## Physics 132-02 Test 3

I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Name \_\_\_\_\_ Signature \_\_\_\_\_

Questions (5 for 8 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

- 1. During the radioactivity laboratory you made several runs with the radiation counter with no radioactive sources nearby. Why?
- 2. Radiocarbon dating relies on the observation that the fraction of <sup>14</sup>C in living organisms has been at least roughly constant for many thousands of years. How can this be if the <sup>14</sup>C is constantly decaying away?
- 3. Recall the discussion of Newton's corpuscular theory of light in the laboratory on interference. Does the data you collected for that lab support Newton's theory or the wave theory? Why?
- 4. The position of each interference maxima (bright spot) in the interference lab is

$$y_m = \frac{m\lambda L}{d}$$

where  $y_m$  is the distance of a bright spot from the central maximum (the distance along the slide in this experiment), d is the slit separation, and L is the distance from the slits to the phototransistor. The wavelength of the light is  $\lambda$ , and m is the order of the bright spot. Generate an expression for the distance  $\Delta y$  between adjacent bright spots. Explain. 5. The figure shows two rays of light (in red) with  $\lambda = 600 \ nm$  that reflect from mirrors that are separated by 150 nm. The rays are initially in phase and there is no phase change upon reflection. What is the path difference  $\delta$  of the two rays? When they have cleared the reflection region are the rays in phase, 180° out of phase, or in some intermediate state? Explain.



Problems (3). Clearly show all reasoning for full credit. Use a separate sheet to show your work.

- 1. 15 pts. There are radioactive substances all around us. Consider the radioactivity of milk we studied in a problem on the Chernobyl nuclear accident. The radioactivity is due to the presence of potassium. Assume that one liter of milk contains a mass  $m_K = 2.6 \ g$  of potassium, of which a fraction f = 0.012% is the isotope <sup>40</sup>K with half-life  $t_K = 1.28 \times 10^9 \ yr$ . What is the activity (decays/s) of milk?
- 2. 20 pts. High-power lasers in factories are used to cut through cloth and metal. One such laser has a beam diameter of  $d = 1.0 \ mm$  and generates an electric field having an amplitude of  $E_m = 0.70 \ MV/m$  at the target. (a) What is the amplitude of the magnetic field produced? (b) What is the intensity of the laser? (c) At an instant in time the electric field from the laser is  $\vec{E} = 5.7341 \times 10^5 \ V/m \ \hat{i} + 4.015 \times 10^5 \ V/m \ \hat{j}$  and the magnetic field is  $\vec{B} = -1.3192 \times 10^{-3} \ V - s/m^2 \ \hat{i} + 1.884 \times 10^{-3} \ V - s/m^2 \ \hat{j}$ . Are these fields perpendicular to each other? Explain.



- 3. 25 pts. The double-slit effect is used to guide aircraft to safe landings in poor visibility. In the figure below two radio antennas (the black dots) are adjacent to the runway separated by d = 40 m. The antennas broadcast radio waves at a frequency  $f = 30 \times 10^6 cycles/s$ . The red lines in the figure represent paths along which maxima in the interference pattern of the radio waves exist. The pilot 'locks on' to a strong signal along the interference maximum and follows it to the airport runway.
  - 1. What if the pilot locked on to the first side maximum as shown in the figure. How far to the side of the runway centerline will the plane be when it is a distance  $L = 1 \ km$  from the antennas as measured along its direction of travel?
  - 2. To identify the central interference maximum a second pair of transmitters sends out radio waves at a different frequency from the same position as the first pair. The pilot now searches for two strong signals at different frequencies. How would the pilot be able to tell if the plane was on the central maximum in this situation? Hint: Consider the angular positions of the peaks in the two interference patterns. You do not necessarily have to make any calculations to answer part 2. Explain.



DO NOT WRITE BELOW THIS LINE.

## Physics 132-2 Test 3 Equations

$$R = \frac{dN}{dt} = -\lambda N \quad N = N_0 e^{-\lambda t} \quad t_{1/2} = \frac{\ln 2}{\lambda} \quad y = A\sin(kx - \omega t + \phi) \quad k\lambda = \omega T = 2\pi \quad f = \frac{1}{T}$$

 $E = E_m \sin(kx - \omega t + \phi) \quad B = B_m \sin(kx - \omega t + \phi) \quad \sin \theta = \frac{y}{\sqrt{L^2 + y^2}} \approx \frac{y}{L} \quad \sin \theta \approx \theta$ 

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B} \quad E = cB \quad |\vec{S}| = Intensity = \frac{E^2}{2\mu_0 c} \quad v_{wave} = \frac{\lambda}{T} = \lambda f$$

