Physics 152 Roster No.:__________________________

Score:___________23 pts. possible________

FALL 2004 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 friction, air resistance, and gravity in all problems unless told otherwise, and ignore relativistic effects in non-relativistic problems.

<u>Physical constants:</u>

$k_e = 8.988 \times 10^9$ N·m²/C²	$e = 1.602 \times 10^{-19}$ C	$h = 6.626 \times 10^{-34}$ J·s
$\varepsilon_0 = 1/(4\pi k_e) = 8.854 \times 10^{-12}$ C²/(N·m²)	$c = 2.998 \times 10^8$ m/s	$= 4.136 \times 10^{-15}$ eV·s
$\mu_0 = 4\pi \times 10^{-7}$ T·m/A	$\sigma_B = 5.671 \times 10^{-8}$ W/(m²·K⁴)	Wien constant (λ)=2.898×10^{-3} m·K
<u>Useful rest masses</u>:		Wien constant (f)=1.034×10^{11} Hz/K
$m_p = 1.6726231 \times 10^{-27}$ 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

$$1 \text{ u} = 1.6605 \times 10^{-27} \text{ kg} = 931.49432 \text{ MeV}/c^2$$

(1 pt. each, unless otherwise specified)

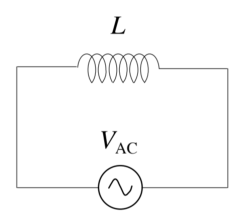
1. (2 pts.) You take measurements of **E**-field strength and V at distance r from a large point charge Q. As you **reduce your distance to r/2**, you find that…

A. **E** field strength is multiplied by 2, and V is multiplied by $\sqrt{2}$.
B. **E** field strength is multiplied by $\sqrt{2}$, and V is multiplied by 2.
C. **E** field strength is multiplied by 2, and V is multiplied by 2.
D. **E** field strength is multiplied by 4, and V is multiplied by 2.
E. **E** field strength is multiplied by 2, and V is multiplied by 4.
F. **E** field strength is multiplied by 4, and V is multiplied by 4.

2. (2 pts.) You and your friend are standing 1.0 m apart, each holding an equal amount of charge. If the electrostatic force between the two charges equals 750 N (approx. the weight of one person), **how much charge** is each of you holding?

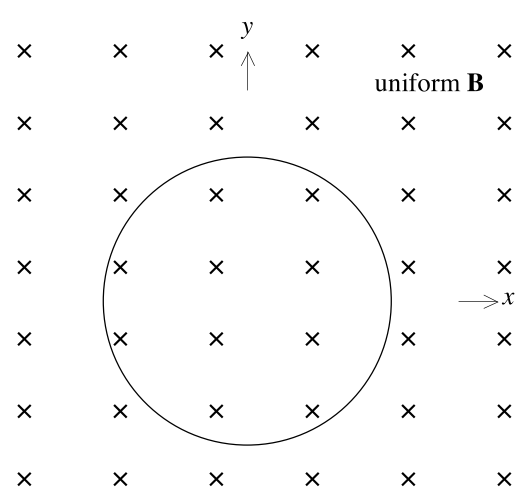
A. 4.4 nC
B. 380 nC
C. 9.1 μC
D. 58 μC
E. 290 μC
F. 1.7 mC

3. (2 pts.) Which one of the following is **TRUE** for the circuit at right?



A. The units of L are webers.
B. The L creates an emf which acts to oppose any change in I.
C. The cycles of I are exactly in phase with the cycles of V_{AC}.
D. The reactance of L does not depend on the frequency of the voltage source.

4. a. (2 pts.) The wire loop shown at right is located in a uniform **B** field that extends infinitely in all directions. Any one of the following would **induce an emf** in the wire, **EXCEPT**:



A. Moving the loop in the x-direction.
B. Making the loop larger.
C. Spinning the loop about its y-axis.
D. Shutting off the **B**-field.

b. If the **B** field as shown were quickly *doubled in strength*, in which **direction** would a current be induced in the wire?

