

Note: **THIS IS A REPRESENTATION OF THE ACTUAL TEST.** *It is a sample and does not include questions on every topic covered since the start of the semester.*

Also be sure to review

homework assignments on WebAssign

White board problems worked in the class

Exercises, Examples, and Review Questions (at the end of each chapter) in your textbook

On the actual test, do not use other paper. If you need more space, write on the blank page included at the beginning of the test, and indicate that you did this.

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- You must show all your work, including correct vector notation.
- Correct answers without adequate explanation will be counted wrong.
- Incorrect work or explanations mixed in with correct work will be counted wrong. *Cross out anything you don't want us to read!*
- Make explanations complete but brief. Do not write a lot of prose.
- Include diagrams!
- Show what goes into a calculation, not just the final number:

$$\frac{a \cdot b}{c \cdot d} = \frac{(8 \times 10^{-3})(5 \times 10^6)}{(2 \times 10^{-5})(4 \times 10^4)} = 5 \times 10^4$$

- Give standard SI units with your results.

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can't calculate(explain that you are doing this), and use it to do the rest of the problem.

NAME: _____

Phys 0175

Practice Final Exam

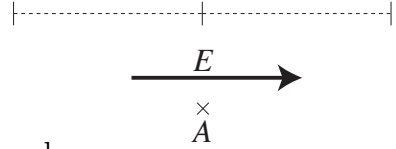
Apr 21, 2008

INSTRUCTIONS: Please print your name above in the space provided.

The exam consists of N questions worth differing number of points. WRITE NEATLY. Clearly mark your answers with a bounding box at the bottom of your work area. It is important to show your work to get credit. You may use calculators.

Question Number	Possible Points	Score
1	?	
2	?	
\vdots	\vdots	
N	?	
Total	100	

1. When the electric field in a region reaches 3×10^6 N/C, the air becomes ionized and a spark occurs. On average, a free electron in the ionized air can travel about 5×10^{-7} m before it collides with a gas molecule.

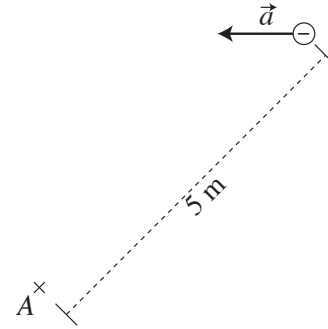


Consider an electron that starts from rest at location A and travels 5×10^{-7} m under the influence of a uniform electric field pointing to the right, with magnitude 3×10^6 N/C.

- (a) On the diagram place an “x” at the final location of the electron.
- (b) Calculate the potential difference between the electron’s final location and its initial location $\Delta V = V_{\text{final}} - V_A$. Show your work.

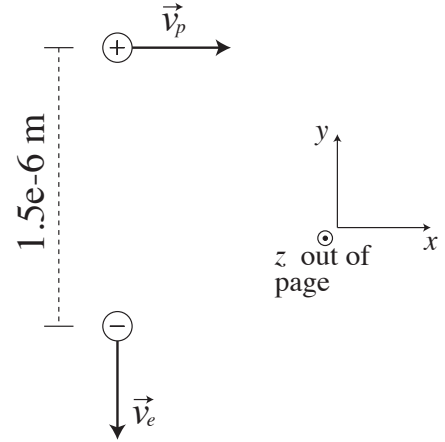
- (c) How much kinetic energy does the electron gain during this process? Show your work.

2. An electron is briefly accelerated in the direction shown in the diagram.



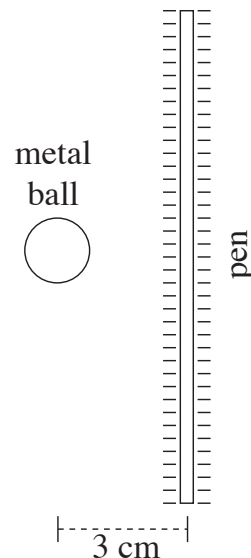
- (a) Draw an arrow on the diagram showing \vec{a}_\perp for an observer at location A , and label it \vec{a}_\perp .
- (b) Draw an arrow at location A representing the radiative electric field at that location and label it \vec{E}_{rad} .
- (c) Draw an arrow at location A representing the radiative magnetic field at that location and label it \vec{B}_{rad} .
- (d) Location A is 5 m from the electron. If the electron is accelerated at $t = 0$ s, at what time does the radiation from the accelerated electron reach location A ? Show your work.

