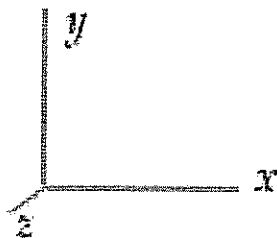


To specify directions, use the coordinate system shown below where $+x$ is to the right, $+y$ is toward the top of the page, and $+z$ is out of the page.

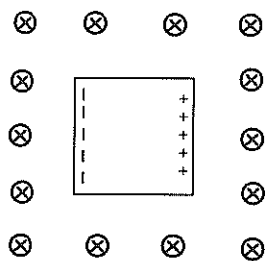


Note the following terminology for directions:

- to the right ($+x$)
- to the left ($-x$)
- upward or toward the top of the page ($+y$)
- downward or toward the bottom of the page ($-y$)
- out of the page ($+z$) \odot
- into the page ($-z$) \otimes

Section 1. Multiple Choice

Questions 1–3: A piece of metal is moving with a constant velocity through a region of uniform magnetic field that is in the $-z$ direction. The metal is polarized due to its motion through the magnetic field, as shown below.



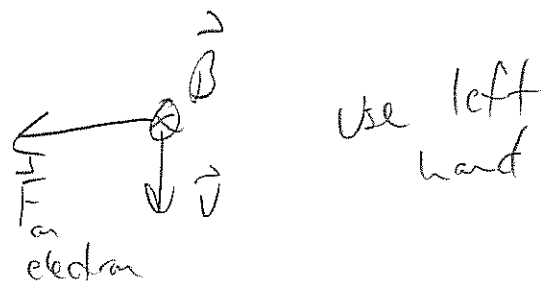
1. In what direction is the magnetic force on a mobile electron in the metal? This is what causes the polarization.

- (a) to the right
- (b) to the left
- (c) up, toward the top of the page
- (d) down, toward the bottom of the page
- (e) None of the above because the magnetic force on a mobile electron is zero.

The magnetic force pushes free electrons so that they pile up on the left side.

2. In what direction is the velocity of the metal object?

- (a) to the right
- (b) to the left
- (c) up, toward the top of the page
- (d) down, toward the bottom of the page
- (e) None of the above because the object is at rest.



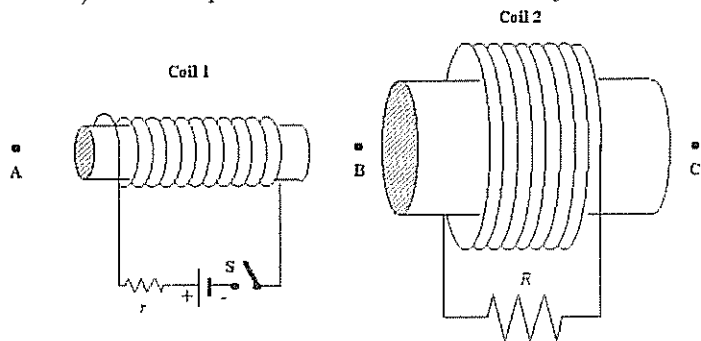
3. The block of metal is 2 m on each side. Its speed is 50 m/s. What strength magnetic field is needed to have a motional emf of 10 V?

- (a) 10 T
- (b) 0.05 T
- (c) 0.4 T
- (d) 2.5 T
- (e) 0.1 T

$$\mathcal{E} = vBL$$

$$B = \frac{\mathcal{E}}{vL} = \frac{10\text{V}}{(50 \frac{\text{m}}{\text{s}})(2\text{m})} = \boxed{0.1\text{T}}$$

Questions 4–6: Two coils, 1 and 2, with iron cores are positioned as shown in the figure. (Note that the iron cores make the coils stronger electromagnets but do not otherwise change your answers to any of the questions.) Coil 1 is part of a circuit with a battery and a switch.



At $t = 0$, the switch S becomes closed.

