Physics 152 Roster No.:________________________

Score:__________23 pts. possible________

FALL 2003 Final Exam, Part A

Exam time limit: 2 hours. You may use a calculator and both sides of 2 sheets of notes, *handwritten only*. Closed book; no collaboration. For multiple choice questions, circle the letter of the one best answer (unless more than one answer is asked for). Ignore gravity in all problems unless told otherwise, and ignore relativistic effects in non-relativistic problems.

$k_e = 8.988 \times 10^9$ N·m^2/C^2	$e = 1.602 \times 10^{-19}$ C	$h = 6.626 \times 10^{-34}$ J·s
$\varepsilon_0 = 1/4\pi k_e = 8.854 \times 10^{-12}$ C^2/(N·m^2)	$\mu_0 = 4\pi \times 10^{-7}$ T·m/A	$= 4.136 \times 10^{-15}$ eV·s
$c = 2.998 \times 10^8$ m/s	$\sigma_B = 5.671 \times 10^{-8}$ W/(m^2·K^4)	Wien constant $= 2.898 \times 10^{-3}$ m·K

useful rest masses:

$m_p = 1.6726231 \times 10^{-27}$ kg	$m_n = 1.6749286 \times 10^{-27}$ kg	$m_e = 9.1093897 \times 10^{-31}$ kg
= 1.007 276 470 u	= 1.008 664 904 u	= 0.000 548 579 903 u

1 u = 1.6605×10^{-27} kg = 931.49432 MeV/c^2

(1 pt. each, unless otherwise specified)

1. In a simple model of the H atom, an electron in the lowest possible energy level "orbits" the proton at a distance of approx. 5.29×10^{-11} m.

a. (2 pts.) What is the **electric field** at this distance from a proton?

A. 8.18×10^4 N/C
B. 4.02×10^6 N/C
C. 3.65×10^7 N/C
D. 1.70×10^8 N/C
E. 2.29×10^{10} N/C
F. 5.15×10^{11} N/C

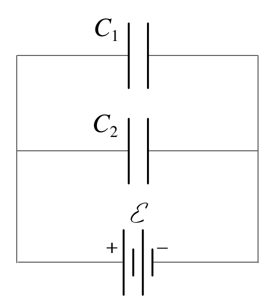
b. In which **direction** does the electric field vector point?

A. toward the proton
B. away from the proton

c. (2 pts.) If the electrostatic potential at this distance from a proton is +27.2 V, how much **energy** is required to remove an electron from this point to an infinite distance from the proton? (Assume $V = 0$ at $r = \infty$.)

A. 0.0220 eV
B. 0.0588 eV
C. 0.850 eV
D. 17.0 eV
E. 27.2 eV
F. 43.5 eV

2. Two capacitors, $C_1 = 25\ \mu$F and $C_2 = 45\ \mu$F, are connected as shown to a 50.-volt DC battery.



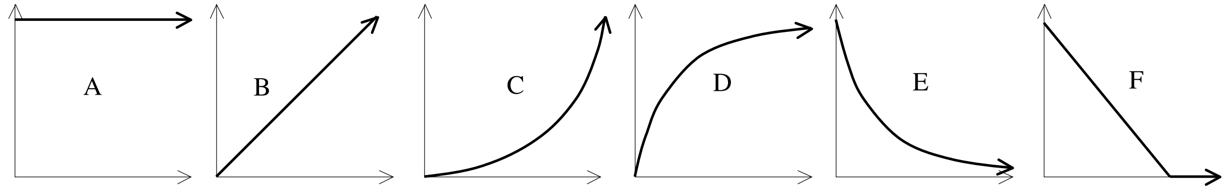
a. (2 pts.) What is the **equivalent capacitance** of the circuit?

A. 16 μF
B. 20. μF
C. 35 μF
D. 51 μF
E. 70. μF
F. 1.1 mF

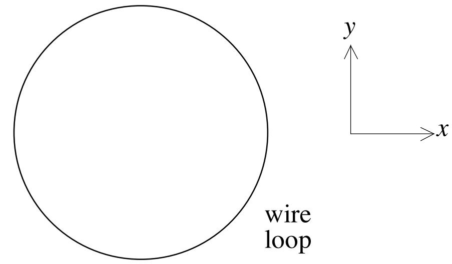
b. (2 pts.) After a long period of time, which one of the following is **TRUE**?

