Physics 152 Roster No.:________________

December 12, 2005

Score:________________

Final Exam, Part A

Exam time limit: 2 hours. You may use a calculator and both sides of TWO 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
		Wien constant (f)=1.034×10^{11} Hz/K

<u>Useful rest masses:</u>

$m_p = 1.672\,623\,1 \times 10^{-27}$ kg	$m_n = 1.674\,928\,6 \times 10^{-27}$ kg	$m_e = 9.109\,389\,7 \times 10^{-31}$ kg
$= 1.007\,276\,470$ u	$= 1.008\,664\,904$ u	$= 0.000\,548\,579\,903$ u

<u>Conversions:</u>

1 T = 10^4 G   1 u = 1.6605×10^{-27} kg = 931.49432 MeV/c^2

1. (8 pts.) **Convert** the following quantities into the given units. Fill in the blanks. (You do NOT need to show your work.) Use *scientific notation* where appropriate (very large or very small values), and express all final values to *2 significant figures*.

a. 2.8×10^{-5} mA = ____________________ nA

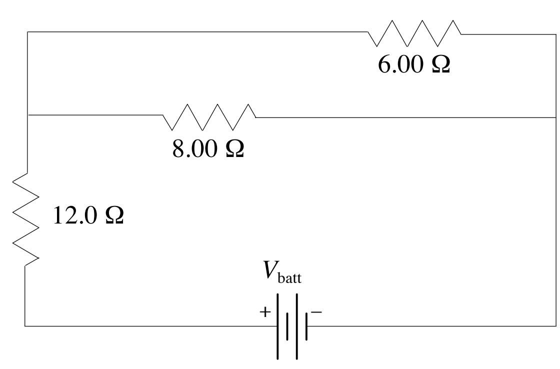
b. 8.2×10^{-14} J = ____________________ keV

c. 197 u = ________________________ kg

d. 96 μC/cm² = ____________________ C/m²

2. a. (2 pts.) What is the **equivalent resistance** for the circuit shown here? (Assume the battery has zero internal resistance.)

A. 7.67 Ω D. 18.3 Ω
B. 10.8 Ω E. 22.2 Ω
C. 15.4 Ω F. 26.0 Ω



b. (2 pts.) If V_{batt} = 25.0 V, what is the **power dissipated** in the 12.0-Ω resistor *only*?

A. 31.5 W D. 52.9 W
B. 38.7 W E. 72.5 W
C. 45.1 W F. 79.0 W

3. a. (2 pts.) If a charge of 0.220 nC resides on each of the plates of a capacitor while their potential difference is maintained at 95.0 V, what is the **capacitance** of the system?

A. 2.3 pF
B. 5.0 pF
C. 8.9 pF
D. 13 pF
E. 28 pF
F. 54 pF

b. (2 pts.) How much **energy** is stored in the capacitor?

A. 1.0×10^{-9} J
B. 1.0×10^{-8} J
C. 1.0×10^{-7} J
D. 1.0×10^{-6} J
E. 1.0×10^{-5} J
F. 1.0×10^{-4} J

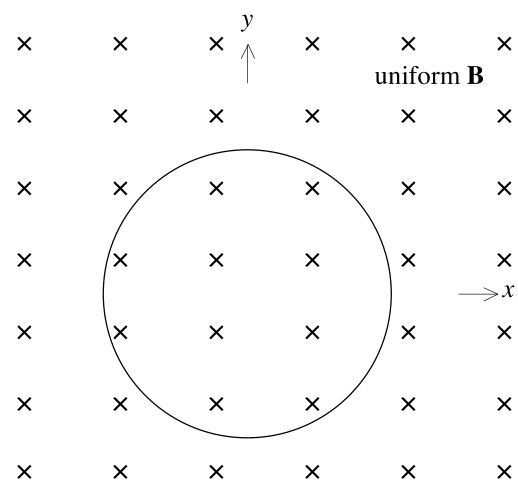
4. The metal ring shown at right lies in the plane of the page, and it is located in a region of strong, uniform **B**-field.

a. (1 pt.) If the strength of the **B**-field quickly dropped to zero, in which **direction** would a current be induced in the ring?

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

b. (1 pt.) Suppose, instead of the strength of the **B**-field changing, that the region of **B**-field ends at the edge of the page, and that the ring is quickly removed from the **B**-field by pulling it in the $+x$-direction. In which **direction** would a current be induced in the wire?

