

**Part A:** Multiple choice questions. Fill in your answers to these questions in Section 4 of the response form, items 1-16. Each question has a value of 4 points.

The first four questions concern the fundamental equations of electromagnetism (in the absence of magnetic materials), which are numbered 1-5 here:

1. Gauss's Law for  $\mathbf{E}$ :  $\oint \mathbf{E} \cdot d\mathbf{A} = 4\pi k_e Q_{\text{enc}}$
2. Faraday's Law:  $\oint \mathbf{E} \cdot d\mathbf{r} = -\int (\partial \mathbf{B} / \partial t) \cdot d\mathbf{A}$
3. Gauss's Law for  $\mathbf{B}$ :  $\oint \mathbf{B} \cdot d\mathbf{A} = 0$
4. Ampere-Maxwell Law:  $\oint \mathbf{B} \cdot d\mathbf{r} = \mu_0 \int [\mathbf{J} + \epsilon_0 (\partial \mathbf{E} / \partial t)] \cdot d\mathbf{A}$
5. Lorentz Force Law:  $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$

1. The law which tells us that lines of the electrostatic field start on positive charges and end on negative charges is:

- |                             |    |    |    |
|-----------------------------|----|----|----|
| <input type="checkbox"/> a. | 1. | c. | 3. |
| <input type="checkbox"/> b. | 2. | d. | 4. |

2. The laws which tell us that changing fields of either type will produce fields of the other type are:

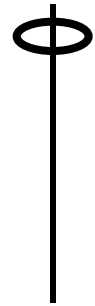
- |  |          |    |          |
|--|----------|----|----------|
| a.                                     | 1 and 3. | c. | 2 and 3. |
| <input checked="" type="checkbox"/> b. | 2 and 4. | d. | 1 and 4. |

3. The law which tells us that lines of the magnetic field always close on themselves is :

- |    |    |  |    |
|----|----|--|----|
| a. | 1. | <input checked="" type="checkbox"/> c. | 3. |
| b. | 2. | d.                                     | 4. |



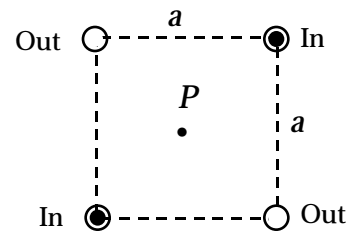
8. A small ring magnet, threaded as shown on a long straight vertical rod, is dropped from rest. It is observed to fall slowly to the floor. Which of the following is **not** true?



- a. The rod is made of a conducting material.
- b. The resistive force exerted by the rod on the ring arises from induced currents in the rod.
- c. If the ring is inverted (upper surface becomes lower, etc., reversing the direction of its B-field) and then dropped, it falls at a different speed. [No difference.]
- d. The resistive force exerted by the rod increases with speed of the ring.

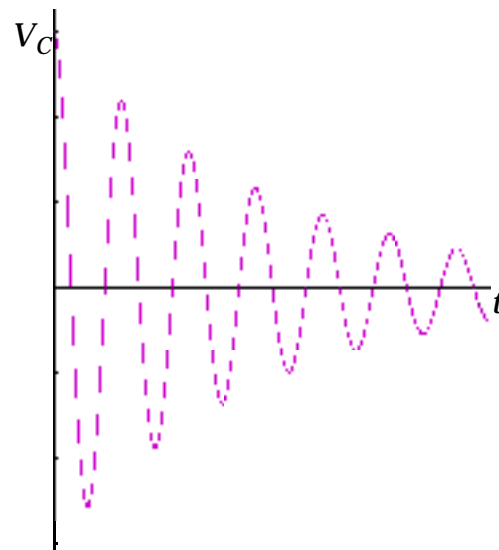
9. Four long wires carry equal currents  $I$  into and out of the page as shown. At point  $P$ , in the geometric center of the square, the B-field is:

- a. Zero.
- b. Out of the page.
- c. To the left.
- d. Upward.



10. The curve shown is a plot of voltage across an initially charged capacitor as a function of time, after the switch is closed at  $t = 0$ . Which circuit exhibits this behavior?

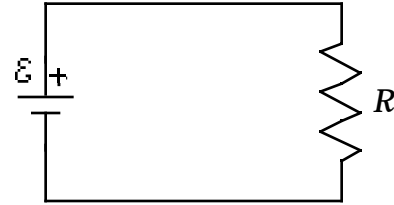
- a.
- b.
- c.



- d. None of the above.

11. In the single loop circuit shown, a battery is connected to a resistor by ordinary wires.

- a. At points inside the loop the Poynting vector is directed from the battery toward the resistor. [Direction of energy flow.]
- b. At points inside the loop the Poynting vector is directed perpendicular to the page.
- c. The energy flow from the battery to the resistor takes place entirely within the wires.
- d. At points outside the loop there is no B-field.



