Physics 228 - Exam 2
2 April 2009
Profs. Rabe and Coleman

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Your
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with
exam
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SIGNATURE ______________________________

Turn off and put away cell phones now!

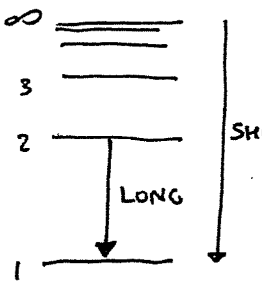
1. The exam will last from 9:40pm to 11:00pm.
2. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
3. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
4. Under STUDENT # enter your 9-digit student ID.
5. Enter 228 under COURSE, and your section number (see label above) under SEC.
6. Under CODE enter the exam code given above.
7. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.
8. There are 16 multiple-choice questions on the exam. For each question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. At the ened of the exam, **hand in the answer sheet and the cover page.** Retain this question paper for future reference and study.
9. When you are asked to open the exam, make sure that your copy contains all 15 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
10. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

Useful information

$c =$ speed of light $= 3.00 \times 10^8$ m/s
$q_e = -e =$ charge on an electron $= -1.602 \times 10^{-19}$ Coulombs
$q_p = +e =$ charge on a proton $= +1.602 \times 10^{-19}$ Coulombs
$m_e =$ electron mass $= 9.11 \times 10^{-31}$ kg
$m_e c^2 =$ electron rest energy $= 0.511$ MeV
$m_p =$ proton mass $= 1.67 \times 10^{-27}$ kg
$m_p c^2 =$ proton rest energy $= 938.27 MeV$
$m_n c^2 =$ neutron rest energy $= 939.57 MeV$
$k_B =$ Boltzmann's constant $= 1.38 \times 10^{-23}$ J/K
Wien's Constant $= 2.898 \times 10^{-3} m \cdot K$
$\sigma =$ Stefan's Constant $= 5.670 \times 10^{-8} W/(m^2 K^4)$
$\hbar = \frac{h}{2\pi}$
$h = 6.626 \times 10^{-34}$ J-s
$h = 4.136 \times 10^{-15}$ eV-s (in units of electron volts-second)
$hc = 1240$ eV $\cdot$ nm $= 1240$ MeV $\cdot$ fm
1 nm $= 10^{-9}$ m
1 Å $= 10^{-10}$ m $= 0.1$ nm
1 μm $= 10^{-6}$m
1 mHz $= 10^{-3}$ Hz   1 kHz $= 10^{+3}$ Hz
1 MHz $= 10^{+6}$ Hz   1 GHz $= 10^{+9}$ Hz

1. The Lyman series corresponds to transitions to the hydrogen ground state (n = 1). What is the ratio of the longest wavelength in the Lyman series to the shortest?

   a) 4
   b) 3/2
   [✓ c)] None of the other answers
   d) 3
   e) 2



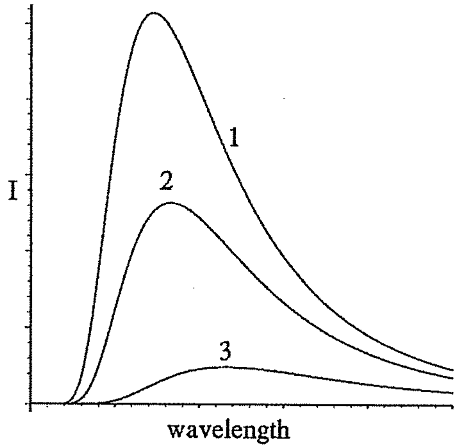
$$\frac{hc}{\lambda_{short}} = E_\infty - E_1 = 13.6\,eV$$

$$\frac{hc}{\lambda_{Long}} = E_2 - E_1 = 13.6\left(\frac{-1}{4}+1\right) = \frac{3}{4}13.6eV$$

$$\frac{\lambda_{Long}}{\lambda_{short}} = \frac{13.6}{3/4(13.6)} = \underline{\underline{\frac{4}{3}}}.$$