3. At a particular instant a proton is moving with velocity $\langle 5.5 \times 10^5, 0, 0 \rangle$ m/s, and an electron is moving with velocity $\langle 0, -7 \times 10^5, 0 \rangle$ m/s. The electron is located 1.5×10^{-6} m below the proton (in the -y direction).



- On the diagram draw an arrow representing the electric field at the location of the electron, due to the proton. Label it \vec{E}_p .
- On the diagram draw an arrow representing the magnetic field at the location of the electron, due to the proton. Label it \vec{B}_p .
- On the diagram draw an arrow representing the electric force on the electron at this instant. Label it \vec{F}_{el} .
- On the diagram draw an arrow representing the magnetic force on the electron at this instant. Label it \vec{F}_{mag} .
- Calculate the magnetic force on the electron at this instant. Your answer should be a vector. Show all work.

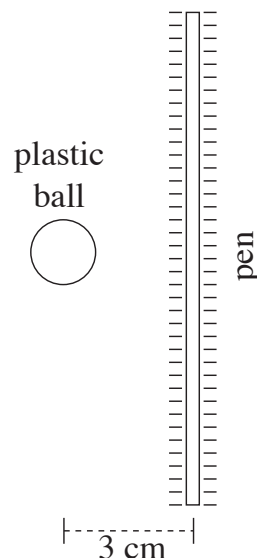
4. A plastic ballpoint pen of length 14 cm is rubbed all over with wool, and acquires a charge of -3×10^{-8} C, distributed more or less evenly over the surface of the pen. A small solid aluminum ball suspended from an insulating string is touched to a Van de Graaff generator, and acquires a charge of -2×10^{-9} C. The charged ball is brought near the pen, as shown. The center of the ball is 3 cm from the pen.



- On the diagram clearly show the distribution of charge in and/or on the aluminum ball.
- On the diagram draw an arrow showing the electric force on the aluminum ball. Label the arrow \vec{F}_{el} .
- Calculate the magnitude of the electric force on the aluminum ball due to the charged rod. Show your work.

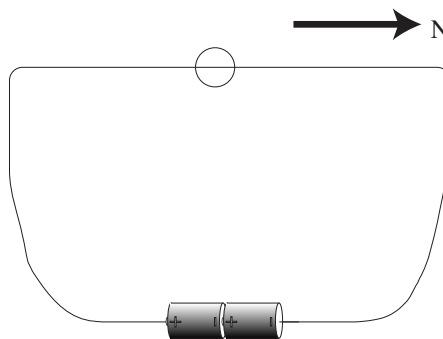
- What approximation, if any, did you make in your calculations?

Now the aluminum ball is replaced by a neutral, solid plastic ball.



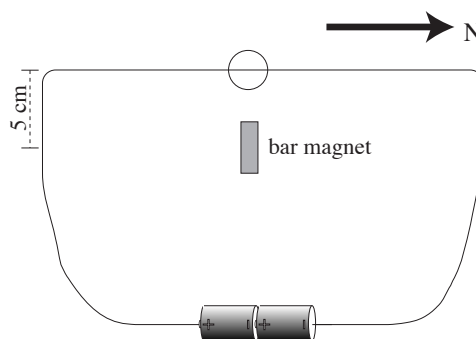
- On the diagram show clearly the distribution of charge in and/or on the plastic ball.
- On the diagram draw an arrow showing the electric force on the plastic ball. Label the arrow \vec{F}_{el} .

5. A compass lies on a table, originally pointing North. A wire is placed on top of the compass, and is connect to two batteries as shown in the diagram (top view, looking down at talbe). A conventional current of 0.25 A runs through the wire.



