Physics 1B: Electricity & Magnetism
Summer Session I, 2010
Final Exam, July 30, 2010

This is version **A**!

Useful coefficients:
Mass of proton, $m_p = 1.67 \times 10^{-27}$ kg; Mass of electron, $m_e = 9.11 \times 10^{-31}$ kg
Unit of elementary charge $e = 1.6 \times 10^{-19}$ C
Coulomb's constant, $k_e = 8.99 \times 10^9$ N m^2 C^{-2}
Permittivity of free space $\epsilon_0 = \frac{1}{4\pi k_e} = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$
1 eV = 1.6 $\times 10^{-19}$ J
$g = 9.8$ m s^{-2}
Permeability of free space $\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}
Speed of light $c = 3 \times 10^8$ m/s

1. Which of the following characteristics are held in common by both gravitational and electrostatic forces when dealing with either point masses or charges?
a. inverse square distance law applies
b. forces are conservative
c. potential energy is a function of distance of separation
d. all of the above choices are valid

Solution: d.

2. An electrical device with a resistance of 1Ω is operated at a voltage of 2.0 V. How many electrons pass through a point inside the device in a time Δt = 0.8 seconds?
a. 16 electrons
b. 6.4 $\times 10^{19}$ electrons
c. 1.56 $\times 10^{18}$ electrons
d. 1.0 $\times 10^{19}$ electrons
e. 7.8 $\times 10^{17}$ electrons

We must calculate the current via I = ΔV/R = 2V/1.0Ω = 2.0 A.
From the definition of current, I = ΔQ/Δt we can calculate the total charge which passes through the device: ΔQ = I Δt = (2.0 C/s)(0.8 s) = 1.6 C
Finally, we divide by the unit of elementary charge:
N = ΔQ/(1.6 $\times 10^{-19}$ C/e$^-$) = 1.6 C / (1.6 $\times 10^{-19}$ C/e$^-$) = 1.0 $\times 10^{+19}$ electrons

3. In the core of a supergiant star, nuclear fusion is occurring: in one reaction, three helium nuclei (^{4}He; 2 protons, 2 neutrons each) fuse together to form a single carbon nucleus (^{12}C; six protons and six neutrons in each). Suppose three ^{4}He nuclei have just fused to create a ^{12}C nucleus, and there's an extra ^{4}He nucleus sitting 4 nm away (1 nm = 10^{-9} m). What is the resulting electrostatic force between the ^{12}C and ^{4}He nuclei? (Note: temperatures here are high enough that all atoms are ionized, i.e., all electrons have been stripped, so assume electrons are not relevant here.)
a. 1.8×10^{-8} N
b. 9.6×10^{-8} N
c. 3.0×10^{-11} N
d. 9.6×10^{-10} N
e. 1.7×10^{-10} N

Solution: $q_1 = +6$e; $q_2 = +2$e. $F_e = \frac{k_e q_1 q_2}{r^2} = 8.99 \times 10^9 Nm^2C^{-2} \times 2 \times 6 \times (1.6 \times 10^{-19}C)^2(4 \times 10^{-9}m)^2 =$ 1.7×10^{-10} N

4. Two protons are initially 2×10^{-9} m apart. What is the CHANGE in potential energy (P.E.$_{\text{final}}$ – P.E.$_{\text{initial}}$) if they're brought in to a separation distance of 1×10^{-9} m?
a. 0.18 eV
b. 0.36 eV
c. 0.72 eV
d. 1.44 eV
e. 2.88 eV

The initial potential energy is PE(initial)= $(k_e q_1 q_2)$/r =
$(8.99 \times 10^9$ N m^2 C^{-2} $\times (1.6 \times 10^{-19}C)^2/2e - 9m) =$
1.15×10^{-19} J.

The final potential energy is PE(final)= $(k_e q_1 q_2)$/r =
(8.99×10^9 N m^2 C^{-2} $\times (1.6 \times 10^{-19}C)^2/1e - 9m) =$
2.30×10^{-19} J.

PE(final) – PE(initial = 1.15×10^{-19} J
Using 1 eV = 1.6e-19 J, this amount of energy is equal to 0.72 eV.