2. The figure shows the black-body spectrum for three different objects. Rank the temperatures of the objects.

   a) $T_1 = T_2 = T_3$
   b) $T_1 < T_2 < T_3$
   [✓ c)] $T_1 > T_2 > T_3$
   d) Impossible to tell
   e) $T_1 = T_2 > T_3$



$$\lambda_{max} = \frac{2.9\times10^{-3}}{T} \qquad T\uparrow \quad \lambda_{max}\downarrow$$

$$\Rightarrow \underline{\underline{T_1 > T_2 > T_3}}.$$

3. Brenda steps into the school library. At the same instant according to earth time, Brandon steps into the office of the school newspaper, which is located 80 m away. In a reference frame moving at speed 0.90c along the line between Brenda and Brandon, what is the time difference between these two events?

   a) 0.30 μs
   b) 0.24 μs
   [✓ c)] 0.55 μs
   d) Zero
   e) 0.13 μs

$$\Delta t' = \left(\Delta t - \frac{v}{c^2}\Delta x\right)\gamma \qquad \gamma = \frac{1}{\sqrt{1-(v/c)^2}}$$

$\Delta t = 0$

$\Delta x = 80m$

$$\Delta t' = -\frac{v}{c^2}\Delta x\,\gamma = -\left(\frac{v}{c}\right)\frac{\Delta x}{c}\,\gamma$$

$$|\Delta t'| = 0.9 \times \frac{80}{3\times10^8} \times \frac{1}{\sqrt{1-(0.9)^2}} = 5.5\times10^{-7}s = \underline{\underline{0.55\,\mu s}}$$

$$L = L_0\sqrt{1-(v/c)^2}$$

If $v/c \ll 1$

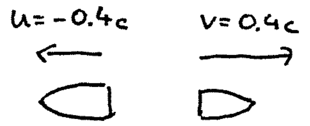
$$\sqrt{1-(v/c)^2} = \left(1-\left(\tfrac{v}{c}\right)^2\right)^{\frac{1}{2}} \simeq 1-\tfrac{1}{2}\left(\tfrac{v}{c}\right)^2$$

$$L = L_0\left(1-\tfrac{1}{2}\left(\tfrac{v}{c}\right)^2\right) \qquad L_0 - L = L_0\left(\tfrac{1}{2}\left(\tfrac{v}{c}\right)^2\right) = \frac{1m}{2}\times\left(\frac{10}{3\times10^8}\right)^2$$

$$= \underline{\underline{5.6\times10^{-16}}}\ m$$

4. A meter stick moves in the laboratory along the direction of its length with a speed of 10 m/sec. The amount by which it is contracted is:

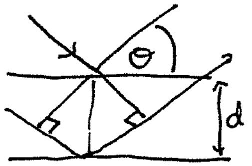
   a) 3.3×10^{-8} m
   [✓ b)] 5.6×10^{-16} m
   c) 1.7×10^{-8} m
   d) zero
   e) 1.1×10^{-15} m



$$v' = \frac{v-u}{1-(vu)/c^2} \qquad v' = \frac{0.4-(-0.4)}{1-(0.4)(-0.4)}\,c = \underline{\underline{0.69c}}$$

5. Two rockets each move with speed 0.4 c in opposite directions in the laboratory frame of reference. What is the speed of one rocket, as determined by an observer in the other?