A. The charge residing on each plate of C_1 is the same as on C_2.
B. The potential difference across C_1 is the same as across C_2.
C. The energy stored in C_1 is the same as in C_2.
D. The capacitance of C_1 is the same as C_2.

c. Suppose that there is an internal resistance of a few ohms in the battery. Starting from the moment that the circuit is closed, which one of the following best represents the **current** flowing from the battery as a function of time?



3. A circular loop of wire lies in the plane of the page. You hold the north pole of a permanent bar magnet above the plane of the page, pointing it into the page at the center the loop. In which **direction** will an emf be induced in the loop if you…



a. move the north pole toward the page?

A. clockwise
B. counter-clockwise

b. pull the north pole away from the page?

A. clockwise
B. counter-clockwise

c. hold the magnet at a fixed distance from the loop, but start to spin the loop about its *y*-axis?

A. clockwise
B. counter-clockwise

4. (2 pts.) All of the following are true about the electromagnetic spectrum **EXCEPT**:

A. Radio waves have the longest wavelength.
B. Radio waves have the lowest frequency.
C. Gamma rays have the greatest energy per photon.
D. Of the visible region, violet light has the greatest energy per photon.
E. Of the visible region, red light has the shortest wavelength.

5. (2 pts.) Which one of the following is always TRUE for an image with a **diverging lens**?

A. The image is always inverted.
B. The image is always on the opposite side of the lens from the object.
C. The image is always closer to the lens than the object.
D. The image is always real.
E. All of the above.
F. None of the above.

6. A ray of sunlight passes from air (n = 1.00) into sea water (n = 1.33).

a. (2 pts.) What is the **speed** of the sunlight in the water?

A. 1.98×10^8 m/s   D. 2.67×10^8 m/s
B. 2.25×10^8 m/s   E. 3.00×10^8 m/s
C. 2.50×10^8 m/s   F. 3.99×10^8 m/s

b. (2 pts.) If the sun is shining on the ocean at an angle of 60.° from the vertical in the late afternoon, and the surface of the ocean is exactly horizontal, what is the **angle** (from vertical) of the rays of sunlight inside the water?

A. 30°   D. 41°
B. 34°   E. 45°
C. 38°   F. 53°

7. (2 pts.) You are attempting to measure the mass of a fast-moving object to an accuracy of 0.1% or better, when you suddenly wonder if you should be concerned with correcting for relativity. Above what **speed** must the object be traveling for its mass to undergo a relativistic increase to more than 1.001 times its rest mass?

A. $0.001c$ D. $0.045c$
B. $0.010c$ E. $0.071c$
C. $0.033c$ F. $0.089c$

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FALL 2003 Final Exam, Part B

(1 pt. each, unless otherwise specified)

8. (2 pts.) Suppose that the light given off by the filament of a household light bulb has a peak wavelength of 620 nm. Assuming that the filament is a perfect blackbody emitter, its **temperature** is:

A. 2700 K
B. 3700 K
C. 4700 K
D. 5700 K
E. 6700 K
F. 7700 K

9. Monochromatic light from a source with adjustable wavelength is used to illuminate a photoelectric surface. By slowly varying the wavelength, it is found that the limiting wavelength of light needed to eject electrons from the surface is 590 nm.

a. (2 pts.) What is the **work function** of the photoelectric surface?

A. 2.1 eV
B. 2.5 eV
C. 2.9 eV
D. 3.3 eV
E. 3.7 eV
F. 4.2 eV

b. (2 pts.) Which one of the following is **TRUE**?

A. Incident 400-nm light is unable to eject an electron from this surface, no matter how intense the light.
B. The KE of the ejected electrons from a surface is always equal to the work function of the surface.
C. For incident photons of a single energy, all ejected electrons will have the same speed.
D. The photoelectric effect experiment is considered to be a demonstration of the particle nature of light.

10. (2 pts.) Suppose that a particular electron has a de Broglie wavelength of 3.1×10^{-10} m. What is the **speed** of the electron?

A. 9.7×10^4 m/s
B. 2.0×10^5 m/s
C. 5.8×10^5 m/s
D. 8.8×10^5 m/s
E. 2.3×10^6 m/s
F. 5.1×10^6 m/s

11. The **Heisenberg uncertainty principle** asserts that the *more* accurately we are able to measure a particle's position, the *less* accurately we can ever measure its:

A. charge
B. half-life
C. mass
D. momentum
E. spin
F. wavelength

12. (2 pts.) Which one of the following sets of quantum numbers (n, l, m_l, m_s) is an **allowed electron state** for an electron in a 4p orbital of an atom?