A. clockwise
B. counter-clockwise
C. no current is induced

5. (2 pts.) Your cell phone recharger contains a transformer whose input uses 40. mA at 120 V. If its output voltage is 4.4 V, what is its **output current**? (Assume that the transformer is 100% efficient.)

A. 9.2 mA
B. 33 mA
C. 40. mA
D. 250 mA
E. 1.1 A
F. 3.0 A

6. (2 pts.) You look through a peephole's lens at a visitor (the "object") standing d_o = 1.0 m away from the peephole. You see an upright image which you estimate has a magnification of +0.010 (i.e., one-hundredth of the visitor's actual size). The **focal length** of the lens must be:

A. – 0.10 cm
B. – 0.9 cm
C. – 1.0 cm
D. – 9.0 cm
E. – 1.0 m
F. – 9.0 m

7. (2 pts.) Which one of the following is always TRUE for the image created by a **concave mirror**?

A. The image is always upright.
B. The image is always taller than the object.
C. The image is always located farther from the mirror than *f*.
D. The image is always virtual.
E. All of the above.
F. None of the above.

8. (2 pts.) Monochromatic light from a helium-neon laser (λ = 632.8 nm) passes through a *single slit* 0.30 mm wide. The resulting pattern is observed on a screen 2.0 m away. How **wide** is the broad **central maximum** on the screen?

A. 8.4 mm
B. 19 mm
C. 38 mm
D. 54 mm
E. 13 cm
F. 30. cm

9. (2 pts.) What is the **angle** between two crossed polarizers if only 10.% of the intensity of light that passes through the first also makes it through the second?

A. 72°
B. 75°
C. 77°
D. 81°
E. 84°
F. 89°

10. (2 pts.) **How fast** must an electron be traveling so that an observer at rest measuring its mass would find it to have increased by exactly 10% due to relativity?

A. 0.1c
B. 0.42c
C. 0.87c
D. 0.9c
E. 0.98c
F. 0.993c

11. (2 pts.) Which one of the following statements about special relativity is **TRUE**?

A. An observer at rest measures clocks in a moving frame to run faster than his own.
B. Length contraction occurs only along the direction of relative motion, not in all 3 dimensions.
C. Every observer measures c to have a different value, depending on the speed of his reference frame.
D. A baseball thrown at 0.75c inside a spaceship moving (in the same direction) at 0.75c will appear to an observer at rest to be moving at 1.5c.

Physics 152 Roster No.:________________________

Score: ________26 pts. possible________

FALL 2004 Final Exam, Part B

(1 pt. each, unless otherwise specified)

12. a. (2 pts.) Suppose you want a night-vision camera to be able to see objects via their thermal radiation. Specifically, your camera should be sensitive to peak blackbody radiation emitted by buildings at 285 K and people at 310 K. You need a camera sensitive to **wavelengths** near:

A. 1 μm C. 10 μm E. 100 μm
B. 5 μm D. 50 μm F. 500 μm

b. This wavelength lies in which **region of the EM spectrum**?

A. radio C. visible E. x-ray
B. infrared D. ultraviolet F. gamma ray

13. Two pigments (complex molecules) found in chlorophyll are named P680 and P700, since they absorb light with wavelengths near 680 nm and 700 nm, respectively.

a. What is the **color** of the light that both pigments absorb?

A. infrared C. yellow-green E. ultraviolet
B. red D. violet

b. (2 pts.) The **frequency** of a 680-nm photon is:

A. 4.4×10^{11} Hz D. 4.4×10^{20} Hz
B. 4.4×10^{14} Hz E. 4.4×10^{23} Hz
C. 4.4×10^{16} Hz F. 4.4×10^{25} Hz

c. When absorbed, which photon delivers **more energy** to the absorbing molecule?

A. a 680-nm photon B. a 700-nm photon

14. All of the following are true regarding wave-particle duality **EXCEPT**:

A. Light has momentum.
B. Photons can have electric charge.
C. Moving masses have de Broglie wavelengths.
D. Moving masses can diffract or interfere.

