

# PHY2054 General Physics II

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(Substituting for Prof. David Judd)

Exam 4

Take-Home, Fall 2019

Name: \_\_\_\_\_

**Instructions:**

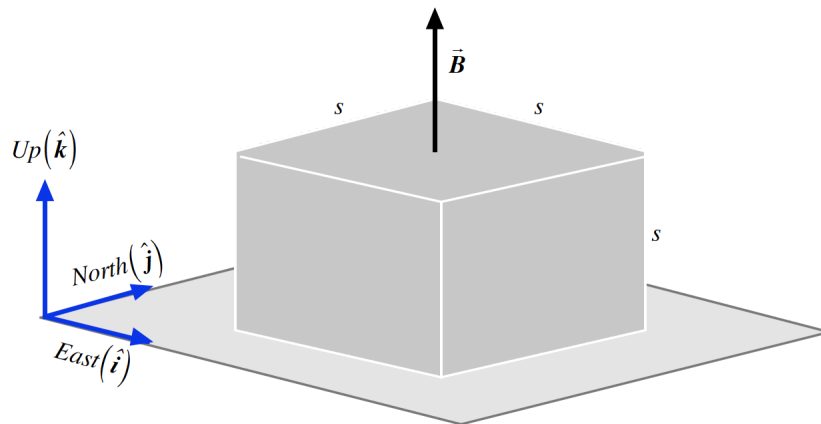
This exam is composed of **3 free-response problems**, each question worth 25 points. To receive a perfect score (75 points) on the exam, not only must your answers be correct, but you **must show all work**; the final answer isn't as important as the logic you use to attain that final answer. **This 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	
<b>Total</b>	

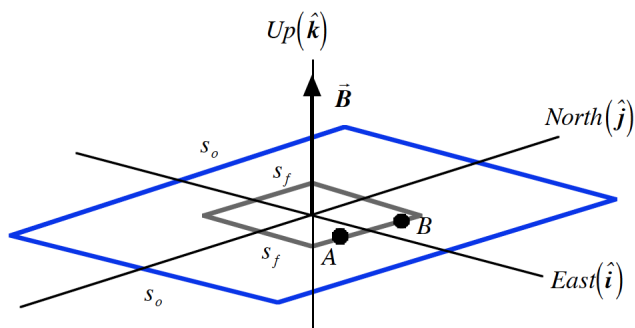
### PROBLEM 1



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  $s_o = 50\text{cm}$  lies in an horizontal plane. A uniform magnetic field of  $B = 0.085\text{ T}$  is directed vertically upward and passes through the square. If the square collapses into a smaller square of side length  $s_f = 10\text{cm}$  in a time interval of  $\Delta t = 0.3\text{s}$ , 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.  $1.50 \times 10^8$  m/s
  - ii.  $2.04 \times 10^8$  m/s
  - iii.  $3.00 \times 10^8$  m/s
  - iv.  $4.41 \times 10^8$  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:

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

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:

$$\vec{F}_{cond}^M = I (\vec{l} \times \vec{B}) \quad (2)$$

The Lorentz force:

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

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:

$$F_{rad} = \frac{mv^2}{R} \quad (4)$$

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:

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

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:

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

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

$$k' = \frac{\mu_0}{4\pi} = 1 \times 10^{-7} \frac{\text{Ns}^2}{\text{C}^2} \quad (6)$$

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

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

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

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:

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

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

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

Magnetic flux is defined by:

$$\Phi_M = \int \vec{B} \cdot d\vec{A} \quad (10)$$

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

$$\Phi_M = \vec{B} \cdot \vec{A} = BA \cos \angle_{bet} \quad (11)$$

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

$$\Phi_M = \oint \vec{B} \cdot d\vec{A} = 0 \quad (12)$$

Faraday's law is given by:

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

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

$$|\mathcal{E}_{avg}| = I_{induced}R \quad (14)$$

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

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

The mass of the electron and proton are given by:

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

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

$$\sum \vec{F} = m\vec{a} \quad (17)$$

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

$$\begin{aligned} \vec{A} &= A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \\ \vec{B} &= B_x\hat{i} + B_y\hat{j} + B_z\hat{k} \end{aligned} \quad (18)$$

then the dot product is defined as:

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

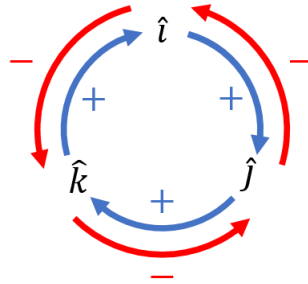
while the cross product is defined as:

$$\vec{A} \times \vec{B} = \vec{C} = (A_yB_z - A_zB_y)\hat{i} + (A_zB_x - A_xB_z)\hat{j} + (A_xB_y - A_yB_x)\hat{k} \quad (20)$$

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  $\hat{A}$  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:

$$\vec{E} = \frac{kq}{r^2} \hat{r} \quad (21)$$

where the constant  $k$  is given by:

$$k = 8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \quad (22)$$

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:

$$\vec{F}^E = q' \vec{E} \quad (23)$$

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

$$g = \frac{GM_{\oplus}}{R_{\oplus}^2} = 9.810 \frac{\text{m}}{\text{s}^2} \quad (24)$$

where the constants in the above equation are given by:

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

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

$$c = 3 \times 10^8 \text{ m/s} \quad (26)$$

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

$$v = \frac{c}{n} \quad (27)$$