A. (4, 0, 0, 1/2)
B. (4, 0, 1, 1/2)
C. (4, 0, 2, 0)
D. (4, 1, 0, –1/2)
E. (4, 1, –2, –1)
F. (4, 2, 0, 0)

13. **Gamma decay** of an excited nucleus results in the emission of a(n)…

A. electron
B. neutrino
C. neutron
D. photon
E. positron
F. proton

14. The **α-decay** of $^{232}_{90}$Th produces:

A. $^{228}_{86}$Rn
B. $^{228}_{88}$Ra
C. $^{230}_{88}$Ra
D. $^{232}_{88}$Ra
E. $^{230}_{90}$Th
F. $^{228}_{92}$U

15. (2 pts.) In order to balance this nuclear reaction: $^{28}_{14}\text{Si} + {}^{28}_{14}\text{Si} \rightarrow {}^{56}_{26}\text{Fe} + 2\,\_\_\_\_\_\_\_ + 2\,\nu_e$ + energy two of **what particle** are created?

A. alpha
B. electron
C. neutron
D. photon
E. positron
F. proton

16. Suppose that a free neutron undergoes the following decay: $n \rightarrow p + e^- + \bar{\nu}_e$

a. This reaction is an **example** of:

A. α decay
B. β^- decay
C. β^+ decay
D. γ decay
E. nuclear fission
F. nuclear fusion

b. (2 pts.) Suppose that the free neutron starts at rest. Assuming zero mass for $\bar{\nu}_e$, and assuming that no photons are generated by the decay, what is the **total kinetic energy** carried away by the products of this reaction? *(Refer to the masses listed at the start of this exam.)*

A. 782 keV
B. 2.87 MeV
C. 8.72 MeV
D. 82.7 MeV
E. 278 MeV
F. 728 MeV

17. (2 pts.) Approximately what **percentage** of any radioactive substance has ***decayed*** after 4 half-lives have elapsed?

A. 88%
B. 90%
C. 92%
D. 94%
E. 96%
F. 98%

18. (2 pts.) Which one of the following is **TRUE**?

A. The world around us is made up of almost equal parts of matter and anti-matter.
B. If an electron touches another electron, the two will annihilate, converting their masses into energy.
C. A particle always has equal and opposite electric charge from its anti-particle.
D. Matter exerts attractive gravitational force on other matter, while anti-matter exerts repulsive anti-gravitational force on all matter.

19. Electrons, positrons, and neutrinos are **all**…

A. members of the lepton family
B. found only in the nucleus of atoms
C. massless
D. examples of anti-matter

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FALL 2003 Final Exam, Part C

Show your work on all free-response questions. Be sure to use **proper units** and **significant figures** in your final answers. Ignore gravity in all problems unless told otherwise, and ignore relativistic effects in non-relativistic problems.

1. You have a 120.-V DC source and three light bulbs with resistances of $R_1 = 192\ \Omega$, $R_2 = 240.\ \Omega$, and $R_3 = 360.\ \Omega$, respectively. Assume that the resistance of each bulb is constant and independent of temperature or current.

a. (5 pts.) **Draw a circuit diagram** using all three bulbs in which the ***smallest*** *possible current* is being drawn from the voltage source. (There must be a nonzero current flowing through each bulb.) **Calculate this current**, showing your work.

b. (5 pts.) **Draw a circuit diagram** using all three bulbs in which the ***largest*** *possible current* is being drawn from the voltage source. (You may not short-circuit the voltage source.) **Calculate this current**, showing your work.

c. (1 pt.) Which one of the above two situations is analogous to the arrangement of light bulbs all plugged into the same **ordinary household circuit**? (Of course, the voltage source would be 120-V-rms AC instead of DC.)