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



5. a. (2 pts.) A slide projector uses a converging lens with a focal length of 21.0 cm to form a real image of a slide on a distant screen. In order to form an image on a screen that is 12.0 m away from the lens, you should **position the slide** (the "object")…

A. 19.8 cm away from the lens
B. 20.2 cm away from the lens
C. 20.6 cm away from the lens
D. 21.4 cm away from the lens
E. 21.8 cm away from the lens
F. 22.2 cm away from the lens

b. (1 pt.) In order for the real image on the distant screen to be right-side-up, how should you **orient the slide** itself?

A. right-side-up
B. upside-down

6. (2 pts.) Monochromatic green light (λ = 532 nm) from a laser passes through two very narrow slits spaced 0.50 mm apart. The resulting pattern is observed on a white wall 10. m away. What is the **distance** between any two neighboring bright maxima near the middle of the pattern?

A. 2.0 mm
B. 5.9 mm
C. 8.4 mm
D. 1.1 cm
E. 2.4 cm
F. 5.3 cm

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Final Exam, Part B

7. a. (2 pts.) Physics can require a lot of caffeine, especially during finals week! The surface temperature of hot coffee is around 340 K. Assuming that the coffee is an ideal blackbody emitter, it glows with a **peak wavelength** of:

A. 850 nm	D. 35 μm
B. 3.5 μm	E. 85 μm
C. 8.5 μm	F. 350 μm

b. (1 pt.) Your answer to part (a) lies in which **region of the EM spectrum**?

A. gamma ray	D. ultraviolet
B. infrared	E. visible — blue
C. radio	F. visible — red

8. (2 pts.) Monochromatic light with λ = 325 nm shines on a photoelectric surface whose work function is 3.00 eV. What is the **maximum kinetic energy** of the electrons ejected from the surface?

A. 8.85 eV	D. 2.18 eV
B. 5.86 eV	E. 0.82 eV
C. 4.32 eV	F. no electrons are ejected

9. (2 pts.) All of the following are true **EXCEPT** which one?

A. A photon has both a momentum and a wavelength.
B. A moving electron has both a momentum and a wavelength.
C. A photon can travel at speed *c*, but no faster.
D. An electron can travel at speed *c*, but no faster.

10. (1 pt.) ${}^{252}_{100}$Fm is *produced by* the **α-decay** of an element with what **atomic number**?

A. 98	D. 101
B. 99	E. 102
C. 100	F. none of the above

11. (1 pt.) Which one of the following is produced by the **β^+-decay** of ${}^{13}_{7}$N?

A. ${}^{13}_{6}$C	D. ${}^{14}_{7}$N
B. ${}^{14}_{6}$C	E. ${}^{13}_{8}$O
C. ${}^{12}_{7}$N	F. ${}^{14}_{8}$O

12. (2 pts.) What are the correct products of the **β^--decay** of ${}^{36}_{17}$Cl?

A. ${}^{37}_{17}Cl + e^- + \bar{\nu}_e$	D. ${}^{37}_{16}S + e^- + \nu_e$
B. ${}^{36}_{17}Cl + e^- + \nu_e$	E. ${}^{35}_{18}Ar + e^- + \nu_e$
C. ${}^{36}_{16}S + e^- + \bar{\nu}_e$	F. ${}^{36}_{18}Ar + e^- + \bar{\nu}_e$

13. a. (2 pts.) In order to balance this nuclear reaction: $^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + 2$ _______ + energy
two of **what particle** are created?

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

b. (2 pts.) If the mass of all reactants is 0.029 u greater than the mass of all products in the above nuclear reaction, how much **energy** is produced?

A. 3.4×10^{-21} J
B. 4.3×10^{-19} J
C. 3.4×10^{-15} J
D. 4.3×10^{-12} J
E. 3.4×10^{-9} J
F. 4.3×10^{-2} J

14. (1 pt.) What **fraction** of *any* radioactive substance **remains** after exactly 8 half-lives have elapsed?

A. 1/8
B. 1/16
C. 1/64
D. 1/80
E. 1/256
F. zero — none remains after the 2nd half-life

15. (2 pts.) Carbon-14 has a half-life of 5730 years. **What percentage** of a sample of initially pure carbon-14 will have *decayed* after 2005 years?