15. (2 pts.) The Sun has a total energy output of 3.9×10^{26} J every second. If all of this energy is created in nuclear reactions, how much of the Sun's **mass** is destroyed (and converted into energy) every second?

A. 8.9×10^{-25} kg D. 0.65 kg
B. 6.1×10^{-16} kg E. 6.6×10^{3} kg
C. 1.3×10^{-11} kg F. 4.3×10^{9} kg

16. (2 pts.) Isotopes like ${}^{20}_{7}N$, ${}^{22}_{8}O$, and ${}^{23}_{9}F$ are unstable because they have too many neutrons for their number of protons. All of these isotopes undergo the same mode of decay, one that produces a "daughter" nucleus with a smaller neutron-to-proton ratio than the "parent." Which *one* of the following **decays** would accomplish that?

A. beta-minus C. alpha
B. beta-plus D. gamma

17. (2 pts.) What **percentage** of an initially pure radioactive sample has **decayed** after 6 half-lives have passed?

A. 92.0% D. 98.4%
B. 96.0% E. 99.5%
C. 97.5% F. 99.8%

18. Two different **isotopes** of the same element have:

A. different numbers of protons, but the same number of neutrons
B. the same number of protons, but different numbers of neutrons
C. the same number of protons and the same number of neutrons, but different atomic masses
D. different numbers of both protons and neutrons, but the same atomic mass

19. Potassium has two stable isotopes: $^{39}{}_{19}K$ and $^{41}{}_{19}K$. One unstable isotope, $^{40}{}_{19}K$, has such a long half-life (1.28×10^9 years), that it is easily found as "naturally occurring" on Earth.

a. (2 pts.) If potassium-40 undergoes β^- decay, which **nucleus** is produced?

A. $^{39}{}_{18}Ar$ D. $^{39}{}_{20}Ca$
B. $^{40}{}_{18}Ar$ E. $^{40}{}_{20}Ca$
C. $^{39}{}_{19}K$ F. $^{41}{}_{20}Ca$

b. (2 pts.) Suppose that a geologist finds that only 8.1% of the original potassium-40 remains in a very old meteorite, while 91.9% of it has decayed into the daughter nucleus you determined in part (a). **How long ago** did the meteorite form?

A. 4.2×10^9 years D. 4.8×10^9 years
B. 4.4×10^9 years E. 5.0×10^9 years
C. 4.6×10^9 years F. 5.2×10^9 years

20. (2 pts.) You are told that a nucleus of element number 98 undergoes a spontaneous decay, which might be alpha, beta, or gamma, but you don't know which one. Which one of the following CANNOT be the **atomic number** of the nucleus produced by the decay?

A. 96 D. 99
B. 97 E. 100
C. 98

21. **Neutrons** and **neutrinos** both are…

A. the same mass D. leptons
B. the same charge E. baryons
C. found in the nucleus F. anti-particles of each other

22. (2 pts.) Which one of the following is **TRUE** about nuclear fission and nuclear fusion?

A. Fission is the primary energy source of stars.
B. Fusion can be used as an energy source for human society, while fission cannot.
C. Fusion of any two nuclei always results in the net release of energy, no matter how large the nuclei involved.
D. Fission results in the net release of energy only if the parent nucleus is very large.

23. (2 pts.) The **nucleons** in the nucleus of an atom…

A. are bound together by the electrostatic force
B. can be either positively or negatively charged
C. are each made up of 3 quarks
D. can be leptons or baryons

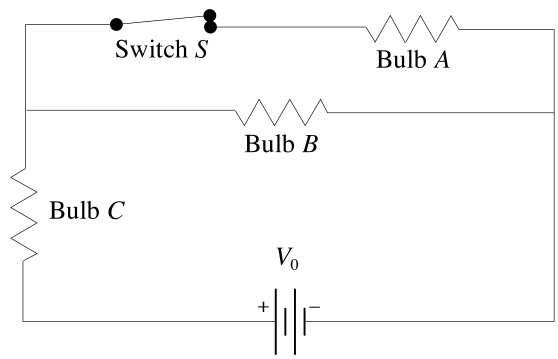
Physics 152 Roster No.:_________________________

Score:_________ 27 pts. possible _______

FALL 2004 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 friction, air resistance, and gravity in all problems unless told otherwise, and ignore relativistic effects in non-relativistic problems.