A. part (a) B. part (b)

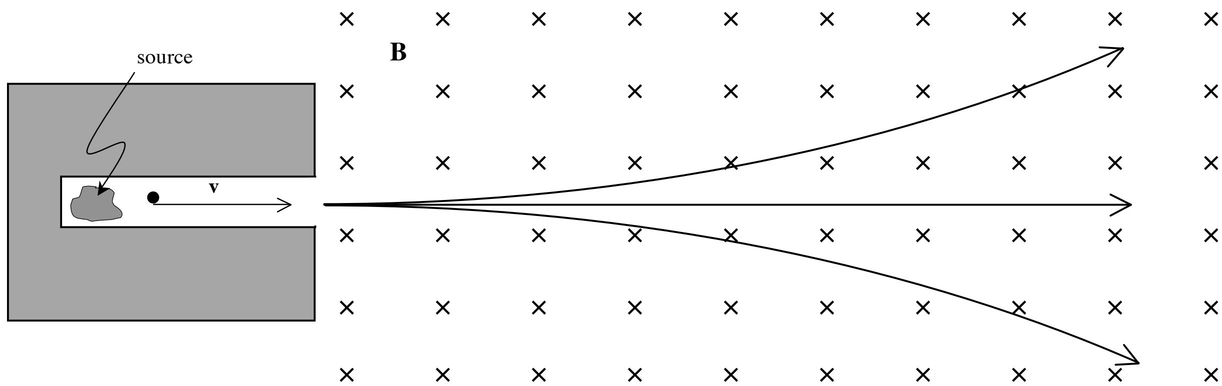
d. (2 pts.) For each light bulb, what is the **wattage** rating you would find printed on the bulb if you bought it at a store? (This is the average power dissipated by the bulb if it were connected alone to ordinary household 120-volt-rms AC.) You do NOT need to show your work. *Use each letter exactly once:*

______ 192 Ω A. 40 W

______ 240 Ω B. 60 W

______ 360 Ω C. 75 W

2. Suppose that you have a radioactive source that undergoes one single type of decay, but the type of particle emitted is unknown. You place the source in a narrow shielded tube, so that only those particles with velocities directed exactly to the right are able to enter the neighboring uniform magnetic field.



a. (3 pts.) Using the paths shown, **label** the path that you would expect each of the following four particles to follow inside the region of uniform **B**-field: α, β^+, β^-, and γ. (*Label each path as many times as you wish, or not at all.*)

b. (6 pts.) Later, you discover that the escaping decay particles follow an upward-curving path. By placing a velocity-selector between the source's tube and the **B**-field, you ensure that only particles with a velocity of 2.0×10^6 m/s are able to enter the region of **B**-field. You measure the radius of their path to be 7.6 mm. If the **B**-field strength is 0.0015 T, calculate the **charge-to-mass ratio (q/m), in [C/kg],** for the unknown particle. Using the masses listed at the start of this exam, **show that** that your value of q/m is consistent with the particle (or one of the particles) you labeled for the upward-curving path.

c. (5 pts.) Using a Geiger counter, you measure 1430 decays per second from the source. You measure the rate again in exactly the same way 3.00 hours later, and you find a count rate of 572 decays per second. Calculate the **half-life, in either hours or minutes,** of this decay process.

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FALL 2003 Final Exam, Part D