A. 11.7%
B. 13.8%
C. 17.5%
D. 21.5%
E. 26.7%
F. 35.0%

16. (2 pts.) All of the following are true **EXCEPT** which one?

A. The mass of a $^{4}_{2}\text{He}$ nucleus is *less* than the sum of the masses of 2 protons plus 2 neutrons.
B. There is only one stable isotope of each chemical element.
C. All isotopes of a given element share the same atomic number.
D. Nuclear fusion is the main source of energy inside all stars.

17. (2 pts.) All of the following are true **EXCEPT** which one?

A. Electrons are leptons.
B. Neutrinos are nucleons.
C. Positrons are anti-matter.
D. Photons have no charge.
E. Neutrons and protons are baryons.
Φ. Physics is phun. (This one is *true*!)

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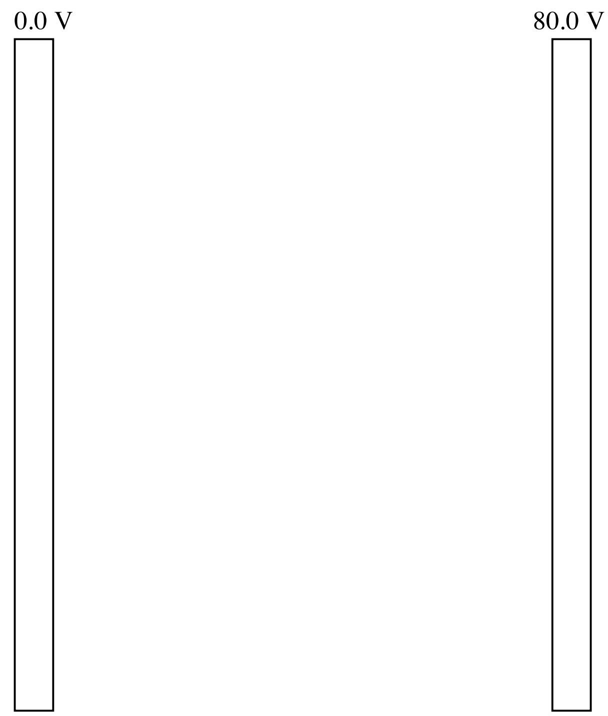
Final Exam, Part C

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, gravity, and relativistic effects in all problems, unless told otherwise.

1. Two infinite, ideal, parallel metal plates are shown edge-on at right. They are connected to an emf so that the left-hand plate is held at 0.0 V and the right-hand plate at +80.0 V. The plate separation is 5.0 cm.



a. (2 pts.) On the diagram at right, **draw *E* field lines** between the plates. Include **arrowheads**. (Ignore the effect of "fringes" near the ends of the plates.)

b. (2 pts.) Also on the diagram at right, **draw and label equipotential lines** at 20, 40, and 60 volts.

c. (5 pts.) An electron is released at rest at a point *exactly halfway between the two plates*. Find the **magnitude and direction** of the **electric force $\mathbf{F_E}$** on the electron.

After it is released from rest, the electron travels freely until it hits one of the two plates.

d. (3 pts.) As the electron moves closer to one plate, which ***ONE OR MORE*** of the following **remain(s) constant**? ***Circle ALL that apply:***

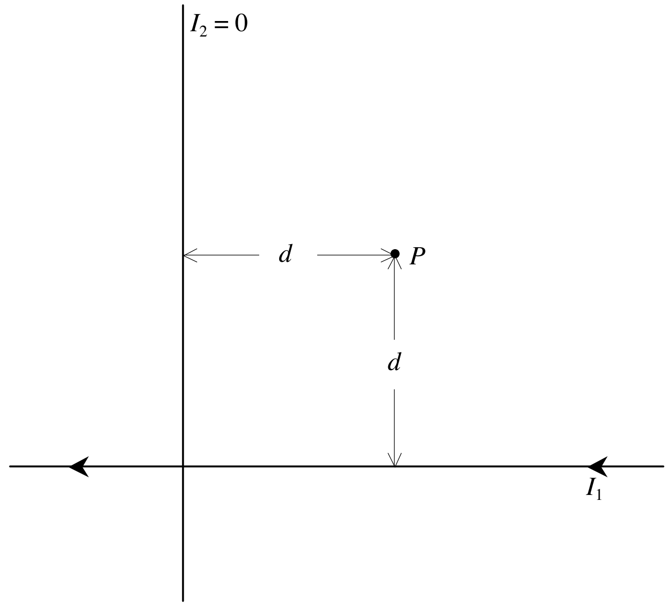
A. magnitude of electric force
B. direction of electric force
C. magnitude of acceleration
D. direction of acceleration
E. magnitude of velocity
F. direction of velocity