5. A proton is moved 4 cm along the direction of a uniform E-field whose strength is 100 N/C. What's the electric potential difference between these two points in space?
a. 40 V

b. 100 V
c. 4 V
d. 400 V
e. 16 V

$\Delta V = Ed = (100N/C)(0.04m) = 4V.$
Note that the magnitude of the charge is extra information and not needed for this problem.

6. A 9.0-volt battery moves 300 milliCoulombs of charge through a circuit connecting the battery's terminals. How much energy was delivered to the circuit?
a. 27.0 J
b. 2.7 J
c. 0.3 J
d. 33.3 J
e. 0.03 J

The energy can calculated via $\Delta PE = q\Delta V$ = (0.3 C)(9.0 V) = 2.7 J.

7. In which case does an electric field do a positive quantity of work on a charged particle?
a. a negative charge moves opposite to the direction of the electric field.
b. a positive charge is moved from a point of low potential energy to a point of higher potential energy.
c. a positive charge completes one circular path around a stationary positive charge.
d. a positive charge completes one elliptical path around a stationary positive charge.

Solution: In order to make choices b, c, or d happen, we'd have to supply some work ourselves at some point. For choice a, the E-field does all the work in moving the negative charge.

8. Consider two charged spheres, one with charge +2 C and the other with –2 C. A proton is located at the point halfway between the spheres. What is not zero?
a. the potential energy of the proton (due to its interaction with the two spheres)
b. the work needed to move the proton from a distance r = infinity to that point
c. the net force on the proton

Solution: The PE of the proton as it interacts with the +2C charge is $\frac{k_e(+2C)(+1e)}{r}$, and the PE of the proton as it interacts with the –2C charge is $\frac{k_e(+2C)(-1e)}{r}$ The total PE of the proton is thus zero. The work required to move the proton from infinity to this point is equal to choice a, so it's also zero. The answer is choice c: The proton will be attracted to the –2C charge and repelled by the +2C charge. The two force vectors at work on the proton work in the same direction (and have the same magnitude), so there will be a non-zero netforce on the proton.

9. Two capacitors are connected in parallel with a battery: capacitor A has capacitance C_A; capacitor B has capacitance C_B; C_A is greater than C_B. Which of the following statements is true?
a. There is a larger potential difference across capacitor A.
b. There is a larger potential difference across capacitor B.
c. There is the same quantity of charge stored on each capacitor.
d. There exists the same potential difference across both capacitors.

Answer: Because they are connected in parallel, the voltage difference across each must be identical (confirming choice d), and equal to the EMF supplied by the battery. So choices a and b are rejected.
Capactitance is defined as C = Q/ΔV. ΔV is identical for each capacitor, but the capacitance differs. So the amount of charge Q on each must differ. So choice c is rejected.

10. You're an EMT working on a patient who's suffering a heart attack and needs the maximum amount of energy delivered from a defibrillator machine. You have four such devices available to choose from; you must choose one. Which parameters describe the one that can store the most energy? (Assume there is one single capacitor used in each machine.)
a. $\Delta V = 1000$ V and C= 1×10^{-4} F
b. $\Delta V = 10000$ V and C= 1×10^{-4} F
c. $\Delta V = 1000$ V and C= 1×10^{-3} F
d. $\Delta V = 100$ V and C= 1×10^{-3} F

Solution: The energy stored in a capacitor can be calculated as $U = 1/2\ C\ (\Delta V)^2$. For the above choices, U = 50, 5000, 500 and 5 J, respectively. So choice b is the largest value.

11. If the current in a wire is tripled, what effect does this have on the electron drift velocity in the wire?
a. It stays the same.
b. It triples.
c. It decreases by a factor of three.
d. It increases by a factor of nine.

Answer: Drift velocity and current are linearly proportional to each other, so if you triple one, you triple the other (assuming that the wire's cross section, composition, etc. do not change)

12. Replacing a wire resistor with another of the same material and length but with three times the diameter will have the effect of changing the resistance by what factor compared to the original?
a. 1/3
b. 1/9
c. 3
d. 9
e. no change in R occurs

Solution: recall R = ρl/A. Increasing the diameter by 3 will increase the area by 9, so the resistance will by a factor of 9 smaller: choice b.