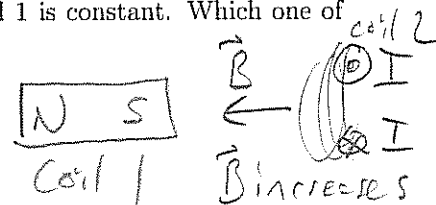
4. Assume the switch S has been closed for a long time and the current through Coil 1 is constant. Which of the following statements is true?

- (a) An induced current in Coil 2 flows through R to the right.
- (b) An induced current in Coil 2 flows through R to the left.
- (c) There is no induced current through Coil 2.

There is no change in flux in coil 2.

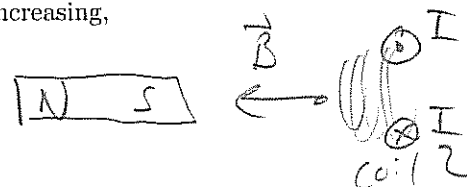
5. Assume S has been closed for a long time and the current through Coil 1 is constant. Which one of the following statements is true when coil 1 is moved toward point B?

- (a) An induced current in Coil 2 flows through R to the right.
- (b) An induced current in Coil 2 flows through R to the left.
- (c) There is no induced current through Coil 2.



6. Suppose that the switch is closed and the voltage of the power supply is increased (by turning a knob on the power supply for example). As the current through Coil 1 is increasing,

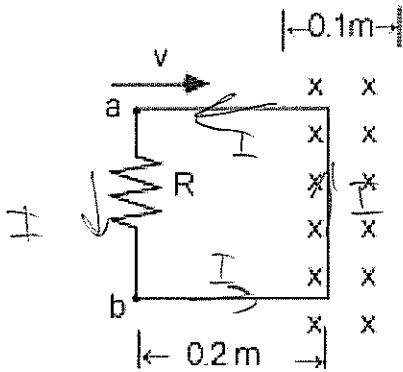
- (a) an induced current in Coil 2 flows through R to the right.
- (b) an induced current in Coil 2 flows through R to the left.
- (c) there is no induced current through Coil 2.



For increasing flux, point thumb opposite B.

B increases.

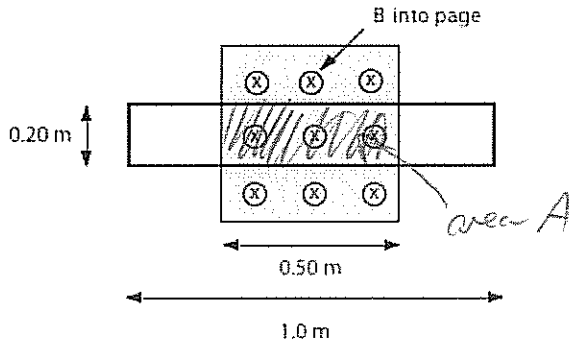
7. A rectangular loop 0.2 m wide moves with a constant speed v into a region of width 0.1 m having a uniform magnetic field perpendicular to the loop as shown. The right edge of the loop enters the field at $t = 0$.



flux is increasing.
 Right thumb opposite \vec{B} .

In what direction is the induced current around the loop at the instant shown in the image.

- (a) clockwise
 (b) counterclockwise
 (c) neither, because the induced current is zero.
8. What is the absolute value of the magnetic flux through the loop shown below if the magnetic field is equal to 10 T? The magnetic field outside the shaded region is zero.