1. Three light bulbs (A, B, and C) of identical 3.00-Ω resistance are connected to a battery (V_0 = 12.0 V) as shown at right. Assume that the resistance of each bulb is constant (independent of temperature, current, etc.)



a. (10 pts.) Determine the **following values** while switch S is closed (as shown). You do NOT need to show your work, but your answers must have proper units and 3 significant figures to receive full credit.

Current through Bulb A: __________

Current through Bulb B: __________

Current through Bulb C: __________

Voltage drop across Bulb A: __________

Voltage drop across Bulb B: __________

Voltage drop across Bulb C: __________

Power dissipated by Bulb A: __________

Power dissipated by Bulb B: __________

Power dissipated by Bulb C: __________

Which bulb is the **brightest**? __________

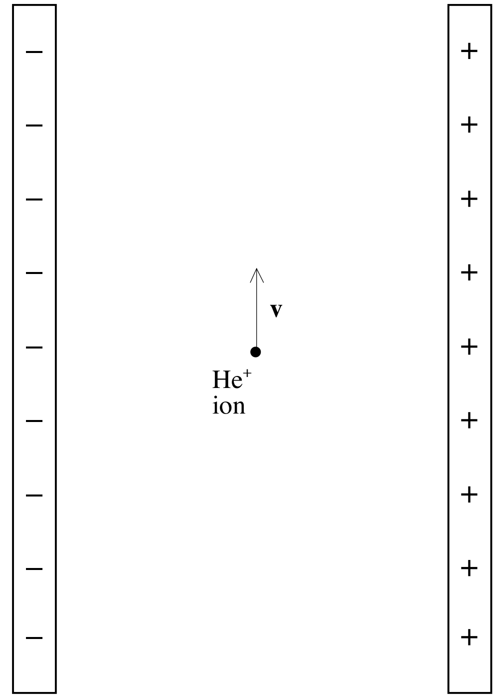
b. (3 pts.) Switch S is opened. How does the **brightness** of each bulb change?

i. The brightness of bulb A…
A. increases B. decreases C. is unchanged

ii. The brightness of bulb B…
A. increases B. decreases C. is unchanged

iii. The brightness of bulb C…
A. increases B. decreases C. is unchanged

2. At the instant shown here, a singly-ionized ^4_2He atom (He^+ ion) is at the midpoint between two infinite parallel plates. Its velocity is 7500 m/s toward the top of the page. The plates are separated by 20. cm and have a potential difference of 4200 V.



a. (5 pts.) Determine the **magnitude** of the **electric force** acting on the He^+ ion. Show your work.

b. (1 pt.) The **direction** of this **electric force** on the ion is:

A. to the right
B. to the left
C. into the page
D. out of the page
E. toward top of the page
F. toward bottom of the page

c. (2 pts.) How would your answers to parts (a)&(b) **change** if the He^+ ion were replaced by…

i. an **α-particle**?

A. weaker force, same direction
B. same force, same direction
C. stronger force, same direction
D. weaker force, opposite direction
E. same force, opposite direction
F. stronger force, opposite direction

ii. a **proton**?

A. weaker force, same direction
B. same force, same direction
C. stronger force, same direction
D. weaker force, opposite direction
E. same force, opposite direction
F. stronger force, opposite direction

d. (1 pt.) In order to allow the He^+ ion to continue upward on an undeflected straight-line path, we can impose a uniform magnetic field in the region between the plates. This **B-field** must point in which **direction**?

A. to the right
B. to the left
C. into the page
D. out of the page
E. toward top of the page
F. toward bottom of the page

e. (5 pts.) Determine the **magnitude** of this **magnetic field**. Show your work.

Physics 152 Roster No.:_________________________

Score: 24 pts. possible

FALL 2004 Final Exam, Part D

3. After taking a spectrum of sunlight, you find that the most common photons emitted by the Sun have a wavelength of 510 nm.
a. (3 pts.) Assuming that the Sun is a blackbody, calculate the **temperature**, in kelvins, of the Sun's "surface."