13. Point charge Q_1 has 50 electric field lines radiating outward and Q_2 has 100 field lines converging inward. What is the ratio Q_1/Q_2?
a. 2
b. –2
c. 1/2
d –1/2

Answer: Q_1 must be positive and Q_2 must be negative. Q_2 must contain twice as much charge, so $Q_1/Q_2 = -1/2$.

14. A van de Graaf generator has a spherical conducting dome. Operating in dry air, where "atmospheric breakdown" occurs at $E_{\rm max} = 3 \times 10^6$ N/C, what is the minimum charge needed on the dome to induce electrical discharge at a distance of 1 meter? (Hint: outside the dome, the E-field looks like that from a point charge at the center of the dome)
a. 1 C
b. 3×10^{-7} C
c. 3×10^{-4} C
d. 3×10^6 C
e. 3 C

Answer: Use $E_{\rm max} = \frac{k_e Q}{r^2}$ and solve for Q:
$Q = \frac{r^2 E_{\rm max}}{k_e} = \frac{(1m)^2 3e6N/C}{9e9Nm^2C^{-2}} = 3 \times 10^{-4}$ C

15. You wish to design a velocity selector such that the energy of each electron that passes through undeflected will be 45 eV. You have a magnet which can produce a uniform magnetic field of 0.1 T. You want to produce just the right electric field (oriented perpendicular to the magnetic field) using a capacitor whose plates are separated by 0.01m. What voltage difference across the plates of the capacitor is required?
a. 4.0×10^5 V
b. 40 V
c. 0.4 V
d. 400 V
e. 4000 V

Solution: Step 1 is to calculate the required velocity. We're given that the energy of each electron must be 45 eV. Since 1 eV is 1.6e-19 J, 45 eV = 7.2e-18 J. Since this is the kinetic energy of each electron, K.E. = $\frac{1}{2}$ m_e v^2, we can solve for v = $\sqrt{2 \times KE/m_e} = 4.0 \times 10^6$ m/s
Step 2 is to calculate the required E-field strength. For a velocity selector, v = E/B. Or, E = vB = (4e6 m/s)(0.1T) = 4e5 V/m
Step 3: Calculate the voltage difference across the capacitor plates: ΔV = Ed = (4e5 V/m)(0.01m) = 4000 V.

16. A stream of protons from the solar wind are caught in the magnetic field lines just above the surface of Jupiter, where the magnetic field strength is 5 Gauss (about ten times the Earth's magnetic field); each particle traces out a helical path with a radius of 10.4 m. From this information, what is the component of the particles' velocity perpendicular to the local magnetic field?
a. 1000 km/s
b. 100 km/s
c. 50 km/s
d. 0.5 km/s
e. 500 km/s

Solution: qrB = mv
v = qrB/m = (1.6e-19C)(10.4m)(5e-4T)/(1.67e-27 kg) = 5e5 m/s = 500 km/s.

17. Which condition of motion must be met with regard to a charged particle if it is in the process of emitting electromagnetic radiation?
a. moves at constant velocity

b. accelerates
c. moves at the speed of light
d. moves parallel to a uniform magnetic field

Answer: B

18. A current-carrying wire 40 cm in length is taped to an inside wall of a compartment in which a steady, uniform magnetic field of 3 T exists, with $\vec{B}$ perpedicular to the direction of current. If a force of 30 N will be sufficient to overcome the adhesion of the tape and pull the wire from the wall, what is the maximum current that can the wire can carry without this occurring?
a. 250 A
b. 25 A
c. 2.5 A
d. 0.25 A

Solution: Use F_B = B I l sin(θ).