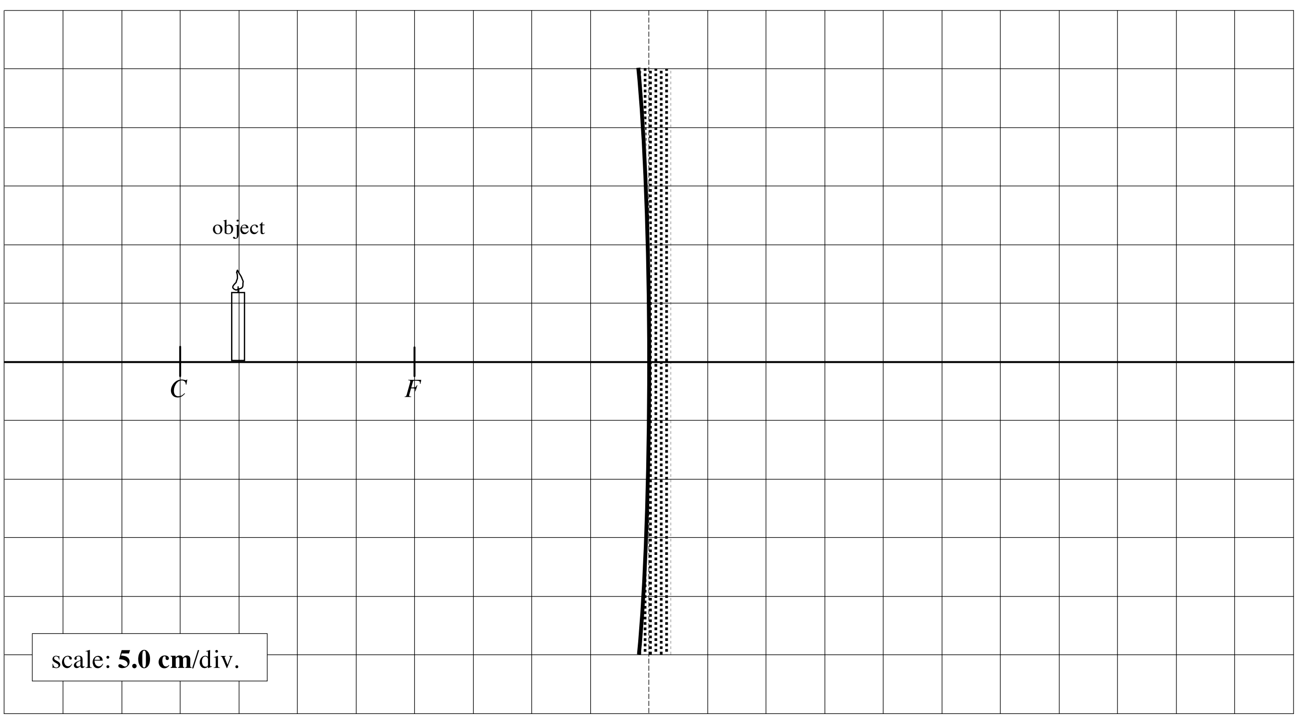
3. You have a concave mirror with a focal length of 20. cm. Your "object" is a small birthday candle 7.5 cm tall.

a. (4 pts.) When the object is placed 35 cm from the mirror, calculate the distance of the **image** from the mirror. Employ our usual sign conventions for all quantities.

b. (3 pts.) *Circle as many of the following* as are TRUE for the **image in part (a)**:

real	upright	larger than object	same side of mirror as object
virtual	inverted	smaller than object	opposite side of mirror from object

c. (3 pts.) **Draw a ray diagram to scale** showing the resulting image, using at least 2 principal rays. [Your diagram should agree with all of your answers to parts (a) and (b).] *Use a straightedge. Draw in the image. Use solid lines for rays and dashed lines for any "tracebacks." Include directional arrowheads on your rays.*

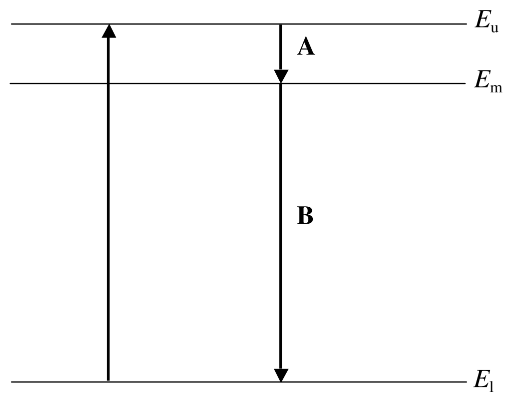


d. (3 pts.) Instead of the configuration above, suppose that the candle is placed just 10. cm from the mirror. *Circle as many of the following* as are TRUE for the **new image**:

real	upright	larger than object	same side of mirror as object
virtual	inverted	smaller than object	opposite side of mirror from object

4. In a helium-neon (He-Ne) laser, electrons in the neon atoms are excited from a lower energy level E_l to an upper energy level E_u by way of collisions with fast-moving helium atoms. From E_u, the electrons de-excite first to the middle energy level E_m, then back down to level E_l.

a. (5 pts.) The photons emitted by transition "A" have a visible wavelength of 632.8 nm, and give He-Ne laser light its familiar red color. What is the **energy difference, in eV,** between levels E_u and E_m?



b. (3 pts.) The He-Ne laser used in class by your instructor to demonstrate one-slit and two-slit diffraction, has a continuous power output of 20. mW. Assuming that all of this power is output as photons from transition "A," calculate the **number of photons** emitted by the laser **each second**.

c. (4 pts.) Calculate the **momentum** of a single photon generated by transition "A." Use simplified MKS units on your answer.

e. (2 pts.) The energy difference between E_m and E_l is a much larger 18.70 eV. Are the photons generated by transition "B" **visible**, **infrared**, or **ultraviolet**? **Briefly justify** your answer.