no work is required to justify your response.** Please try to be neat in your writing and clear in your explanations; the clearer the logic and presentation of your work, the easier it will be for the instructor to follow your logic and assign partial credit accordingly. There is a **formula sheet** attached to the back of the exam will can be used to aid you in solving the problems.

Please do not write in the rubric below; it is for grading purposes only. The exam begins on the next page.

Exam Grade:

Problem 1	
Problem 2	
Problem 3	
Total	

PROBLEM 1



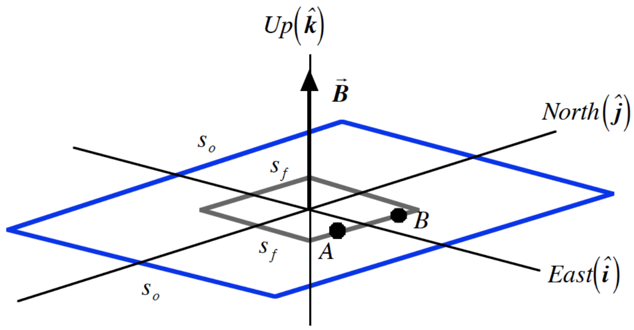
A metallic cube of side length s = 0.550 m rests on an horizontal insulating surface, as represented in the diagram above. A uniform magnetic field of magnitude B = 4.5 T is directed vertically upward. Use this information to determine the following:

(a) The magnetic flux through each of the six faces of the cube.

(b) The total magnetic flux through the entire cube.

(c) The magnetic flux through each face of the cube if the field were directed east rather than upward.

PROBLEM 2



A square winding of copper of side length so lies in an horizontal plane. A uniform magnetic field of $B = 0.085$ T is directed vertically upward and passes through the square of side length $s_o = 50$cm. If the square collapses into a smaller square of side length $s_f = 10$cm in a time interval of $\Delta t = 0.3$s, determine the following:

(a) The magnitude of the average induced EMF in the winding.

(b) The magnitude of the average induced current in the winding if the resistance of winding is $R = 5\Omega$

(c) The direction the induced current moves through the winding, either $A \rightarrow B$ or $B \rightarrow A$. *Hint: Lenz's Law states that a conductor resists changes to the magnetic* ***flux****.*

PROBLEM 3

Problem 3 is composed of three, equally weighted multiple-choice questions. Note that you ***do not*** *need to include any work to justify your choice of answer; multiple-choice questions are not graded with partial credit. Simply circle the answer that you feel is the most correct for each question.*

(a) Light is a wave composed of:

i. Oscillating electric fields
ii. Oscillating magnetic fields
iii. Oscillating electric and magnetic fields
iv. Light contains neither electric nor magnetic fields

(b) As you stare through a window, you see two different images superimposed on each other: yourself reflected on the glass, and the world outside your window. From this, you conclude that light hitting your window undergoes:

i. Reflection
ii. Transmission
iii. Both reflection and transmission
iv. Neither reflection nor transmission

(c) If the index of refraction of olive oil is 1.47, what is the speed of light in olive oil?

i. 1.50×10^8 m/s
ii. 2.04×10^8 m/s
iii. 3.00×10^8 m/s
iv. 4.41×10^8 m/s

FORMULA SHEET

The magnetic force on an electric point charge q moving with instantaneous velocity $\vec{v}$ in an external magnetic field $\vec{B}$ is given by:

$$\vec{F}^M = q\left(\vec{v} \times \vec{B}\right) \tag{1}$$

The magnetic force on a conductor of length l carrying a steady current I in the direction $\hat{l}$ where the external magnetic field $\vec{B}$ is uniform over $\vec{l}$ is given by:

$$\vec{F}^M_{cond} = I\left(\vec{l} \times \vec{B}\right) \tag{2}$$

The Lorentz force:

$$\vec{F}_{Lorentz} = q\left(\vec{E} + \vec{v} \times \vec{B}\right) \tag{3}$$

The magnitude of the net radial (centripetal) force on a mass m moving along a circular path of radius R with instantaneous speed v is given by:

$$F_{rad} = \frac{mv^2}{R} \tag{4}$$

An electric point charge q moving with velocity $\vec{v}$ produces a magnetic field at a point P which is at a distance r and in the direction $\hat{r}$ from q that is given by:

$$\vec{B} = \frac{k'q}{r^2}\left(\vec{v} \times \hat{r}\right) \tag{5}$$

Alternatively, written in terms of the vector $\vec{r}$ pointing from the charge q to the point P, the magnetic field at P is given by:

$$\vec{B} = \frac{k'q}{r^3}\left(\vec{v} \times \vec{r}\right)$$

where, in both equations, k' is given by:

$$k' = \frac{\mu_0}{4\pi} = 1 \times 10^{-7}\ \frac{\mathrm{Ns}^2}{\mathrm{C}^2} \tag{6}$$

The SI unit for the magnetic field is the *Tesla*, signified by T.

A solenoid of length l_s an having N_s turns, carrying a steady current I_s, produces an axial magnetic field the magnitude of which is given by:

$$B_{sol} = \mu_0\left(\frac{N_s}{l_s}\right)I_s = \mu_0 n_s I_s \tag{7}$$

where n_s is the so-called turn density – the number of turns per unit length.