I = F_B / (B l sin(θ)) = 30 N / (3 T $\times$ 0.40m $\times$ 1) = 25 A

19. A rectangular coil measuring 0.20 m $\times$ 0.80 m has 200 turns and is immersed in a uniform magnetic field of 0.30 T. If the orientation of the coil is varied through all possible positions, the maximum torque on the coil by magnetic forces is 0.080 N m. What is the current in (each loop of) the coil?
a. 2.0 mA
b. 1.7 A
c. 8.3 mA
d. 1.0 A
e. 0.083 A

Solution: Because the torque τ = NBIAsin(θ), the maximum torque value will be τ = NBIA. We can solve for the current I = τ / (NBA) =
(0.080 Nm)/(200 $\times$ 0.3T $\times$ 0.20 m $\times$ 0.80 m) = 0.0083 A = 8.3 mA

20: Two long parallel wires 40 cm apart are carrying currents of 10 A and 20 A in the same direction. What is the magnitude of the total magnetic field at a point halfway between the wires?
a. 1.0×10^{-5} T
b. 2.0×10^{-5} T
c. 3.0×10^{-5} T

d. 4.0×10^{-5} T
e. 0

Because the wires carry currents in opposite directions, their respective B-field lines will circulate in opposite directions. At the midway point, the B-field vectors will be pointing in opposite directions. The magnitude of the net magnetic field will be the difference between the B-fields from each wire spearately.
At a point 20cm = 0.2m from the wire carrying 10A, the B-field will be
B $\frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}TmA^{-1}10A}{2\pi 0.20m} = 1.0 \times 10^{-5}$ T
At a point 20 cm from the wire carrying 20 A, the magnitude of the magnetic field will be exactly twice that from the 10-A wire (since B is linearly proportional to I). So B will be 2.0×10^{-5} T.
The net magnetic field strength will thus be 2.0×10^{-5} T – 1.0×10^{-5} T = 1.0×10^{-5} T.

21. When current is flowing in a superconductor, which statement is not true?
a. A battery is needed to keep the current going.
b. Electrical charges are moving.
c. The resistance is zero.
d. No power is given off in the form of heat.

Solution: choice a is incorrect

22. A particle is traveling freely in a circular trajectory perpendicular to a uniform magnetic field. The radius of the trajectory is 1 m. At a given instant in time, the particle has a kinetic energy of 3.0 $\times 10^{-14}$ J. Assuming no other external forces act on the particle, what is the particle's kinetic energy at a time t=10.0 seconds later?
a. 6.0 $\times 10^{-14}$ J
b. 3.0 $\times 10^{-14}$ J
c. 1.5 $\times 10^{-14}$ J
d. 0.6 $\times 10^{-14}$ J
e. 0.3 $\times 10^{-14}$ J

Solution: The particle's kinetic energy and velocity both remain constant, as the magnetic field acts perpendicular to the particle's forward motion.

23. Two parallel wires are separated by 0.25 m. Wire A carries 5.0 A and Wire B carries 10.0 A, with both currents in the same direction. The total magnetic force acting on 0.80 m of Wire A is:
a. half that on 0.80 m of wire B.
b. one-fourth that on 0.80 m of wire B.

c. directed toward Wire B.
d. directed away from Wire B.

The force per length on either wire is given by $F_1/l = F_2/l = \mu_o I_1 I_2 \ / \ 2\pi r$. That is, the force on 0.8 m of wire A will be identical to that acting on 0.8m of wire B. So choices a and b must be eliminated. Two wires carrying parallel currents will attract each other, so the anwser is "c".

24. A superconducting wire is formed into an air-core solenoid electromagnet of length 0.31416 m with 300 turns. What (very large) current is required to produce a magnetic field of 4.8 T?
a. 400 A
b. 2000 A
c. 2667 A
d. 4000 A
e. 8000 A

Solution: Inside a solenoid, the magnetic field $B = \mu_o$ I n, where n is the number of turns N per unit length l. We can rearrange to solve for the required current:
$I = B \ / \ (\mu_0 \ n) = B \ / \ (\mu_0 \ (N/l)) = 4.8 \text{ T} \ / \ (4\pi\text{e-7 Tm/A} \times (300 \ / \ 0.31416\text{m}))$
$I = 4000$ A

25. A magnet moving past an object will produce eddy currents in the object if the object:
a. is magnetic material only.
b. is an insulator.
c. is a liquid.
d. is a conductor.
e. is shaped like a hollow cylinder

Answer: D

26. A long, straight conducting rod 1.5 m in length is moved perpendicular to a uniform magnetic field of 0.001 T. What velocity is required to induce an EMF of 2.0 V?
a. 1.77 km/s
b. 0.13 km/s
c. 1.33 km/s
d. 0.27 km/s
e. 2.67 km/s

