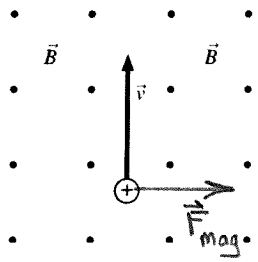
31 Electromagnetic Fields and Waves

31.1 *E* or *B*? It Depends on Your Perspective

1. In frame A, a positive charge moves through the magnetic field shown.



   a. Draw a vector on the charge to show the magnetic force in A.

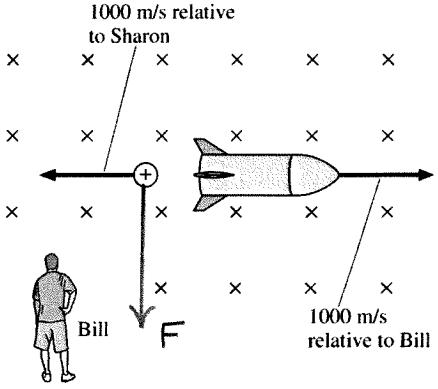
   b. What are the speed v_{BA} and direction of a reference frame B in which there is no magnetic force? Explain.

Refrence frame B moves straight up with a velocity $\vec{v}_{BA} = \vec{v}$. So, in frame B, the charge is at rest and no magnetic force acts on it.

   c. What are the type and direction of any fields in B that could cause the observed force on the charge?

In frame B, the force on the charge comes from an electric field that points to the right.

2. Sharon drives her rocket through a magnetic field, traveling to the right at a speed of 1000 m/s as measured by Bill. As she passes Bill, she shoots a positive charge backward at a speed of 1000 m/s relative to her.



   a. According to Bill, what kind of force or forces act on the charge? In which directions? Explain.

In Bill's reference frame, the charge is at rest so no magnetic force acts on it. But the observed force must be the same, and in Bill's frame there is a downward electric force on the charge.

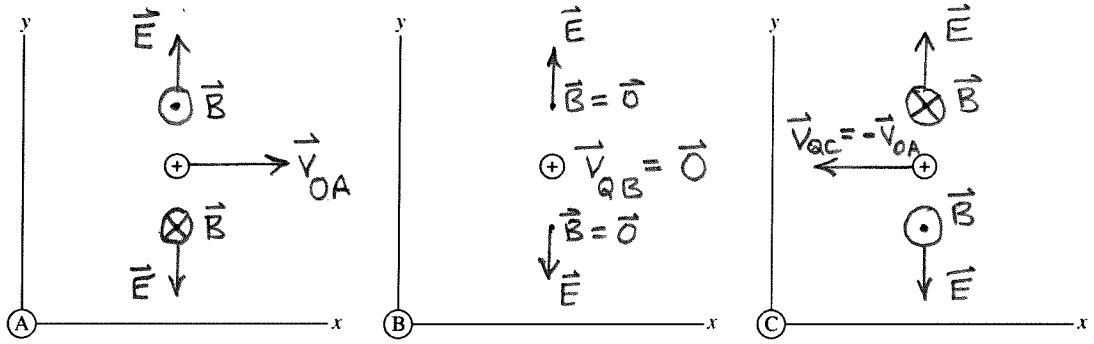
   b. According to Sharon, what kind of force or forces act on the charge? In which directions? Draw the forces on the charge.

Sharon observes a downward magnetic force acting on the charge. (Bill and Sharon agree on the size and direction of $\vec{F}$ but disagree on the field that caused $\vec{F}$.)

3. In frame A, a positive charge Q moves to the right with velocity v_{OA}. Frame B travels to the right at $v_{BA} = v_{OA}$ relative to A. Frame C travels to the right at $v_{CA} = 2v_{OA}$ relative to A. The figure below shows the charge three times, once in each reference frame.

   a. For each:

   - Draw and label a velocity vector on the charge showing its motion in that frame.
   - Draw and label the electric and magnetic field vectors due to the charge at the points marked with small dots above and below the charge. Use the notation of circled × and • to show fields into or out of the page.



   b. Does it make sense to talk about "the" magnetic field? Why or why not?