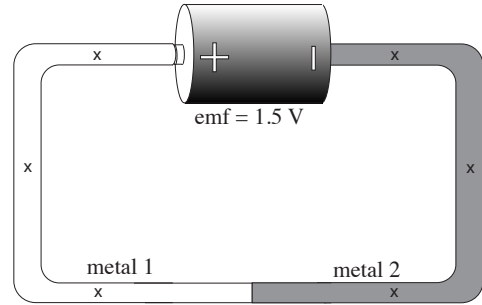
- On the diagram, draw an arrow indicating the direction of the electron current in the wire. Label the arrow i .
- Draw the position of the compass needle while the current is running.
- Calculate the magnitude of the deflection angle of the compass needle. Show all work.

With current still running in the circuit, a bar magnet is placed with its center 5 cm from the compass, as shown to the right. The compass needle now returns to pointing North.



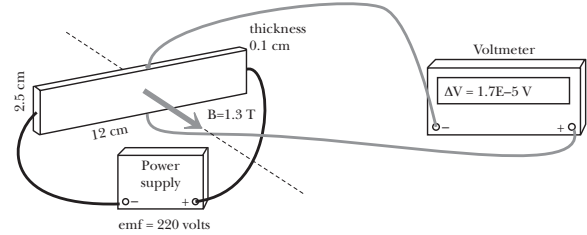
- Label the North and South ends of the bar magnet.
- Find the magnetic dipole moment of the bar magnet. Show all work.

6. The circuit shown in the diagram contains two wires made of different metals. The radius of each wire is 0.5 mm, and the length of each wire is 16 cm. Both metals have 9×10^{28} mobile electrons per cubic meter. The electron mobility in metal 1 is $5 \times 10^{-5} \text{ (m/s)/(N/C)}$, and the electron mobility in metal 2 is $2 \times 10^{-4} \text{ (m/s)/(N/C)}$. The emf of the battery is 1.5 volts.



- At each location marked by an x, draw an arrow representing the electric field at that location in the steady state. Label these arrows E . The relative lengths of your arrows should be correct.
- At each location marked by an x, draw an arrow representing the drift velocity of electrons at that location in the steady state. Label these arrows v . The relative lengths of your arrows should be correct.
- Draw the approximate distribution of surface charge on the circuit in the steady state. You may add a verbal description of the main features of the charge distribution you draw, if you think that will clarify your intent.
- How many electrons per second leave the negative terminal of the battery in the steady state? Show all your work.

7. A bar of conducting material is connected to a 220 volt power supply, and a current runs through the bar. There is a uniform magnetic field of magnitude 1.3 T

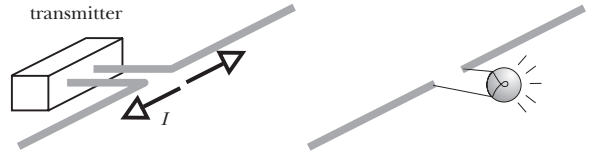


perpendicular to the bar as shown. A voltmeter is placed so its leads are directly opposite each other on the top and bottom surfaces of the bar, as shown. The dimensions of the bar are given in the diagram. Remember that a voltmeter gives a positive reading if the lead labeled “+” is connected to the higher potential location and the lead labeled “-” is connected to the lower potential location.

- Are the mobile charges in the bar negative (electrons) or positive (holes)? Explain every step in your reasoning in detail. On the diagram show all relevant fields.
- On the diagram draw an arrow representing the drift velocity of a mobile charge in the bar. Label the arrow “ v ”.
- What is the mobility of the mobile charges? Show your work.
- Now the coils producing the magnetic field are moved far away, so the magnetic field inside the bar is zero. What is the reading on the voltmeter now? Explain clearly.

8. A sinusoidally varying potential difference is applied to an antenna in a radio transmitter, resulting in a current in the antenna that varies sinusoidally in time. A detector consisting of a light bulb connected to two straight wires is held in the air near the transmitter.

- (a) When the detector is held with the wires parallel to the transmitter



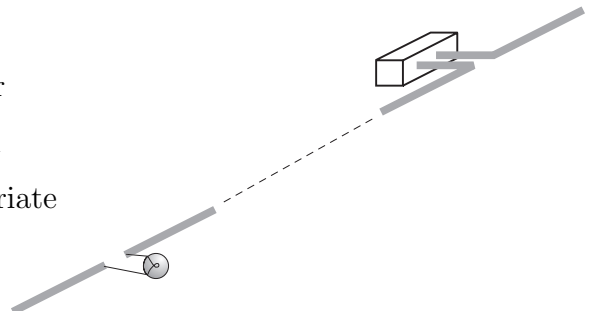
antenna, the light bulb lights. Explain in detail why this happens, using appropriate diagrams.