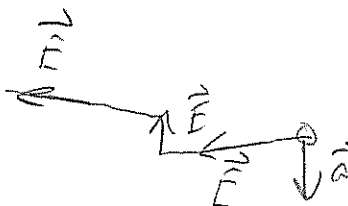
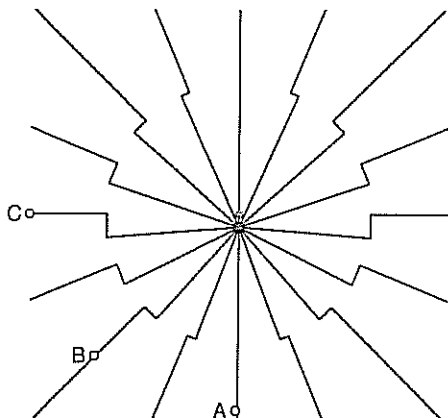
$$\begin{aligned} \Phi &= BA \cos \theta \\ &= BA \quad \text{use } \theta = 0 \\ &\quad \text{or } \theta = 180^\circ \\ &= (10 \text{ T})(0.2 \text{ m})(0.5 \text{ m}) \\ &= 1 \text{ T} \cdot \text{m}^2 \end{aligned}$$

- (a) $2 \text{ T} \cdot \text{m}^2$
 (b) $2.5 \text{ T} \cdot \text{m}^2$
 (c) $1 \text{ T} \cdot \text{m}^2$
 (d) $0.4 \text{ T} \cdot \text{m}^2$
 (e) $10 \text{ T} \cdot \text{m}^2$
9. If the magnetic field in the previous question has a value of 10 T at $t = 0$ and starts increasing at the rate of 5 T/s. According to Faraday's law, what is the magnitude of the emf induced around the loop?

- (a) zero
 (b) 1.0 V
 (c) 5 V
 (d) 0.5 V
 (e) 1.25 V

$$\begin{aligned} \frac{\Delta B}{\Delta t} &= \frac{5 \text{ T}}{\text{s}} \quad |\mathcal{E}| = \left| \frac{\Delta \Phi}{\Delta t} \right| \\ &= A \frac{\Delta B}{\Delta t} \cos \theta \quad \theta = 0 \\ &\quad \text{or } 180^\circ \\ &= (0.2 \text{ m})(0.5 \text{ m}) \left(\frac{5 \text{ T}}{\text{s}} \right) \\ &= \boxed{0.5 \text{ V}} \end{aligned}$$

Questions 10–13: A positively charged particle is at rest when it receives a brief acceleration downward. At the instant shown, it is traveling downward at a constant velocity. The electric field lines at a certain instant t around the particle are shown. The size of the particle is not drawn to scale.



Suppose that light detectors are placed at points A, B, and C which are all at the same distance from the particle.

10. If it takes $6 \mu\text{s}$ for the pulse to travel from the particle to point C, how far is point C from the particle?

- (a) 1.8 m
- (b) 50 m
- (c) 1.8×10^6 m
- (d) 200 m
- (e) 1800 m

$$v = \frac{d}{\Delta t}$$

$$d = v \Delta t = (3 \times 10^8 \frac{\text{m}}{\text{s}})(6 \times 10^{-6} \text{s}) = 1800 \text{ m}$$

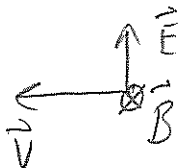
11. At the instant the pulse reaches point C, what is the direction of the radiative electric field?

- (a) $-x$ direction
- (b) $+y$ direction
- (c) $-y$ direction
- (d) $+z$ direction
- (e) $-z$ direction

At the "kink" is E_{rad} .

12. At the instant the pulse reaches point C, what is the direction of the radiative magnetic field?

- (a) $-x$ direction
- (b) $+y$ direction
- (c) $-y$ direction
- (d) $+z$ direction
- (e) $-z$ direction



thumb - \vec{v}
fingers - \vec{E}
palm - \vec{B}

13. Rank the points in order of the intensity of light measured by the detector when the pulse passes the points.

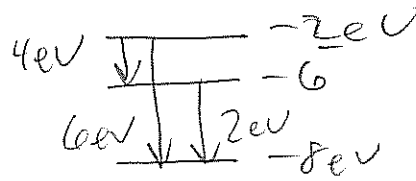
- (a) $A > B > C$
- (b) $B > C > A$
- (c) $C > B > A$
- (d) $A > C > B$
- (e) $A = B = C$

E_{rad} is largest at C.