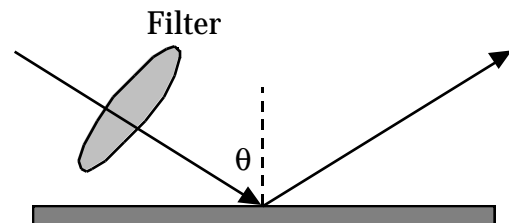
12. Which of the following pairs of fields describes an electromagnetic wave?

- a.  $E_x = E_0 \cos(kz - \omega t)$ ,  $B_y = E_0 \cos(kz - \omega t)$ .
- b.  $E_x = E_0 \cos(kz - \omega t)$ ,  $B_y = (E_0 / c) \sin(kz - \omega t)$ .
- c.  $E_x = E_0 \cos(kz - \omega t)$ ,  $B_y = (E_0 / c) \cos(kz - \omega t)$ .
- d.  $E_x = E_0 \cos(kz - \omega t)$ ,  $B_y = (E_0 / c) \cos(kz + \omega t)$ .

13. A person cannot focus effectively on objects closer than 50 cm or farther away than 5 m. The bifocal glasses to correct this should have lenses of focal lengths:

- a. 50 cm and + 5 m.
- b. +50 cm and + 5 m.
- c. -50 cm and - 5 m.
- d. +50 cm and - 5 m.

14. A beam of unpolarized light in air is being reflected as shown from a horizontal glass plate of refractive index  $n$ . A polaroid filter is placed as shown so that the beam passes through it before striking the plate. When this happens, the reflected beam disappears.



- a. The transmission axis of the filter is in the plane of the page.
- b. The transmission axis of the filter is perpendicular to the plane of the page.
- c. The angle  $\theta$  is such that  $\sin \theta = 1/n$ .
- d. If the filter is rotated  $90^\circ$  about the incident beam direction, there will be a different angle  $\theta$  for which the reflected beam will disappear.

15. An astronomical telescope uses a mirror of diameter  $D$  and focal length  $f$  as its objective. When a distant double star is viewed using this telescope, the images of the two stars are not sufficiently resolved to tell that there are two stars. To get better resolved images, which of the following approaches will work?
- a. Use a mirror of the same diameter but larger focal length.
  - b. Use an eyepiece of smaller focal length.
  - c. Use a mirror of larger diameter. [Sharper diffraction peaks.]
  - d. Use a filter to let through only light of long wavelengths.
16. White light is normally incident on a soap bubble in air, and the reflected light is viewed. As the wall thickness of the bubble approaches zero (just before it breaks) the reflected light:
- a. Becomes dim for all wavelengths. {Only one phase change on reflection.}
  - b. Becomes unusually bright for all wavelengths.
  - c. Becomes bright only for certain wavelengths, dependent on the index of refraction of the bubble.
  - a. None of the above occurs.

**Part B:** True-false questions. Fill in your answers to these questions in Section 4 of the response form, items 17-28. Mark "A" for true, "B" for false. Each question has a value of 3 points.

17. The direction of the static E-field is always toward points of lower potential. **T**
18. An automobile is a relatively safe place to be in a thunderstorm because the rubber tires provide insulation, preventing lightning from reaching the ground. **F**  
[Safe because of shielding. Tires are irrelevant.]
19. No matter what interactions take place within a closed system, the total charge of the system remains constant. **T**
20. Inserting a dielectric slab between the plates of an isolated charged capacitor reduces the stored energy because it reduces the E-field between the plates. **T**
21. The magnetic force on a charge moving in a direction parallel to the direction of the B-field is zero. **T**

22. Just as like charges repel each other, parallel wires carrying currents in the same direction repel each other. **F**
23. The induced current in a wire loop in a changing external B-field produces a B-field of its own that is always opposite in direction to the external field. **F**  
[Opposes change, not necessarily field.]
24. In a series LRC circuit with an AC generator, the fraction of the average power supplied by the generator that the resistor consumes is independent of the values of  $L$  and  $C$ . **T** [Always 100%. The other elements consume no power.]
25. When light of frequency  $f$  travels from a medium with refractive index  $n_1$  into one with index  $n_2$ , the frequency becomes  $(n_1/n_2)f$ . **F**
26. Since the right outside mirror on modern cars has a negative focal length, images seen in that mirror by the driver are farther from the mirror than the object is. **F**  
[Closer, but reduced.]
27. When two light waves interfere destructively the energy in the waves is converted to heat. **F**
28. The resolving power of a grating increases with the number of rulings  $N$  because the peaks of the principal maxima become narrower as  $N$  increases. **T**