- (b) When the detector is held with the wires perpendicular to the transmitter antenna, the light bulb does not light. Explain in detail why



it does not light, using appropriate diagrams.

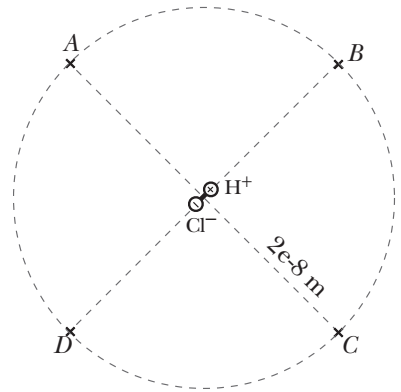
- (c) What will happen when the detector is held so its wires are collinear with the antenna? Explain, using appropriate diagrams.



9. At a particular instant a proton is located at the origin. The proton is traveling with velocity $\langle 3 \times 10^6, 0, 0 \rangle$ m/s. An electron at location $\langle 3 \times 10^{-10}, 5 \times 10^{-10}, 0 \rangle$ m is traveling with velocity $\langle 0, -2 \times 10^6, 0 \rangle$ m/s. Calculate the net electric and magnetic force on the electron due to the proton. Show all steps in your work. Your answer must be a vector.

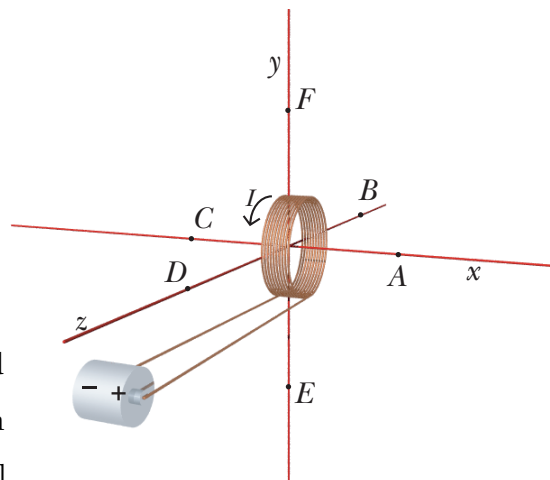
10. A capacitor is constructed from two large circular plates, each of radius 4 m. The capacitor is charged, and the positive plate of the capacitor carries a charge of $+6 \times 10^{-5}$ C. The potential difference across the charged capacitor is 265 V.
- (a) How far apart are the plates of the capacitor?
- (b) An electron is released from rest very near the negative plate of the capacitor. How fast is it traveling when it reaches the positive plate?

11. In the center of the diagram is an HCl molecule, consisting of a Cl^- ion with charge $-e$ and an H^+ ion with charge $+e$, separated by a distance of 1.3×10^{-10} m. Location A , B , C , and D lie on a circle of radius 2×10^{-8} m surrounding the HCl molecule (the diagram is not to scale).



- (a) At each of the locations (A , B , C , D) draw an arrow representing the electric field at that location due to the HCl molecule. Label each arrow "E". Both the directions and relative magnitudes of your arrows should be correct.
- (b) At the particular instant an electron is at location A . Draw an arrow indicating the direction of the force on the electron at this instant. Label the arrow "F".
- (c) What is the magnitude of the force vector that you drew in part (b)? Show all steps in your work. If you make any approximations, state what they are.

12. A coil is centered at the origin, and the axis of the coil is aligned with the x-axis, as shown. The coil is connected to a battery, and a current runs through the coil in the direction indicated (counter-clockwise if viewed from a location on the +x axis). The observation locations labeled A - F are located on the axes as shown, each location is 11 cm from the center of the coil.