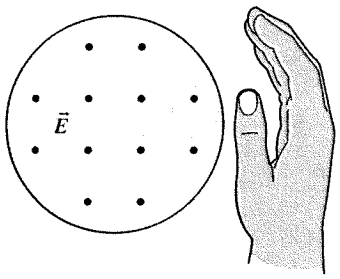
No. Observers in different inertial reference frames do not detect the same magnetic field. So, the magnetic field depends on your reference frame.

31.2 The Field Laws Thus Far

31.3 The Displacement Current

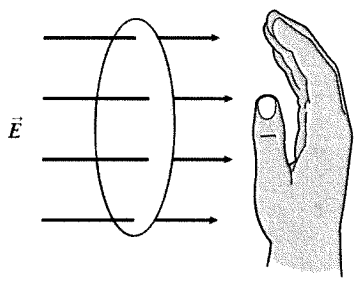
4. If you curl the fingers of your right hand as shown, is the electric flux positive or negative?

a.



Sign of Φ_e positive

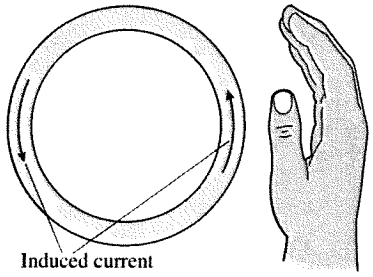
b.



Sign of Φ_e Negative

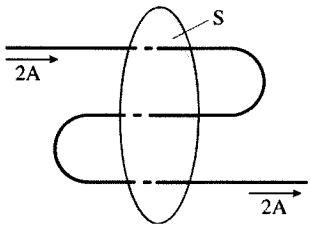
5. If you curl the fingers of your right hand as shown, is the emf positive or negative?

Positive. A positive emf creates an induced current in the direction of your fingers.

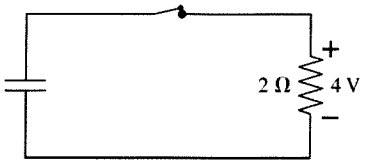


6. What is the current through surface S?

The net current through surface S is 2A.



7. The capacitor in this circuit was initially charged, then the switch was closed. At this instant of time, the potential difference across the resistor is $\Delta V_R = 4$ V.



a. At this instant of time, what is the current through the resistor?

$$I = \frac{\Delta V_R}{R} = \frac{4V}{2\Omega} = 2A$$

b. At this instant of time, what is the current through the space between the capacitor plates?

$$I_{through} = 0$$

c. At this instant of time, what is the displacement current through the space between the capacitor plates?

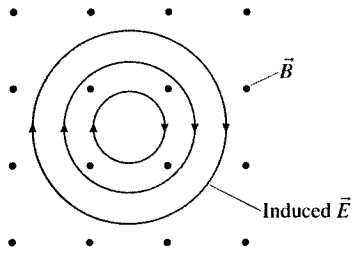
$I_{disp} = 2A$

d. Is the displacement current really a current? If so, what are the moving charges? If not, what is the displacement current?

The displacement current is not a real current with a flow of charge. It is a changing electric flux that creates the same magnetic field as a real current.

8. Consider these two situations:

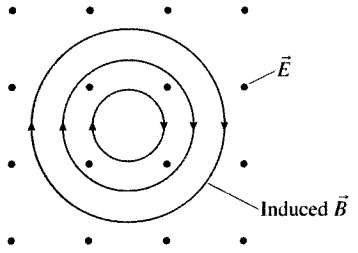
a.



Is the magnetic field strength increasing, decreasing, or not changing? Explain.

$\vec{B}$ is increasing to create cw $\vec{E}_{induced}$ which, in turn, creates $\vec{B}_{induced}$ into page to oppose the increasing $\vec{B}$.

b.