e. (2 pts.) What is the electron's **speed** the instant before it hits the plate?
(*Possibly useful formulas:* $F = m\,a$, $v^2 = v_0^2 + 2\,a\,\Delta x$, $K = (1/2)\,m\,v^2$)

A. 6.5×10^4 m/s
B. 7.9×10^4 m/s
C. 1.8×10^5 m/s
D. 4.5×10^5 m/s
E. 8.1×10^5 m/s
F. 3.8×10^6 m/s

2. Two infinitely long, straight wires lying in the plane of the page are fixed in position at 90° to each other, as shown, and are insulated from each other. Initially, $I_2 = 0$.

a. (5 pts.) If $I_1 = 45$ A to the left, and $d = 10.$ cm, find the **magnitude and direction** of the resulting **magnetic field $\mathbf{B_1}$** at point P.



b. (1 pt.) Now, in addition, an identical current $I_2 = 45$ A flows in the second wire *toward the top of the page* at the same time as I_1 is flowing. What does the **net** (total) **magnetic field** at point P become?

A. 2 times the magnitude in part (a)
B. √2 times the magnitude in part (a)
C. same as the magnitude in part (a)
D. (1/√2) times the magnitude in part (a)
E. (1/2) times the magnitude in part (a)
F. zero

c. (1 pt.) Instead, suppose $I_2 = 45$ A flows *toward the bottom of the page*. I_1 remains unchanged. What does the **net** (total) **magnetic field** at point P become?

A. 2 times the magnitude in part (a)
B. √2 times the magnitude in part (a)
C. same as the magnitude in part (a)
D. (1/√2) times the magnitude in part (a)
E. (1/2) times the magnitude in part (a)
F. zero

Now, let $I_2 = 0$ again. Only $I_1 = 45$ A flows.

A moving charged particle, located momentarily at point P, has an instantaneous velocity of 3.5×10^6 m/s *toward the top of page*. Due to $\mathbf{B}_1$, the particle momentarily experiences a force of 2.0×10^{-16} N *to the left*.

d. (1 pt.) The charge on the particle is:

A. **positive**
B. **negative**

e. (3 pts.) Calculate the magnitude of the **charge** on the particle.

f. (1 pt.) An additional **electric field** directed ______________ could be superimposed at point P to cause the *net force* on the particle to be *zero*.

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

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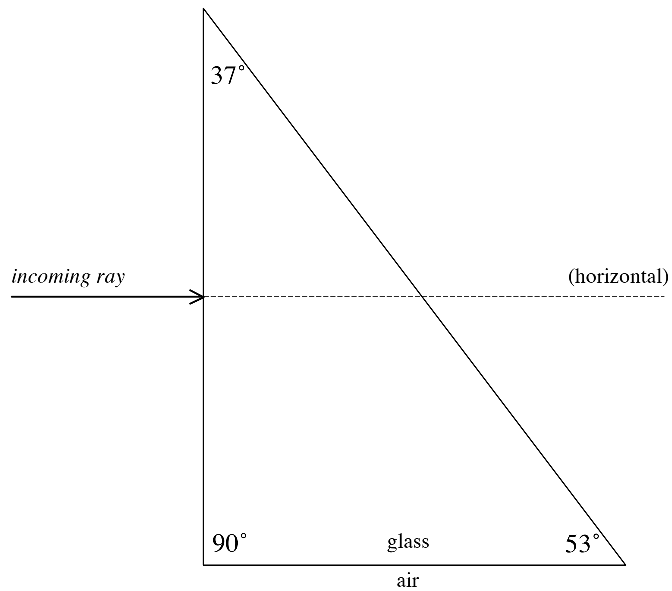
Final Exam, Part D