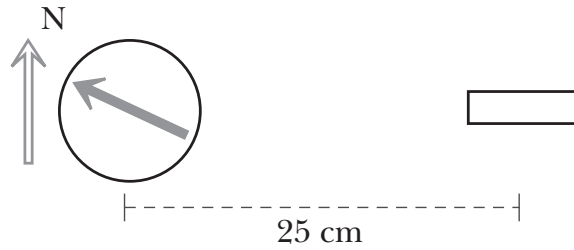


- (a) For each observation location listed in the table below, circle the non-zero components for the magnetic field at that location due to the current in the coil. For example, if the magnetic field at a location has both a $+z$ and a $-y$ component, you should circle both “ $+z$ ” and “ $-y$ ”

A	$+x$	$-x$	$+y$	$-y$	$+z$	$-z$	$B=0$
B	$+x$	$-x$	$+y$	$-y$	$+z$	$-z$	$B=0$
C	$+x$	$-x$	$+y$	$-y$	$+z$	$-z$	$B=0$
D	$+x$	$-x$	$+y$	$-y$	$+z$	$-z$	$B=0$
E	$+x$	$-x$	$+y$	$-y$	$+z$	$-z$	$B=0$
F	$+x$	$-x$	$+y$	$-y$	$+z$	$-z$	$B=0$

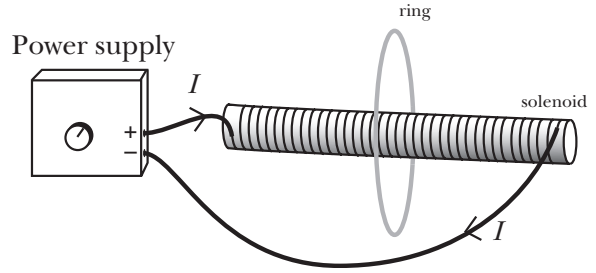
- (b) The magnitude of the magnetic field at location C due to the current in the coil is 1.6×10^{-5} T. At a particular instant an electron with velocity $\langle 0, 0, 4 \times 10^7 \rangle$ m/s is at location C . What is the force on the electron at this instant? Show your work. Express your answer as a vector.

13. A compass originally points North. A bar magnet placed 25 cm from the compass, as shown in the diagram, causes the compass to deflect 65 degrees West (the diagram is not drawn to scale).



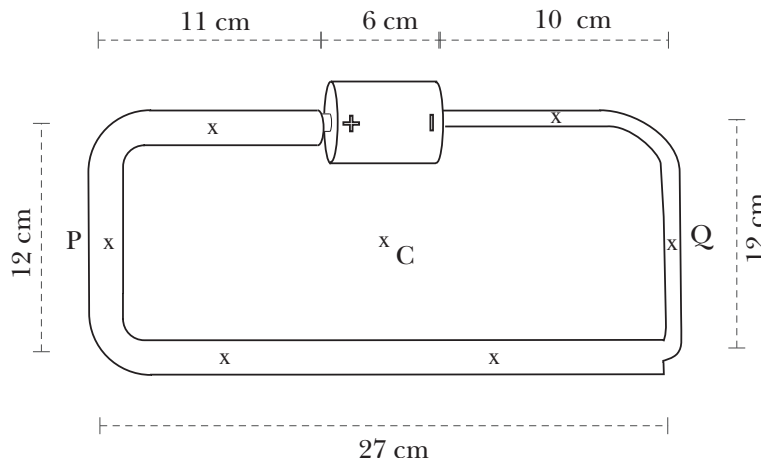
- (a) Label the North and South ends of the magnet.
- (b) What is the magnetic dipole moment of the bar magnet? Show your work.

14. A very long solenoid of radius 2 cm is connected to a power supply, and current runs through it in the direction shown in the diagram. A metal ring of radius 5 cm is centered on the solenoid and is located near the middle of the solenoid.



The current through the solenoid is changing. At time $t = 0.1$ s, the magnetic field inside the solenoid is 0.55 T, and at time $t = 0.3$ s the magnetic field inside the solenoid is 0.9 T.

- (a) On the diagram, show the direction of $-d\vec{B}/dt$ in the ring during this interval.
- (b) On the diagram, indicated the direction of conventional current in the ring during this interval.
- (c) Calculate the emf in the ring during this interval. Clearly show every step in your work.
- (d) What is the magnitude of the non-Coulomb electric field inside the metal of the ring during this interval? Show your work.