Solution: For motional EMF, $\epsilon_{\text{ind}} = B \, l \, v$.
$v = \epsilon_{\text{ind}} \ /(Bl) = (2.0 \text{ V})/(0.001 \text{ T} \times 1.5\text{m}) = 1.33 \times 10^3 \text{ m/s} = 1.33 \text{ km/s}$

27. Consider a patient inside an MRI machine, where the magnetic field strength is 3 T. Calculate the magnetic flux through the patient's skull; assume for simplicity a circular cross-section with radius 15 cm.
a. 0.21 Wb
b. 0.84 Wb
c. 6.79 Wb
d. 42.4 Wb

Solution: Φ_B = BA = 3 T (π (0.15m)^2) = 0.21 Wb

28. A planar loop consists of 50 turns of wire, each enclosing an area of 0.05m^2. It's positioned perpendicular to a uniform magnetic field of 0.10 T. It is then rotated through 180 degrees in a time of 0.5 seconds. Calculate the magnitude of the induced EMF.
a. 5.0 V
b. 0.1 V
c. 0.5 V
d. 1.0 V
e. 2.0 V

Solution: We use Faraday's Law: $\epsilon_{\text{ind}} = N\frac{\Delta\Phi_B}{\Delta t}$.
$\Delta\Phi_B$ = B $\times$ ΔA, where the change in area = 2$\times$ the area given.
So ϵ_{ind} = (50)(0.10T)(2 $\times$ 0.05m^2)/(0.5s) = 1.0 V

29. A planar loop consists of 4 turns of wire, each enclosing an area of 0.02 m^2. It is positioned perpendicularly to a uniform magnetic field whose magnitude increases at a constant rate from 2.0 T to 6.0 T is 2.0 s. The coil's total resistance is 0.40Ω. What is the magnitude of the induced current?
a. 1.6 A
b. 6.0 A
c. 0.8 A
d. 3.2 A
e. 4.0 A

Solution: We can calculate the induced EMF via Faraday's Law: $\epsilon_{\text{ind}} = N\frac{\Delta\Phi_B}{\Delta t} = 4\frac{4.0T\times0.02m^2}{2.0s} = 0.16V$
The induced current I = ϵ_{ind}/R = 0.16V / 0.40Ω = 4.0 A.

30. A bar magnet is falling through a loop of wire with constant velocity. The north pole

enters first. As the south pole leaves the loop of wire, the induced current (as viewed from above) will be:
a. clockwise.
b. counterclockwise.
c. zero.
d. along the length of the magnet.

Solution: As the south pole leaves, the magnetic field lines from the magnet are pointing dowards, but the magnitude of the magnetic field is decreasing. The induced current in the loop acts to "shore up" the decreasing magnetic field. It will rotate clockwise as seen from above to generate an induced B-field which points downward (right-hand rule: as seen from above, when your thumbs points downward, your fingers curl clockwise).

31. Electricity may be generated by rotating a loop of wire between the poles of a magnet. The instantaneous induced current is greatest when:
a. the plane of the loop is parallel to the magnetic field.
b. the plane of the loop is perpendicular to the magnetic field.
c. the magnetic flux through the loop is a maximum.
d. the plane of the loop makes an angle of 45° with the magnetic field.

Solution: The change in magnetic flux is greatest when the the plane of the loop is PARALLEL to the magnetic field.

32. You wish to construct an alternating-current generator by rotating a 100-turn circular coil inside a constant magnetic field of 0.5 T. Each turn of wire encloses an area of 0.01 m^2. How quickly do you need to rotate the loop in order to achieve a maximum instantaneous EMF of 10 V? Note that the responses below are in units of Hz (revolutions per second, or cycles per second), not radians/sec!
a. $10/\pi$ Hz
b. $50/\pi$ Hz
c. 200 Hz
d. $20/\pi$ Hz
e. 20 Hz

Solution: In an AC generator, the EMF as a function of time will follow
ϵ(t) = NBAωsin(ω t). Here, ω is the angular speed, measured in radians/sec.
The maximum value of the EMF will be NBAω.
Solve for ω:
$\omega = \epsilon_{\max}/(\text{NBA}) = (10\text{V})/(100 \times 0.5T \times 0.01m^2) = 20$ rad/sec.
The frequency $f = \frac{\omega}{2\pi} = \frac{20rad/sec}{2\pi} = 10/\pi$ cycles per second.