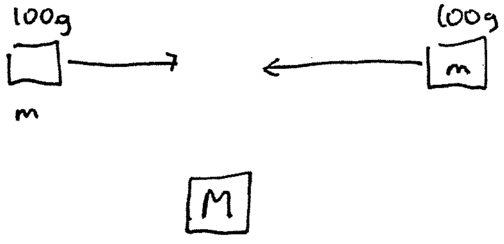
   a) .44 c
   b) .95 c
   c) .8 c
   d) .75 c
   [✓ e)] .69 c



$$\lambda = 2d\sin\theta = 2\times0.359nm\times\sin 20^\circ$$
$$= \underline{\underline{0.27nm}}$$

6. Certain planes of a crystal of halite have a spacing of 0.399 nm. The crystal is irradiated by a beam of x-rays. First order constructive interference occurs when the beam makes an angle of 20° with the planes. The wavelength of the x-rays, in nm, is closest to:

   [✓ a)] 0.27nm
   b) 0.24nm
   c) 0.21nm
   d) 0.17nm
   e) 0.14nm



$$E_{TOT} = 2\gamma mc^2$$
$$= Mc^2$$

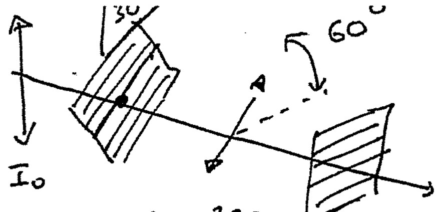
$$M = 2\gamma m = \frac{2}{\sqrt{1-(0.6)^2}}\times100g$$
$$= \underline{\underline{250g}}$$

7. Two lumps of clay, each having a mass of 100 grams and a speed of 0.6c, collide head-on and stick together. Assuming that no radiation is emitted in the collision, what is the mass of the composite?

   a) 160 grams
   b) None of the other answers
   c) 125 grams
   [✓ d)] 250 grams
   e) 200 grams

8. A beam of light linearly polarized in the vertical direction is travelling horizontally towards the observer. It is incident on a perfect polarizing sheet oriented so its transmission axis is 30° left of vertical, and then through another perfect polarizer with transmission axis horizontal. What fraction of the incident beam intensity reaches the observer?

   a) .87
   b) .43
   c) .75
   [✓ d)] .19
   e) 0



$I_o \cos^2 30$

$= I_o \, 3/4$

$I_o \cos^2 30 \cos^2 60$

$= I_o \times \frac{3}{4} \times \frac{1}{4} = \frac{3}{16} I_o$

$= \underline{\underline{0.1875 \, I_o}}$

9. A helium-neon laser is emitting 10^{17} photons every second, all at a wavelength of 633 nm. What is the laser's power output?

   a) About 4.1 W
   b) About 12 W
   c) About 0.75 W
   [✓ d)] About 0.03 W
   e) About 0.20 W

$$P = Nhf = \frac{Nhc}{\lambda} = \frac{10^{17}/s \times 6.634 \times 10^{-34} \times 3 \times 10^{8}}{633 \times 10^{-9}}$$

$$= 0.031 \, J/s = \underline{\underline{0.031 \, W}}$$

10. In the photoelectric effect we wish to decrease the maximum kinetic energy of the photoelectrons. This will happen if

   a) increase the intensity of the incident beam of light
   [✓ b)] increase the wavelength of the photons
   c) we polish the metal surface so that it is as shiny as possible.
   d) decrease the speed of the photons
   e) leave the light on for only a short period of time

$$KE = hf - W = \frac{hc}{\lambda} - W$$

$$KE \downarrow \quad \therefore \frac{hc}{\lambda} \downarrow \quad \therefore \lambda \uparrow \quad (b)$$

11. The de Broglie wavelength of an electron whose kinetic energy is 54.0 eV is

   a) 0.962 nm
   [✓ b)] 0.167 nm
   c) 23.0 nm
   d) 2.50 nm
   e) 0.333 nm

Since 54 eV << 0.5MeV $= m_e c^2$ can use non-relativistic formula.

