General Physics II Final Exam - Electricity, Magnetism & Quantum Physics May 12, 2009

Name: Rec. Instr.: Rec. Time:

For full credit, present clear work and show the formulas used, the essential steps, and results with correct units and correct number of significant figures. Point values are given in parenthesis. Total points = 224.

Coulomb's Law constant $k = 8.988 \times 10^9$ Nm^2/C^2, permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ T·m/A,
elementary charge $e = 1.602 \times 10^{-19}$ C, 1 electron-volt = 1.0 eV = 1.602×10^{-19} J,
speed of light c = 2.9979 $\times 10^8$ m/s, Wien's Law $\lambda_p T = 2.90 \times 10^{-3}$ m·K,
Planck's constant h = 6.626×10^{-34} J·s, 1 u = 1.6605×10^{-27} kg = 931.5 MeV/c^2,
electron mass $m_e = 9.11 \times 10^{-31}$ kg = 0.51100 MeV/c^2, neutron mass = 1.008665 u,
hydrogen atomic mass = 1.007825 u, helium-4 atomic mass = 4.002603 u.

---

1. (8) A flashlight uses two 1.5-volt batteries in series to produce a current of 250 mA through a light bulb. The flashlight is turned on for 3.0 minutes.

a) (4) What quantity of charge flowed through the lightbulb?

b) (4) How much energy did the battery supply during the 3.0 minutes?

---

2. (10) A parallel plate capacitor is charged to 36 V by a battery. During charging, 2.4 mC of charge flowed out of the positive terminal of the battery.

a) (2) Which statement is true about the potentials on its plates?

a) One plate has +36 V and the other has -36 V. b) The sum of the potentials on the plates is 36 V.
c) Both of its plates have a potential of 36 V. d) The potential difference between the plates is 36 V.

b) (4) What is the value of the capacitance, in μF?

c) (4) How much energy is stored in the capacitor?

---

3. (2) Four identical capacitors are connected **in series** to a battery. If a charge Q flowed from the battery during their charging, how much charge is stored on each capacitor?

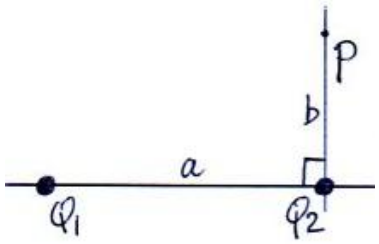
a. Q b. $4Q$ c. $Q/4$ d. $Q/16$

---

4. (2) Four identical resistors are connected **in parallel** to a battery. If a current I is flowing through the battery, how much current flows through each resistor?

a. I b. $4I$ c. $I/4$ d. $I/16$

5. (16) In the diagram shown, the charges $Q_1 = 2.00\ \mu$C and $Q_2 = -1.00\ \mu$C are fixed in place, and $a = 4.00$ cm, $b = 3.00$ cm.



a) (6) Determine the x component of the electric field produced at point P.

b) (6) Determine the y component of the electric field produced at point P.

c) (4) If a third charge, $q = 0.500\ \mu$C is placed at P, what is the electric force that acts on it? Give the result in components, like $\vec{F} = (F_x, F_y)$.

---

6. (10) An initially uncharged spherical droplet of water (a good conductor) has a radius of 0.25 mm. It is given a charge by adding 50.0 billion electrons to it.

a) (4) Now what is the net charge (with correct sign) of the droplet in coulombs?

b) (4) How large is the electric potential at the surface of the droplet?

c) (2) Where in the droplet does the excess charge reside?

a. spread throughout its volume b. concentrated at the center c. spread out on the surface

7. (6) Usual 100 W lightbulbs are designed to run on 120 VAC at 60.0 Hz.

a) (2) Which arrangement uses the most total electric power?

a. three 100 W lightblubs connected in series to 120 VAC.
b. three 100 W lightbulbs connected in parallel to 120 VAC.
c. a single 100 W lightbulb connected to 120 VAC.

b) (4) How many identical 100 W lightbulbs can be turned on together, in parallel in a household circuit, if the fuse protecting the circuit is rated at 20.0 A (rms)?