33. By what factor is the self-inductance of an air-core solenoid changed if only its number of coil turns, N, is tripled?
a. 1/3
b. 3
c. 6
d. 9

Solution: L = μ_o N^2 A/l
Tripling N means L increases by a factor of 9.

34. A 12-V battery is connected in series with a switch, resistor, ammeter and solenoid (inductor). You are told that the circuit's time constant is 0.2 milliseconds. You close the switch, and after several seconds, the ammeter is registering a current of 1.0 A. What is the value of the inductance?
a. 1.2 mH
b. 2.4 mH
c. 9.6 mH
d. 48 mH
e. 0.6 mH

Solution: Several seconds is effectively many time constants here. The current has reached its maximum value, ϵ/R. The voltage drop across the resistor is ϵ.
The resistance can be calculated as ϵ/I = 12V/1.0A = 12Ω.
Now that we know the resistance, we can use τ = L/R to solve for L:
L = Rτ = (12Ω)(2×10^{-4} s) = 2.4×10^{-3}H = 2.4 mH.

35. An AC power source produces a peak voltage of 7200 V and a peak current of 100 A in a circuit. This circuit is attached to an ideal transformer whose job is to step-up the voltage to 200,000 V (peak) for energy transmission in a long-distance power line. What is the peak current in the long-distance line?
a. 1.0 A
b. 2.8 A
c. 24 A
d. 2800 A
e. 3.6 A

Solution: Power input at primary = power output at secondary:
$I_1 \Delta V_1 = I_2 \Delta V_2$
$I_2 = I_1 \Delta V_1 / \Delta V_2$ = (100 A)(7200 V)/ (2×10^5 V) = 3.6 A

36. An ideal transformer is used to increase the 30 kV (rms) output of a power plant to the

transmission line voltage of 345 kV (rms). If the primary winding has 80 turns, how many turns must the secondary have?
a. 7
b. 80
c. 651
d. 920
e. 1301

Solution: For an ideal transformer, $\frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$. As this is a "step-up" transformer, we need N_2 to be greater than N_1
$N_2 = N_1 \frac{\Delta V_2}{\Delta V_1} = 920$

37. An AC voltage source, with a peak output of 200 V, is connected to a 50-Ω resistor. What is the rate of energy dissipated due to heat in the resistor?
a. 200 W
b. 400 W
c. 566 W
d. 800 W
e. 1131 W

Solution: Average power dissipated P for an AC current is ΔV_{rms}^2/R
and $\Delta V_{rms} = \Delta V_{max}/\sqrt{2}$
$P = (\Delta V_{max}/\sqrt{2})^2$ / R = $(\Delta V_{max}^2/2)$ / R = 400 W

38. How is the direction of propagation of an electromagnetic wave oriented relative to the associated $\vec{E}$ and $\vec{B}$ fields?
a. perpendicular to both $\vec{E}$ and $\vec{B}$
b. parallel to both $\vec{E}$ and $\vec{B}$
c. parallel to $\vec{E}$ and perpendicular to $\vec{B}$
d. perpendicular to $\vec{E}$ and parallel to $\vec{B}$

Solution: choice a

39. At the orbital radius of the Earth, the sun's intensity is 1370 W/m^2. The sun emits isotropically. At the orbital radius of which of the following planets will the sun's intensity be 2796 W/m^2?
a. Jupiter, whose orbital radius is 5.2 times that of the Earth
b. Mars, whose orbital radius is 1.6 times that of the Earth
c. Venus, whose orbital radius is 0.7 times that of the Earth