3. The triangular glass prism shown here has an index of refraction $n = 1.55$ and internal angles of exactly 37˚, 53˚, and 90˚. A beam of monochromatic light ($\lambda = 514.5$ nm) enters the prism horizontally from air (n = 1.00) on the left. (Ignore reflected rays throughout this problem.)



a. (2 pts.) **Carefully draw** the path of the ray as it passes through the prism and emerges to the right. *Continue the ray well into the air on the right side*. (You do NOT need to measure exact angles for this sketch.) *Use a straightedge*!

b. (5 pts.) Calculate the **angle to the horizontal** made by the ray emerging from the glass back into air on the right side.

c. (2 pts.) A second prism of exactly the same shape but different n is used to replace the prism above. Instead of emerging to the right, the beam of light experiences total internal reflection at the right surface. What is the **minimum possible index of refraction** of this new prism's glass?

A. 1.61 D. 1.76
B. 1.66 E. 1.81
C. 1.71 F. 1.86

d. (3 pts.) As the light passes *from air into glass*, does each of its following properties *increase*, *decrease*, or *remain unchanged*? (You do NOT need to show your work.)

i. speed: A. increases B. decreases C. unchanged

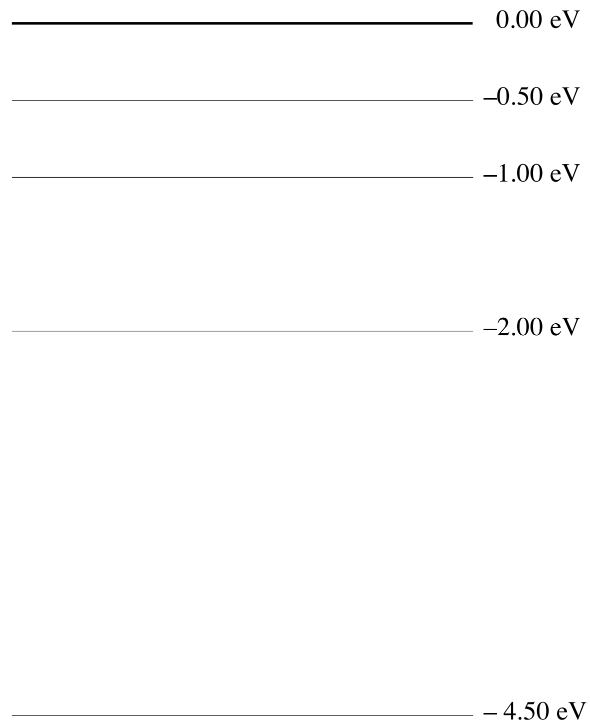
ii. wavelength: A. increases B. decreases C. unchanged

iii. frequency: A. increases B. decreases C. unchanged

e. (1 pt.) How would your **answer to part (b) change** if the prism were surrounded by water (n = 1.33) instead of by air (n = 1.00)?

A. increase B. decrease C. remain unchanged

4. An imaginary atom has only 4 bound energy levels for electrons, as shown at right: the ground state and the 1st, 2nd, and 3rd excited states. (Use the energies shown at right; do NOT attempt to calculate E_n yourself. Assume that the energies shown remain constant, regardless of the number of electrons present in each state.)



a. (4 pts.) If an electron is in the ground state, calculate the **frequency** of the *lowest-energy photon* that could successfully *excite* the electron to any other state. Show your work clearly.

b. (5 pts.) Later, suppose that an electron is in the $E = –1.00$ eV state. The electron can *spontaneously de-excite* to either of the two lower levels. Calculate the **wavelengths** of the photons that would be emitted by those two possible transitions. Show your work clearly.

c. (3 pts.) **Draw** the **three transitions** you calculated in parts (a) & (b) on the energy-level diagram above. Include directional **arrowheads**. Clearly **label** each transition “a” for part (a), or “b” for part (b).

d. (3 pts.) Is each of the three photons in parts (a) & (b) **visible**, **ultraviolet**, or **infrared**? (You do NOT need to show your work.)

part (a): ________________

part (b): ________________ & ________________

e. (1 pt.) In order for an electron in the ground state to become **ionized**, what must happen?

A. The electron must absorb a photon of < 4.50 eV.
B. The electron must absorb a photon of > 4.50 eV.
C. The electron must emit a photon of < 4.50 eV.
D. The electron must emit a photon of > 4.50 eV.