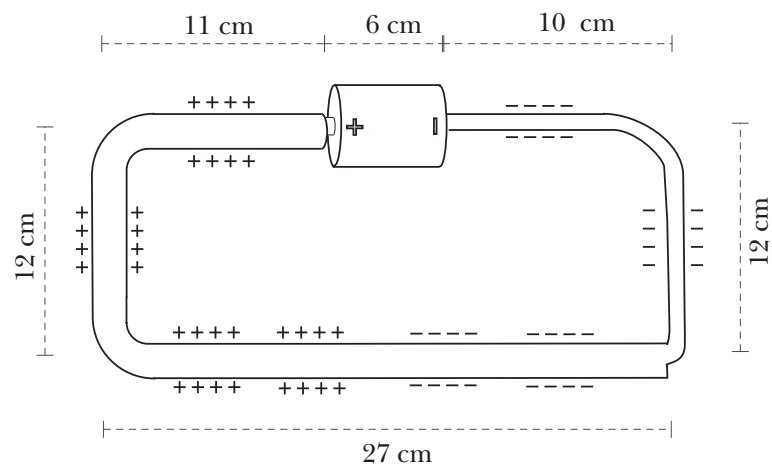
15. A steady state current runs through a circuit composed of a thick wire and a thin wire made of the same metal, as shown in the diagram. The approximate dimensions of the circuit are shown in the diagram (with the diameters of the wires exaggerated). The thin wire has cross-sectional area $5 \times 10^{-8} \text{ m}^2$. The thick wire has cross-sectional area $2 \times 10^{-7} \text{ m}^2$. This metal has 8×10^{28} mobile electrons per cubic meter, and the electron mobility is $4 \times 10^{-5} \text{ (m/s)/(V/m)}$. The emf of the battery is 9 V.

- At each of the location inside the wires marked “x”, draw an arrow showing the magnitude and direction of the electric field inside the wire. Draw all arrows to the same scale (so a longer arrow means a greater magnitude). Label the arrows “E”.
- At locations P and Q draw and label arrows showing the magnitude and direction of drift velocity of a mobile electron in the wire. Draw these arrows to the same scale (so a longer arrow means a greater magnitude). Label the arrows “v”.
- In the steady state, how many electrons per second pass location P? Clearly show all steps in your work.
- At location C, at the center of the rectangular loop, draw an arrow representing the direction of the magnetic field at that location due to the current in the circuit. Label the arrow “B”.

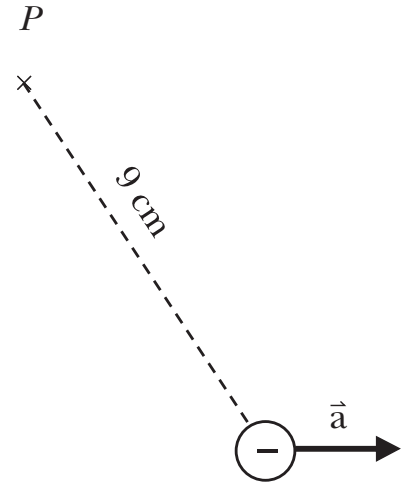
Question continued on next page →

(e) What is the magnitude of the magnetic field at location C? Clearly show all steps in your work.

(f) A student drew the following incorrect surface charge distribution for the circuit in this problem. Circle one region in which the surface charge shown cannot be correct, and explain briefly why the surface charge shown in this region cannot be correct, based on your analysis in the preceding parts.

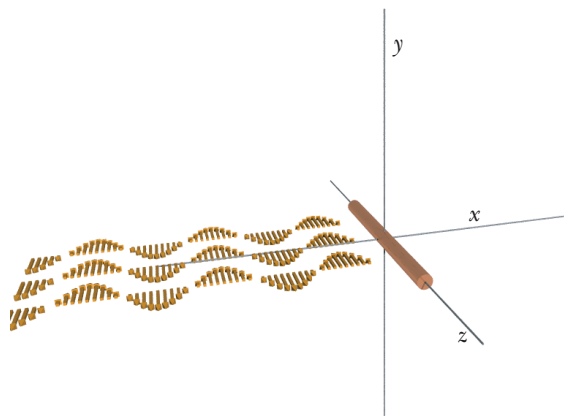


16. At time $t = 0$, an electron at the origin is briefly accelerated in the direction shown in the diagram. You place a detector sensitive to electromagnetic radiation at location P, which is 9 cm from the origin.