d. Mercury, whose orbital radius is 0.4 times that of the Earth

Solution: Since intensity = power/area = P/$(4\pi r^2)$, intensity goes as r^{-2}.
The intensity is stronger than that at the Earth, so [planet] must be closer to the Sun than the Earth is.
So the ratio $\frac{intensity\ at\ [planet]}{intensity\ at\ Earth}$ (which is equal to 2796 W/m^2 / 1370 W/m^2 = 2.04) will be equal to the ratio
$\frac{(orb.\ rad.\ of\ [planet])^{-2}}{(orb.\ rad.\ of\ Earth)^{-2}} = \frac{(orb.\ rad.\ of\ Earth)^2}{(orb.\ rad.\ of\ [planet])^2} = (\frac{(orb.\ rad.\ of\ Earth)}{(orb.\ rad.\ of\ [planet])})^2$
So $(\frac{(orb.\ rad.\ of\ Earth)}{(orb.\ rad.\ of\ [planet])}) = \sqrt{\frac{intensity\ at\ [planet]}{intensity\ at\ Earth}} = \sqrt{2.04} = 1.43$
The orbital radius of [planet] is 1/1.43 = 0.70 times that of the Earth. Correct answer = Venus.

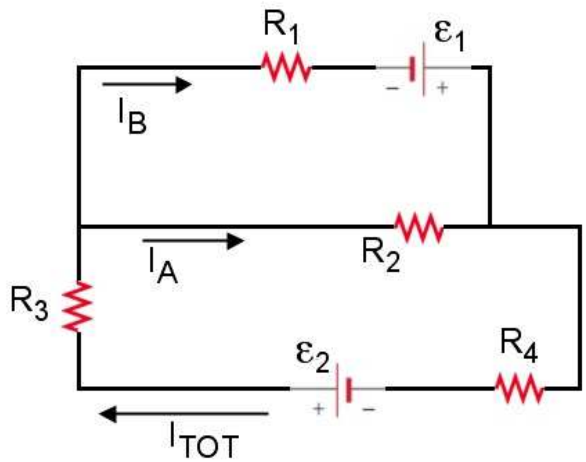
40. In order of increasing frequency, which of the following sequences of electromagnetic radiation is correct?
a. infrared, visible, ultraviolet, gamma-ray
b. visible, radio, ultraviolet, x-ray
c. infrared, x-ray, visible, gamma-ray
d. visible, gamma, ultraviolet, x-ray
e. gamma-ray, x-ray, infrared, radio

Solution: choice A

41. In my X-ray astrophysics research, I commonly make use of the following atomic emission lines due to the following atomic species:
Oxygen, at $f = 1.3 \times 10^{17}$ Hz
Iron, at $f = 1.7 \times 10^{17}$ Hz
Silicon, at $f = 4.2 \times 10^{17}$ Hz
Carbon, at $f = 9.0 \times 10^{16}$ Hz
Which of the following X-ray bandpasses is adequate to study emission from all four spectral features simultaneously?
(Reminder: 1 nm = 10^{-9} m; speed of light $c = 3 \times 10^8$ m/s)
a. 1.50 nm to 5.00 nm
b. 0.50 nm to 5.00 nm
c. 0.50 nm to 2.75 nm
d. 0.80 nm to 3.00 nm

Solution: The last two spectral lines listed have the lowest and highest frequencies, respectively, so they will have the longest and shortest wavelengths, respectively. The other two will fall in between. For silicon, the given frequency corresponds to a wavelength $\lambda = c/f = 7.1 \times 10^{-10}$ m = 0.71 nm. For carbon, the given frequency corresponds to $\lambda = c/f = 3.3 \times 10^{-9}$m = 3.33 nm. Only choice (b) has a bandpass which encompasses that range.

42. Consider the following circuit:



Suppose one wanted to use Kirchoff's Loop and Junction Rules to create a set of algebraic equations relating all the currents, resistors and EMF values. Which of the following is an *invalid* equation?
a. $I_{tot} = I_A + I_B$
b. $\epsilon_2 - I_{tot}R_3 - I_AR_2 - I_{tot}R_4 = 0$
c. $-I_AR_2 - \epsilon_1 + I_BR_1 = 0$
d. $I_{tot}R_4 + \epsilon_2 + I_{tot}R_3 + I_AR_2 = 0$

Solution: choice d is invalid: For ΔV to be positive when traversing ϵ_2, you must be traveling with the current, in the same direction as I_{tot}; there should then be voltage DROPS when encountering the resistors.