For the sake of simplicity in the following parts, assume that the Sun is a *monochromatic* 510-nm light source.

b. (5 pts.) You go outside to measure the power of sunlight at the Earth's distance from the Sun. You find that your light meter measures a maximum power of 0.14 W when its detecting area is oriented exactly perpendicular to the incident sunlight. **How many 510-nm photons** are striking the light meter each second? (Your answer should be between 10^{17} and 10^{18} photons/s.)

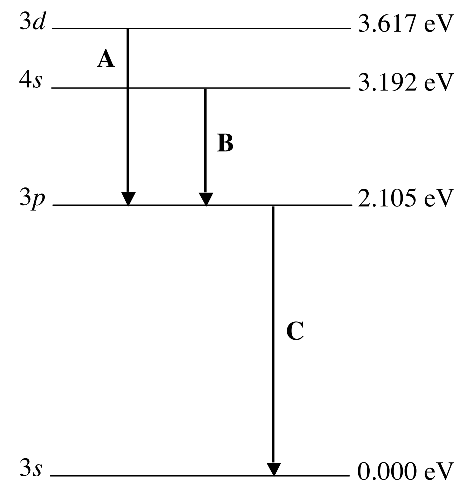
c. (3 pts.) Determine the **momentum** of a single 510-nm photon. Use simplified MKS units on your answer.

d. (2 pts.) A proposed "Solar Sail" spacecraft would spread out a huge sheet of metal foil to act as a sail: as it is struck by photons from the Sun, the photons' momentum would propel the sail (and spacecraft) away from the Sun. If the spacecraft is at the same distance from the Sun as the Earth is, and if the sail has an area of 3500 m^2 (approx. one football field), calculate the total **force** acting on the sail by the sunlight. Your light detector in part (b) had an area of 1.0 cm^2. Assume that incident photons are absorbed by the sail, not reflected. (*Reminder:* Force = $\Delta p/\Delta t$ [momentum absorbed per second]. You do NOT need to show your work.)

A. 0.016 N C. 920 N E. 9.3×10^6 N
B. 2.3 N D. 42,000 N F. 4.5×10^8 N

4. Here is an energy-level diagram for four electron orbitals of a sodium atom. (Many other orbitals exist, but are not shown here.) Suppose that the only *permitted* de-excitations for excited electrons are the three transitions shown at right (A, B, and C); all other possible transitions between the $3s$, $3p$, $4s$, and $3d$ orbitals are *forbidden*.

For convenience, the $3s$ energy level is set at 0 eV, and all other energies are given relative to the $3s$ level.



a. (1 pt.) All of the **permitted transitions** obey which *one* of the following rules?

A. the electron's value of n must not change
B. the electron's value of n must change by ±1
C. the electron's value of n may change by 0 or ±2, but NOT by ±1
D. the electron's value of l must not change
E. the electron's value of l must change by ±1
F. the electron's value of l may change by 0 or ±2, but NOT by ±1

b. (1 pt.) **How many electrons** are allowed to occupy a sodium atom's $3s$ orbital at the same time?

A. 1 C. 4 E. 8
B. 2 D. 6 F. 10

c. (1 pt.) An electron residing in the $3p$ orbital of sodium may have which of the following values for its m_s **(electron spin) quantum number**?

A. 0 C. −1, 0, or +1 E. −1/2 or +1/2
B. −1 or +1 D. 1/2 F. −1/2, 0, or +1/2

d. (1 pt.) You take a spectrum of the light emitted by some excited sodium gas (just like the arc lamps used in PHYS 152L lab), and you find that the **spectrum** is:

A. discrete B. continuous

e. (7 pts.) Assume that transitions A, B, and C are the *only* transitions occurring in the sodium gas. Determine the **wavelengths** of the photons emitted by all three. **How many emission lines** do you see in the *visible region* of the spectrum? (Show your work for at least one of the three calculations. Explain your reasoning: if not all three transitions are visible, state why.)