---

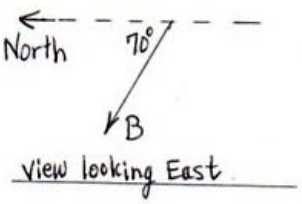
8. (16) An alpha particle is emitted in a nuclear decay with a kinetic energy of 2.58 MeV.

a) (4) Through what potential difference must an α-particle be accelerated to reach this kinetic energy? Hint: How does its charge enter into your calculation?

b) (6) What is the speed of the α-particle?

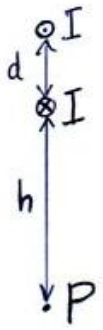
c) (6) What is the de Broglie wavelength of the α-particle?

9. (8) In some location, Earth's magnetic field strength is 0.50 gauss, pointing North at 70.0° below horizontal. For a proton instantaneously moving at 4.0×10^6 m/s due north, find the magnitude and direction of the magnetic force on it.



---

10. (10) Two long straight wires separated by $d = 1.00$ m carry equal 125 A currents in opposite directions as shown.



a) (8) Calculate the net magnetic field that the wires produce at a point P directly below the wires ($h = 4.00$ m below the nearest one). (Hint: draw a vector diagram!)

b) (2) The direction of the magnetic field produced at P is closest to

a. ← b. → c. ↑ d. ↓

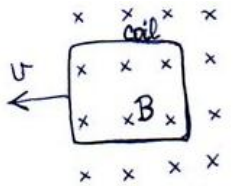
---

11. (6) A circular coil of wire lies in the xy-plane. There is a uniform magnetic field $\vec{B}$ pointing in the z-direction.

In which situation(s) will the coil produce an electromotive force? Check all that apply.

a. B is of constant magnitude and the coil is held stationary.
b. B is increasing in magnitude and the coil is held stationary.
c. B is decreasing in magnitude and the coil is held stationary.
d. B is of constant magnitude and the coil moves in the x-direction.
e. B is of constant magnitude and the coil moves in the z-direction.
f. B is of constant magnitude and the coil rotates around the x-axis.

12. (8) A square 1.00 cm X 1.00 cm coil with 400 turns is pulled to the left, out of a uniform 2.50-tesla magnetic field in 25.0 ms.



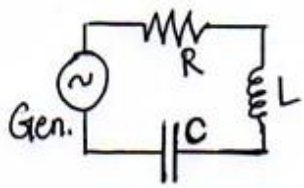
a) (2) In which direction is the induced emf?

a. **clockwise.** b. **counterclockwise.** c. **no emf is produced.**

b) (6) Find the magntiude of the average emf that the coil produces during the 25.0 ms.

---

13. (10) Consider the RLC circuit shown, with generator operating at 3.24 kHz. The rms voltages on the resistor, inductor, and capacitor are $V_R = 12.0$ V, $V_L = 68.0$ V, and $V_C = 48.0$ V, respectively. The resistance is $R = 1.00\ \Omega$.



a) (4) How large is rms voltage of the generator?

d) (6) At what generator frequency (in kHz) would the circuit have the maximum rms current?

---

14. (6) A beam of light contains three different wavelengths, which happen to be in the ultraviolet, visible, and infrared regions of the electromagnetic spectrum.

a) (2) Which makes the widest diffraction pattern after passing through a 0.1 mm wide slit?

a. ultraviolet b. visible c. infrared d. all are the same.

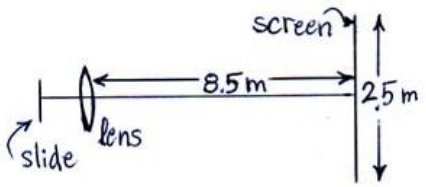
b) (2) Which travels the fastest in vacuum?

a. ultraviolet b. visible c. infrared d. all are the same.

c) (2) Which has the most energetic photons?

a. ultraviolet b. visible c. infrared d. all are the same.

15. (10) A slide projector uses a lens to cast the image of a 35 mm wide slide onto a 2.5 meter wide screen placed 8.5 m from the projector lens. The image of the slide covers the entire width of the screen.



a) (4) What linear magnification should the lens provide?

b) (6) Determine the focal length that the lens should have.