The axial magnetic field produced by N circular windings of radius R, carrying a current I, at a point on the axis of symmetry a distance z from the center has a magnitude given by:

$$B_{circle} = \frac{2\pi N k' I R^2}{\left(z^2 + R^2\right)^{3/2}} \tag{8}$$

The magnetic field produced by a current in a long, straight conductor is given by:

$$\vec{B}_{LSC} = \frac{2k'I}{r_\perp}\hat{\phi} \tag{9}$$

Magnetic flux is defined by:

$$\Phi_M = \int \vec{B} \cdot d\vec{A} \tag{10}$$

The magnetic flux through a planar area of which there is a uniform magnetic field $\vec{B}$ is given by:

$$\Phi_M = \vec{B} \cdot \vec{A} = BA\cos\angle_{bet} \tag{11}$$

The magnetic flux through a closed loop is given by Guass' Law:

$$\Phi_M = \oint \vec{B} \cdot d\vec{A} = 0 \tag{12}$$

Faraday's law is given by:

$$\mathcal{E}_{avg} = -\frac{\Delta\Phi_{M,total}}{\Delta t} = -N\frac{\Delta\Phi_{M,single\ turn}}{\Delta t} \tag{13}$$

The induced current in a conductor of resistance R is related to Faraday's law by:

$$|\mathcal{E}_{avg}| = I_{induced}R \tag{14}$$

The electric charge on an electron and proton are equal in magnitude, but opposite in sign, and are given by:

$$e = q_p = -q_e = 1.602 \times 10^{-19} \text{ C} \tag{15}$$

The mass of the electron and proton are given by:

$$\begin{aligned} m_e &= 9.109 \times 10^{-31} \text{ kg} \\ m_p &= 1.673 \times 10^{-27} \text{ kg} \end{aligned} \tag{16}$$

Newton's second law for a constant mass m is given by:

$$\sum \vec{F} = m\vec{a} \tag{17}$$

Vector operations: If we have two vectors $\vec{A}$ and $\vec{B}$, where:

$$\begin{aligned} \vec{A} &= A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k} \\ \vec{B} &= B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k} \end{aligned} \tag{18}$$

then the dot product is defined as:

$$\vec{A} \cdot \vec{B} = AB\cos\angle_{bet} = A_xB_x + A_yB_y + A_zB_z \tag{19}$$

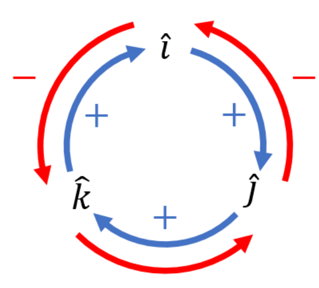
while the cross product is defined as:

$$\vec{A} \times \vec{B} = \vec{C} = (A_yB_z - A_zB_y)\,\hat{\imath} + (A_zB_x - A_xB_z)\,\hat{\jmath} + (A_xB_y - A_yB_x)\,\hat{k} \tag{20}$$

where the new vector $\vec{C}$, perpendicular to both $\vec{A}$ and $\vec{B}$, has a magnitude of:

$$C = AB\sin\angle_{bet}$$

Alternatively, cross products can be computed for individual unit vectors by using the cyclic permutations, the so-called "Wheel of life":



Note that for any vector $\vec{A}$, we can find the unit vector $\vec{A}$ in the direction of $\vec{A}$ by dividing it by its magnitude:

$$\hat{A} = \frac{\vec{A}}{A}$$

The electric field produced by an electric point charge q at a point P a distance r from q in the $\hat{r}$ direction from q is given by:

$$\vec{E} = \frac{kq}{r^2}\hat{r} \tag{21}$$

where the constant k is given by:

$$k = 8.99 \times 10^9 \ \frac{\mathrm{Nm}^2}{\mathrm{C}^2} \tag{22}$$

The electric force on an electric point charge q', which is located at a point where there is an external electric field $\vec{E}$ is given by:

$$\vec{F}^E = q'\vec{E} \tag{23}$$

Close to the surface of the Earth, the acceleration due to the Earth's gravitational force is given by:

$$g = \frac{GM_\oplus}{R_\oplus^2} = 9.810 \ \frac{\mathrm{m}}{\mathrm{s}^2} \tag{24}$$

where the constants in the above equation are given by:

$$\begin{aligned} G &= 6.67 \times 10^{-11} \ \frac{\mathrm{Nm}^2}{\mathrm{kg}^2} \\ M_\oplus &= 5.97 \times 10^{24} \ \mathrm{kg} \\ R_\oplus &= 6.371 \times 10^6 \ \mathrm{m} \end{aligned} \tag{25}$$

Light Equations: Light traveling in a vacuum moves at the following speed:

$$c = 3 \times 10^8 \ \mathrm{m/s} \tag{26}$$

while light traveling in a medium of index of refraction n moves at the following speed:

$$v = \frac{c}{n} \tag{27}$$