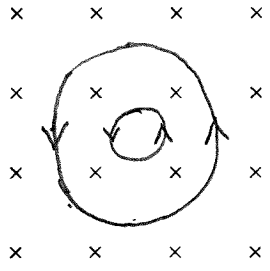


Is the electric field strength increasing, decreasing, or not changing? Explain.

$\vec{E}$ is decreasing to create cw $\vec{B}_{induced}$ by Ampère-Maxwell law.

9. Consider these two situations:

a. Draw the induced electric field.

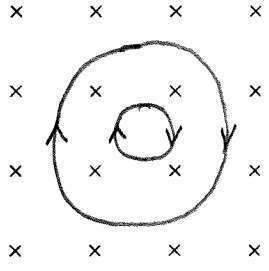


$\vec{B}$-field rapidly increasing

$\vec{E}_{induced}$ is ccw.

$\vec{E}_{induced}$ creates $\vec{B}_{induced}$ out of page opposing the increasing $\vec{B}$-field.

b. Draw the induced magnetic field.



$\vec{E}$-field rapidly increasing

$\vec{B}_{induced}$ is cw.

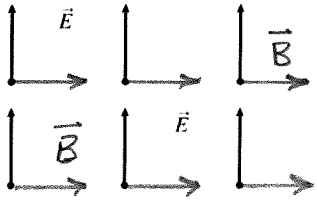
31.4 Maxwell's Equations

31.5 Electromagnetic Waves

31.6 Properties of Electromagnetic Waves

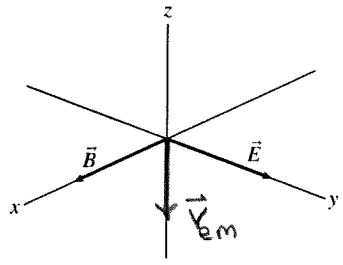
10. This is an electromagnetic plane wave traveling into the page. Draw the magnetic field vectors $\vec{B}$ at the dots.

$\vec{V}_{em} \propto \vec{E} \times \vec{B}$

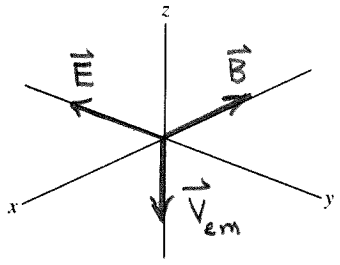


11. This is an electromagnetic wave at one instant of time.

a. Draw the velocity vector $\vec{v}_{em}$.

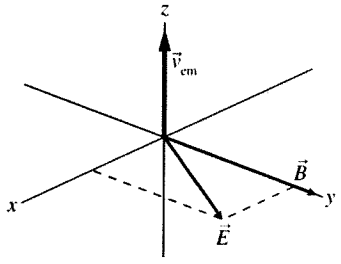


b. Draw $\vec{E}$, $\vec{B}$, and $\vec{v}_{em}$ a half cycle later.



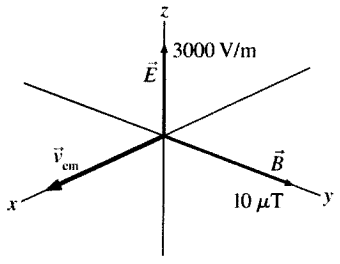
12. Do the following represent possible electromagnetic waves? If not, why not?

a.



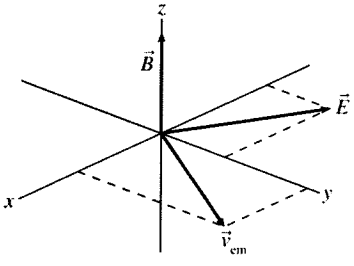
No. $\vec{E}$ must be perpendicular to $\vec{B}$

b.