- (a) On the diagram, draw an arrow showing the direction of propagation of the radiation that reaches your detector. Label the arrow “v”.
- (b) On the diagram draw an arrow showing the direction of the electric field in the radiation reaching your detector. Label the arrow “E”.
- (c) On the diagram draw an arrow showing the direction of the magnetic field in the radiation reaching your detector. Label the arrow “B”.
- (d) At what time does your detector first detect electromagnetic radiation? Show your work.

17. A narrow beam (2 cm in diameter) of sinusoidal electromagnetic radiation propagating in the $+x$ direction, with the electric field in the $\pm z$ direction, strikes a metal rod that is centered on the origin aligned along the z axis.



You place detectors sensitive to electromagnetic radiation at locations

$\langle 0, -17, 0 \rangle$ m (detector A) and location $\langle 0, 0, -17 \rangle$ m (detector B).

Complete the table below, summarizing the results of this experiment. For each detector, state:

- Whether or not electromagnetic radiation will be detected at this location.
- If so, what the direction of propagation of this radiation will be (or “NONE” if no radiation is detected there).
- What the direction of the electric field in the detected radiation will be (or “NONE”). For example, the electric field in the incident radiation is in the $\pm z$ direction.
- What the direction of the magnetic field in the detected radiation will be (or “NONE”).

Detector location	(a) Does this detector detect radiation?	(b) Direction of propagation	(c) Direction of electric field	(d) Direction of magnetic field
A $\langle 0, -17, 0 \rangle$ m				
B $\langle 0, 0, -17 \rangle$ m				

Things you must know

Relationship between electric field and electric force

Relationship between magnetic field and magnetic force

Electric field of a point charge

Conservation of charge

Magnetic field of a moving point charge

The Superposition Principle

Other Fundamental Concepts

$$\begin{aligned} \Delta U_{el} &= q\Delta V & \Delta V &= - \int_i^f \vec{E} \cdot d\vec{l} \approx -\Sigma(E_x\Delta x + E_y\Delta y + E_z\Delta z) \\ \Phi_{el} &= \int \vec{E} \cdot \hat{n} dA & \Phi_{mag} &= \int \vec{B} \cdot \hat{n} dA \\ \oint \vec{E} \cdot \hat{n} dA &= \frac{\sum q_{inside}}{\epsilon_0} & \oint \vec{B} \cdot \hat{n} dA &= 0 \\ |emf| &= \oint \vec{E}_{NC} \cdot d\vec{l} = \left| \frac{d\Phi_{mag}}{dt} \right| & \oint \vec{B} \cdot d\vec{l} &= \mu_0 \left[\Sigma I_{inside \text{ path}} + \epsilon_0 \frac{d}{dt} \int \vec{E} \cdot \hat{n} dA \right] \end{aligned}$$

Specific Results

\vec{E} due to uniformly charged spherical shell: *outside* like point charge; *inside* zero