$$E = \frac{1}{2m} p^2 = \frac{1}{2} \frac{h^2}{m\lambda^2}$$

$$\Rightarrow \lambda = \sqrt{\frac{h^2}{2mE}} = \sqrt{\frac{(6.634 \times 10^{-34})^2}{\frac{1}{2} \times 9.1 \times 10^{-31} \times (54 \times 1.6 \times 10^{-19})}} = 1.67 \times 10^{-10} \, m$$

$$= \underline{\underline{0.167 \, nm}}$$

$$\Delta p \Delta x \gtrsim \hbar$$

$$\Delta p \gtrsim \frac{\hbar}{\Delta x} = \frac{10^{-34}\,Js}{10^{-10}\,m} = \underline{10^{-24}\,kg\,m/s}$$

$$K = \underbrace{\sqrt{(mc^2)^2+(pc)^2}}_{E} - mc^2$$

$$E = \sqrt{(mc^2)^2+[(3mc)c]^2} = \sqrt{10}\,mc^2$$

$$K = \left(\sqrt{10}-1\right)mc^2 = \underline{\underline{2.16mc^2}}$$

Emission ∴ $E_i > E_f$ ↓

Shortest $\lambda \Rightarrow E = \frac{hc}{\lambda}$ largest $\Delta E = E_i - E_f$

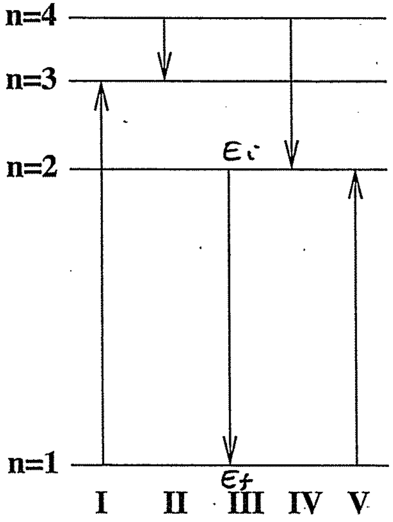
12. An electron is trapped in a one-dimensional box 10^{-10} m in length. What is its minimum uncertainty in the electron's momentum?

    [✓ a)] 10^{-24}kg m/s
    b) 10^{24}kg m/s
    c) zero
    d) 10^{-14}kg m/s
    e) 10^{-34}kg m/s

13. A particle of mass m has a momentum of 3mc. What is its <u>kinetic</u> energy?

    a) $2.00mc^2$
    [✓ b)] $2.16mc^2$
    c) $3.00mc^2$
    d) $4.50mc^2$
    e) $3.16mc^2$

14. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the <u>emission</u> of a photon with the shortest wavelength?



    a) I.
    b) V.
    c) IV.
    d) II.
    [✓ e)] III.

15. The threshold wavelength for the photoelectric effect in silver is 262 nm, i.e. this is the longest wavelength which will just barely cause electrons to be emitted from the surface. For what wavelength will the photoelectric stopping potential be 1.36 V?

a) 175 nm
[✓ b)] 204 nm
c) 912 nm
d) 127 nm
e) 368 nm

$$hf - W = eV_{stop}$$

$$\frac{hc}{\lambda} - W = eV_{stop}$$

THRESHOLD $\frac{hc}{\lambda_T} - W = 0 \Rightarrow W = \frac{hc}{\lambda_T} = \frac{4.14\times10^{-15}\,eVs \times 3\times10^{8}}{262\times10^{-19}}$

$= 4.74\,eV$

$$\frac{hc}{\lambda} = W + eV_{stop} = 4.74 + 1.36 = 6.1\,eV = E$$

$$\Rightarrow \lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\,eVs \times 3\times10^{8}}{6.1} = 2.04\times10^{-7}\,m$$

$= \underline{\underline{204\,nm}}$

16. A nearby star is 4 light years away from the earth. If an astronaut travels from the earth to the star with a speed of 0.8 c, how much time will have elapsed on <u>his</u> clock at the end of the journey?

a) 5 years
[✓ b)] 3 years
c) 4 years
d) 8.3 years
e) 2.4 years

$$\tau = \tau_0 \gamma$$

$$\tau = \frac{4}{0.8} = 5\,yrs$$

$$\tau_0 = \frac{\tau}{\gamma} = 5 \times \sqrt{1-0.8^2} = 5\times0.6 = \underline{\underline{3\,yrs}}$$