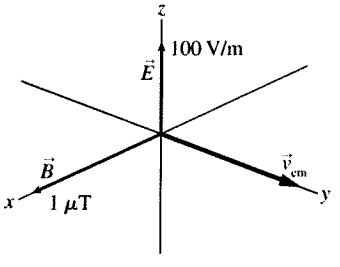
No. The direction of $\vec{v}_{em}$ is along the negative x-axis since $\vec{v}_{em} \propto \vec{E} \times \vec{B}$.

c.



Yes.

d.



Yes, but not in a vacuum since $E/B < c$.

13. The intensity of an electromagnetic wave is 10 W/m^2. What will be the intensity if:

a. The amplitude of the electric field is doubled?

40 W/m^2 since $I \propto E_0^2$

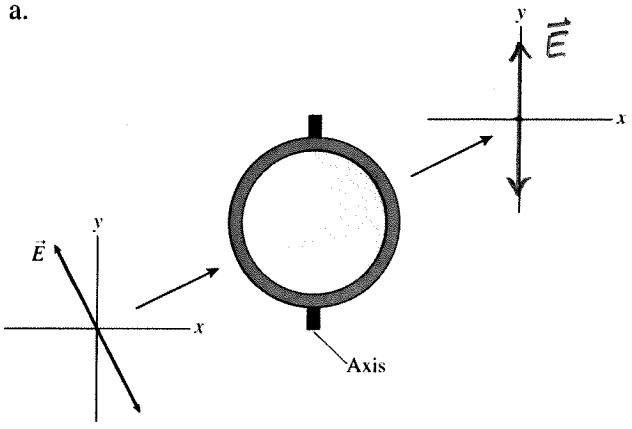
b. The frequency is doubled?

10 W/m^2 since the intensity is independent of frequency

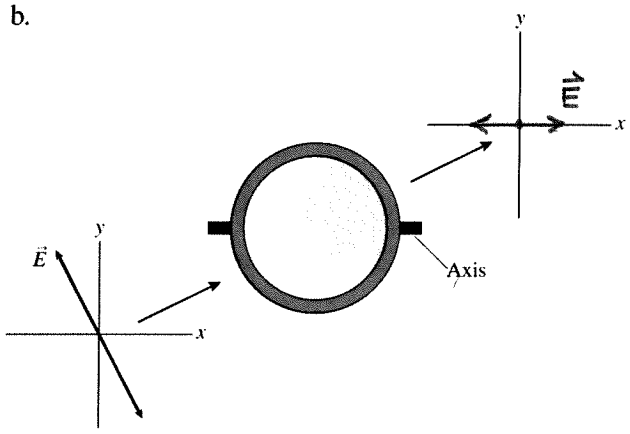
31.7 Polarization

14. A polarized electromagnetic wave passes through a polarizing filter. Draw the electric field of the wave after it has passed through the filter.

a.

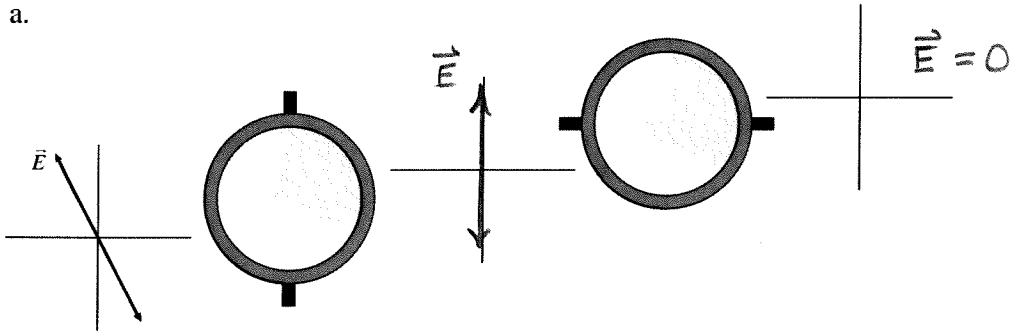


b.



15. A polarized electromagnetic wave passes through a series of polarizing filters. Draw the electric field of the wave after it has passed through each filter.

a.



b.