---

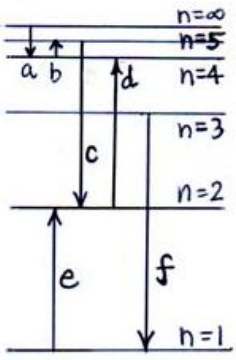
16. (8) A person's left eye has a near point of 1.80 m and a far point of infinity.

a) (2) This eye is: a. normal b. nearsighted c. farsighted.

b) (6) What power contact lens would improve the vision in this eye for reading a book 25 cm away?

---

17. (12) The vertical arrows on the diagram show some transitions that a hydrogen atom can make between energy levels, according to the Bohr model. Of the transitions shown,



a) (2) Which transition(s) correspond to **absorption** of **ultraviolet** light? _____

b) (2) Which transition(s) correspond to **absorption** of **visible** light? _____

c) (2) Which transition corresponds to **emission** of **infrared** light? _____

d) (6) What are that infrared photon's energy and wavelength?

18. (4) What is the longest wavelength of light that could eject photoelectrons from a piece of copper, whose work function is 4.7 eV?

---

19. (8) In a semiconductor device, an electron ($m = 9.11 \times 10^{-31}$ kg) is found localized within a region only $\Delta x = 50.0$ nm wide.

a) (2) The electron's momentum can be

a. any value, including 0. b. any value less than about $\hbar/\Delta x$. c. any value greater than about $\hbar/\Delta x$.

b) (6) Determine the minimum energy that the electron can have, in eV.

---

20. (4) For a 3d subshell, what are the possible values of the magnetic quantum number, m_l?

---

21. (4) What is the maximum number of electrons that can occupy the $n = 3$ shell?

---

22. (2) Which one of the following electron configurations is not allowed?

a. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ b. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ c. $1s^2\ 2s^2\ 2p^5\ 2d^7$ d. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

---

23. (2) For a nuclear decay (like alpha, beta or gamma decays) to take place spontaneously,

a. the masses of the products must be greater than the mass of the parent nucleus.
b. the masses of the products must be less than the mass of the parent nucleus.
c. the masses of the products must be equal to the mass of the parent nucleus.

---

24. (6) A radioactive substance has a half-life of 1.00 day. You start with a 1.000 kg sample. What mass of the substance is left 5.00 days later?

25. (15) For each of the following reactions, find the missing quantity X:

a) (3) $\mathrm{n} + {}^{14}_{7}\mathrm{N} \rightarrow {}^{14}_{6}\mathrm{C} + X$, $X =$

b) (3) ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + X$, $X =$

c) (3) ${}^{238}_{92}\mathrm{U} \rightarrow X + {}^{4}_{2}\mathrm{He}$, $X =$

d) (3) ${}^{60}_{27}\mathrm{Co} \rightarrow X + \beta^{-} + \bar{\nu}$, $X =$

e) (3) $\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{132}_{54}\mathrm{Xe} + {}^{88}_{38}\mathrm{Sr} + X$, $X =$

26. (2) Which reaction in question 25 is an example of a fusion reaction?

a. a b. b c. c d. d e. e

27. (2) Which reaction in question 25 is an example of a fission reaction?

a. a b. b c. c d. d e. e

28. (2) Which reaction in question 25 is an example of beta-decay?

a. a b. b c. c d. d e. e

29. (2) Which reaction in question 25 is an example of alpha decay?

a. a b. b c. c d. d e. e

---

30. (10) Tritium (${}^{3}_{1}\mathrm{H}$) is a heavy isotope of hydrogen, with an atomic mass of 3.016049 u. Normal hydrogen has an atomic mass of 1.007825 u, and neutrons have a mass of 1.008665 u. Tritium decays by β^{-} emission with a half-life of 12.33 years.

a) (4) Write out the β^{-} reaction, in particular, showing the daughter nucleus.

b) (6) Calculate the (radio-)**activity** of a 1.00 micro-gram sample of tritium, in decays/second.