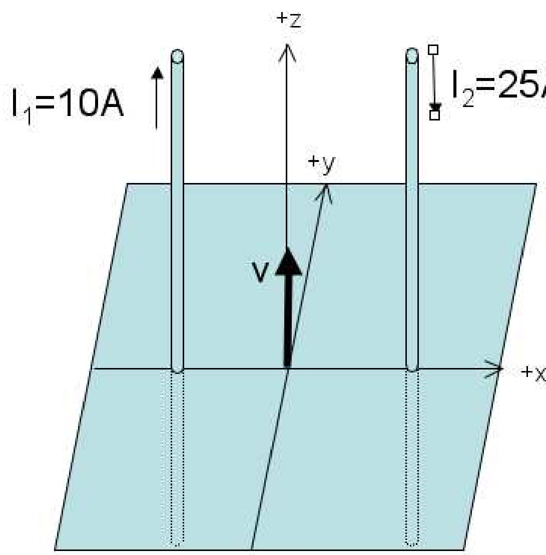
43. Consider an RL circuit consisting of a light bulb with resistance 100Ω, an inductor with L = 0.1 H, a battery with EMF ϵ=15 V, and a switch. At time t=0, the switch is closed. What is the power dissipated in the light bulb at t= 3 milliseconds?
a. 0.22 W
b. 13.6 W
c. 2.25 W
d. 14.3 W
e. 2.03 W

Solution: The time constant $\tau = L/R = 0.1\text{H}/100\Omega = 0.001$ sec.
The current as a function of time will be
$I(t) = (\epsilon/R)(1 - e^(- t/\tau)) = (15\text{ V} / 100\Omega)(1 - e^{(-0.003s/0.001s)}) = (15\text{V}/ 100\Omega)(0.950)$, meaning that the current has reached 95.0% of its maximum value.
I(t=3ms) = 0.143 A.

The power will be $I^2R = 2.03$ W.

Also, $P = I\Delta V_R$, where ΔV_R is the voltage drop across the resistor. At t=3msec, $\Delta V_R = 0.95\epsilon$, yielding the same final answer as above for power.

Questions 44-45:
(The x-y plane is the plane of the page; the +z direction is out of the page towards you).
Wire 1 carries 10 A of current in the +z direction (out of the page), intersecting the x-y plane at coordinates (x=–1.0m, y=0). Wire 2 carries 25 A of current in the –z direction (into the page), intersecting the x-y plane at (x=+1.0m, y=0).



44. What is the magnitude and direction of the net magnetic field at the origin?
a. 0.07 G, along the +y axis
b. 0.03 G, along the +y axis
c. 0.03 G, along the –y axis
d. 0.07 G, along the –y axis
e. 0.10 G, along the +y axis

45. What is the magnitude and direction of the net magnetic force on an object with net charge –5 μC located at the origin but moving in the +z-direction at a velocity of 20 m/s?
a. 3.0×10^{-10} N, in the –x direction
b. 7.0×10^{-10} N, in the –x direction.
c. 1.0×10^{-9} N, in the –x direction.
d. 3.0×10^{-10} N, in the +x direction.
e. 7.0×10^{-10} N, in the +x direction.

Solution for 44: Following the right hand rule and using B=$\frac{\mu_0 I}{2\pi r}$, the magnetic field at the origin due to the wire carrying 10 A downward will be 2.0×10^{-6} T, in the +y direction.
Similarly, the magnetic field at the origin due to the wire carrying 25 A upward will be 5.0×10^{-6} T, in the +y direction.
The net magnetic field is 7.0×10^{-6} T = 7.0×10^{-2} G, in the +y direction.

Solution for 45: Using $F_m = qvB$ to find the magnitude of the magnetic force:
$F_m = (5 \times 10^{-6})(20 \text{ m/s})(7\text{e-}6 \text{ T}) = 7.0 \times 10^{-10}$ N.
Following the right hand rule for a POSITIVE charge: velocity/thumb are in the +z direction. $\vec{B}$/fingers are in the +y direction, so $\vec{F_m}$ points in the negative x-direction.
For a negative charge, $\vec{F_m}$ points in the +x direction.