$E_{\text{rad}} = 0$ at A.

14. The energy levels for a certain quantum system are -2.0 eV, -6.0 eV, and -8.0 eV. Sketch an energy level diagram. What are the energies of the photons that can possibly be emitted by the system?

- (a) 2.0 eV, 6.0 eV, 8 eV
- (b) 8.0 eV, 10 eV, 14 eV
- (c) 2.0 eV, 4.0 eV
- (d) 2.0 eV, 4.0 eV, 6.0 eV
- (e) 6.0 eV, 8.0 eV



15. Suppose that a star has a temperature of 15000 K. The wavelength of its peak will be in what region?

- (a) UV
- (b) blue
- (c) green
- (d) yellow
- (e) IR

$$\lambda_{\text{peak}} T = 2.9 \times 10^{-3} \text{ K}\cdot\text{m}$$

$$\lambda = 1.93 \times 10^{-7} \text{ m} = 193 \text{ nm}$$

UV

16. The normal human body temperature is about 310 K. What is the wavelength of its peak radiation in units of nm?

- (a) 94,000 nm
- (b) 310 nm
- (c) 940 nm
- (d) 3100 nm
- (e) 9400 nm

$$\lambda T = 2.9 \times 10^{-3}$$

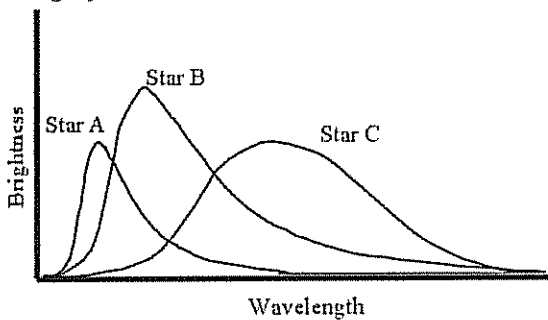
$$\lambda = 9.35 \times 10^{-6} \text{ m} = 9350 \text{ nm}$$

17. If a person is running a high fever, the wavelength of her peak radiation will be

- (a) shorter than normal.
- (b) longer than normal.
- (c) the same as normal.

As $T \uparrow$, $\lambda_{\text{peak}} \downarrow$

18. The graph below shows spectra for three stars. Which star has the lowest temperature?

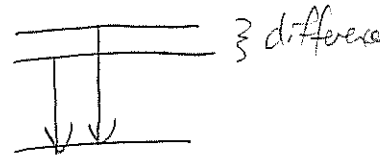


As $T \downarrow$, $\lambda_{\text{peak}} \uparrow$

- (a) Star A
- (b) Star B
- (c) Star C
- (d) Stars A and C have the same temperature and are lower than B.
- (e) None of the above because they all have the same temperature.

19. The spectrum emitted by excited sodium gas includes two very closely spaced lines in the yellow part of the visual spectrum, at wavelengths of 588.995 nm and 589.592 nm, respectively. The photons associated with this light come from electron transitions that start from one of two closely-spaced 3p levels in sodium and end at the same 3s level. What is the energy difference of these two 3p levels?

- (a) 2.105 eV
- (b) 4.208 eV
- (c) 0.00426 eV
- (d) 2.103 eV
- (e) 0.00213 eV

$$E_{\text{photon}_1} = \frac{hc}{\lambda_1} = \frac{1240 \text{ eV} \cdot \text{nm}}{588.995 \text{ nm}} = 2.10528 \text{ eV}$$


$$E_{\text{photon}_2} = 2.10315 \text{ eV} \quad \text{Difference} = 0.00213 \text{ eV}$$

20. How many red photons of wavelength 654 nm are needed to have the same energy as one x-ray photon of energy 25 MeV that is used in nuclear medicine to treat cancer?