$$\begin{aligned} |\vec{E}_{dipole, axis}| &\approx \frac{1}{4\pi\epsilon_0} \frac{2qs}{r^3} \text{ (on axis, } r \gg s) & |\vec{E}_{dipole, \perp}| &\approx \frac{1}{4\pi\epsilon_0} \frac{qs}{r^3} \text{ (on } \perp \text{ axis, } r \gg s) \\ |\vec{E}_{rod}| &= \frac{1}{4\pi\epsilon_0} \frac{Q}{r\sqrt{r^2 + (L/2)^2}} \text{ (} r \perp \text{ from center)} & |\vec{E}_{rod}| &\approx \frac{1}{4\pi\epsilon_0} \frac{2Q/L}{r} \text{ (if } r \ll L) \\ \text{Electric dipole moment } p &= qs & |\vec{E}_{ring}| &= \frac{1}{4\pi\epsilon_0} \frac{qz}{(z^2 + R^2)^{3/2}} \text{ (} z \text{ along axis)} \\ |\vec{E}_{disk}| &= \frac{Q/A}{2\epsilon_0} \left[1 - \frac{z}{\sqrt{z^2 + R^2}} \right] \text{ (} z \text{ along axis)} & |\vec{E}_{disk}| &\approx \frac{Q/A}{2\epsilon_0} \left[1 - \frac{z}{R} \right] \approx \frac{Q/A}{2\epsilon_0} \text{ (if } z \ll R) \\ |\vec{E}_{capacitor}| &\approx \frac{Q/A}{\epsilon} \text{ (+} Q \text{ and - } Q \text{ disks)} & |\vec{E}_{fringe}| &\approx \frac{Q/A}{\epsilon} \left(\frac{s}{2R} \right) \text{ (just outside capacitor)} \\ \Delta \vec{B} &= \frac{\mu_0}{4\pi} \frac{I\Delta \vec{l} \times \vec{r}}{r^2} \text{ (shortwire)} & \Delta \vec{F} &= \Delta \vec{l} \times \vec{B} \\ |\vec{B}_{wire}| &= \frac{\mu_0}{4\pi} \frac{LI}{r\sqrt{r^2 + (L/2)^2}} \approx \frac{\mu_0}{4\pi} \frac{2I}{r} \text{ (} r \ll L) \\ |\vec{B}_{loop}| &= \frac{\mu_0}{4\pi} \frac{2I\pi R^2}{(z^2 + R^2)^{3/2}} \approx \frac{\mu_0}{4\pi} \frac{2I\pi R^2}{z^3} \text{ (on axis, } z \gg R) & \mu &= IA = I\pi R^2 \\ |\vec{B}_{dipole, axis}| &\approx \frac{\mu_0}{4\pi} \frac{2\mu}{r^3} \text{ (on axis, } r \gg s) & |\vec{B}_{dipole, \perp}| &\approx \frac{\mu_0}{4\pi} \frac{\mu}{r^3} \text{ (on } \perp \text{ axis, } r \gg s) \end{aligned}$$

$$\begin{array}{lll}
\vec{E}_{rad} = \frac{1}{4\pi\epsilon_0} \frac{-q\vec{a}_\perp}{c^2 r} & \hat{v} = \hat{E}_{rad} \times \hat{B}_{rad} & |\vec{B}_{rad}| = \frac{|\vec{E}_{rad}|}{c} \\
i = nA\bar{v} & I = |q|nA\bar{v} & \bar{v} = uE \\
\sigma = |q|nu & J = \frac{I}{A} = \sigma E & R = \frac{L}{\sigma A} \\
E_{dielectric} = \frac{E_{applied}}{K} & \Delta V = \frac{q}{4\pi\epsilon_0} \left[\frac{1}{r_f} - \frac{1}{r_i} \right] & \text{(due to a point charge)} \\
Q = C|\Delta V| & \text{Power} = I\Delta V & I = \frac{|\Delta V|}{R} \text{ (ohmic resistor)} \\
K \approx \frac{1}{2}mv^2 \text{ if } v \ll c & \text{circular motion :} & \left| \frac{d\vec{p}_\perp}{dt} \right| = \frac{|\vec{v}|}{R} |\vec{p}| \approx \frac{mv^2}{R}
\end{array}$$

Constant	Symbol	Approximate Value
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N · m ² /kg ²
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N · m ² /C ²
Epsilon-zero	ϵ_0	8.85×10^{-12} C ² /(N · m ²)
Magnetic Constant	$\frac{\mu_0}{4\pi}$	1×10^{-7} T · m/A
Mu-zero	μ_0	$4\pi \times 10^{-7}$ T · m/A
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} molecules/mole
Planck's constant	h	6.6×10^{-34} J·s
Atomic radius	R_a	$\approx 1 \times 10^{-10}$ m
Proton radius	R_p	$\approx 1 \times 10^{-15}$ m
E to ionize air	E_{ionize}	$\approx 3 \times 10^6$ V/m
B_{Earth} (horizontal component)	B_{Earth}	$\approx 2 \times 10^{-5}$ T