- (a) 1.3×10^7
- (b) 13
- (c) 3.8×10^4
- (d) 38
- (e) 4.7×10^7

$$\frac{25 \times 10^6 \text{ eV}}{1.90 \text{ eV}} = 1.32 \times 10^7$$

$$E_{\text{red photon}} = \frac{hc}{\lambda} = \frac{1240 \text{ eV} \cdot \text{nm}}{654 \text{ nm}} = 1.90 \text{ eV}$$

21. A blue laser and a green laser both emit 1×10^{17} photons per second. Which laser has a greater power?

- (a) blue laser
- (b) green laser
- (c) They have the same power because they emit the same number of photons per second.

$E_{\text{blue}} > E_{\text{green}}$ since blue has a shorter λ than green.

Questions 22–25 are related to a hydrogen atom. It is helpful to calculate the first 9 energy levels so that you can easily calculate the energies of photons emitted or absorbed for certain transitions.

22. A hydrogen atom transitions from orbit $n = 3$ to orbit $n = 1$. Did it emit or absorb a photon?

- (a) It emitted a photon.
- (b) It absorbed a photon.
- (c) It could have either absorbed a photon or emitted a photon.

The atom lost energy.

23. For the previous question, what energy photon is emitted or absorbed?

- (a) 1.51 eV
- (b) 13.6 eV
- (c) 12.1 eV
- (d) 15.1 eV
- (e) 10.2 eV

$$E_{\text{photon}} = |\Delta E_{\text{electron}}| = \left| -\frac{13.6 \text{ eV}}{3^2} - \left(-\frac{13.6 \text{ eV}}{1^2}\right) \right| = 12.1 \text{ eV}$$

24. A hydrogen atom emits a photon of wavelength 397 nm. What transition did it make?

- (a) $n = 4$ to $n = 1$
- (b) $n = 6$ to $n = 3$
- (c) $n = 7$ to $n = 3$
- (d) $n = 7$ to $n = 2$
- (e) $n = 9$ to $n = 2$

for $n = 7$ to $n = 2$, $E_{\text{photon}} = \frac{hc}{\lambda} = \underline{3.12 \text{ eV}}$

$$|\Delta E| = |-0.278 - -3.4| = 3.12 \text{ eV} = E_{\text{photon}}$$

25. A wavelength of 1945 nm is observed in a hydrogen spectrum for a transition that ends in the $n_f = 4$ level. What was n_i for the initial level of the electron?

- (a) 5
- (b) 6
- (c) 7
- (d) 8
- (e) 9

$$E_{\text{photon}} = \frac{hc}{\lambda} = \frac{1240 \text{ eV}\cdot\text{nm}}{1945 \text{ nm}} = 0.638 \text{ eV}$$

$$|\Delta E| = E_{\text{photon}} = |E_f - E_i|$$

$$E_i = E_f + E_{\text{photon}}$$

$$= \frac{-13.6 \text{ eV}}{4^2} + 0.638 \text{ eV}$$

$$E_i = -0.212 \text{ eV} = \frac{-13.6 \text{ eV}}{n_i^2}$$

$$n_i = \sqrt{\frac{13.6 \text{ eV}}{0.212 \text{ eV}}} = 8$$

Hydrogen

n	E_n (eV)
1	-13.6
2	-3.4
3	-1.511
4	-0.85
5	-0.544
6	-0.378
7	-0.278
8	-0.212
9	-0.168

5A

Answer Key for Exam A

Section 1. Multiple Choice

- | | |
|---------|---------|
| 1. (b) | 14. (d) |
| 2. (d) | 15. (a) |
| 3. (e) | 16. (e) |
| 4. (c) | 17. (a) |
| 5. (b) | 18. (c) |
| 6. (b) | 19. (e) |
| 7. (b) | 20. (a) |
| 8. (c) | 21. (a) |
| 9. (d) | 22. (a) |
| 10. (e) | 23. (c) |
| 11. (b) | 24. (d) |
| 12. (e) | 25. (d) |
| 13. (c) | |