 $\delta = d\sin\theta = m\lambda \approx \frac{dy_m}{L} (m = 0, \pm 1, \pm 2, ...) \quad \delta = a\sin\theta = m\lambda \approx \frac{ay_m}{L} (m = \pm 1, \pm 2, ...) \quad \phi = k\delta$ 

$$I = I_m \cos^2\left(\frac{\pi d}{\lambda}\sin\theta\right)$$

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt} \quad a_c = \frac{v^2}{r} \quad W = \int \vec{F} \cdot d\vec{s} \quad KE = \frac{1}{2}mv^2 \quad KE_0 + PE_0 = KE_1 + PE_1 \quad \vec{F}_C = k_e \frac{q_1 q_2}{r^2}\hat{r}$$

$$\vec{E} \equiv \frac{\vec{F}}{q_0} \quad \vec{E} = k_e \sum_i \frac{q_i}{r_i^2} \hat{r}_i \quad \vec{E} = \int \frac{k_e dq}{r^2} \hat{r} \quad V = k_e \sum_n \frac{q_n}{r_n} \quad V = k_e \int \frac{dq}{r} \quad V = \frac{PE}{q} \quad V = Ed$$
$$\vec{F}_B = q\vec{v} \times \vec{B} \qquad |\vec{F}_B| = |qvB\sin\alpha| \qquad |\vec{F}_c| = m\frac{v^2}{r}$$

$$x = \frac{a}{2}t^2 + v_0t + x_0$$
  $v = at + v_0$   $\sin A + \sin B = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$ 

 $\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\hat{i} - (A_x B_z - A_z B_x)\hat{j} + (A_x B_y - A_y B_x)\hat{k} = |\vec{A}||\vec{B}|\sin\alpha \text{ (right-hand-rule direction)}$ 

 $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z = |\vec{A}| |\vec{B}| \cos \alpha \quad \ln(ab) = \ln a + \ln b \quad \ln(a^b) = b \ln a \quad e^{ab} = e^a e^b$ 

$$\frac{df(x)}{dx} = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x} \quad \frac{d}{dx}(f(u)) = \frac{df}{du}\frac{du}{dx}$$

$$\frac{d}{dx}(x^n) = nx^{n-1} \quad \frac{de^x}{dx} = e^x \quad \frac{d}{dx}(\ln x) = \frac{1}{x} \quad \frac{d}{dx}(\cos ax) = -a\sin ax \quad \frac{d}{dx}(\sin ax) = a\cos ax$$

$$\langle x \rangle = \frac{1}{N} \sum_{i} x_{i} \quad \sigma = \sqrt{\frac{\sum_{i} (x_{i} - \langle x \rangle)^{2}}{N - 1}} \quad A = 4\pi r^{2} \quad V = Ah \quad V = \frac{4}{3}\pi r^{3}$$

$$\int_{a}^{b} f(x)dx = \lim_{\Delta x \to 0} \sum_{n=1}^{N} f(x)\Delta x \quad \int \frac{1}{x}dx = \ln x \quad \int x^{n}dx = \frac{x^{n+1}}{n+1} \quad \int e^{ax}dx = \frac{e^{ax}}{a}$$

$$\int \frac{x}{\sqrt{x^2 + a^2}} dx = \sqrt{x^2 + a^2} \quad \int \frac{x^2}{\sqrt{x^2 + a^2}} dx = \frac{1}{2}x\sqrt{x^2 + a^2} - \frac{1}{2}a^2 \ln\left[x + \sqrt{x^2 + a^2}\right]$$

$$\int \frac{x^3}{\sqrt{x^2 + a^2}} dx = \frac{1}{3}(-2a^2 + x^2)\sqrt{x^2 + a^2} \int \frac{1}{\sqrt{x^2 + a^2}} dx = \ln\left[x + \sqrt{x^2 + a^2}\right]$$

## Physics 132-2 Test 3 Constants and Conversions

Avogadro's number $(N_A)$	$6.022 \times 10^{23}$	Speed of light $(c)$	$3 \times 10^8 \ m/s$
$k_B$	$1.38\times 10^{-23}~J/K$	proton/neutron mass	$1.67\times 10^{-27}~kg$
1 u	$1.67\times 10^{-27}~kg$	g	$9.8 \ m/s^2$
Gravitation constant	$6.67 \times 10^{-11} N - m^2/kg^2$	Earth's radius	$6.37 \times 10^6 m$
Coulomb constant $(k_e)$	$8.99 \times 10^9 \frac{N-m^2}{C^2}$	Electron mass	$9.11\times 10^{-31}~kg$
Elementary charge $(e)$	$1.60 \times 10^{-19} C$	Proton/Neutron mass	$1.67\times 10^{-27}~kg$
Permittivity constant $(\epsilon_0)$	$8.85 \times 10^{-12} \frac{kg^2}{N-m^2}$	$1.0 \ \mathrm{eV}$	$1.6\times 10^{-19}~J$
$1 { m MeV}$	$10^6 \ eV$	atomic mass unit $(u)$	$1.66\times 10^{-27}~kg$
Planck's constant $(h)$	$6.63\times 10^{-34}~Js$	Planck's constant $(h)$	$4.14\times 10^{-15}~eVs$
Permeability constant $(\mu_0)$	$1.26\times 10^{-6}\ Tm/A$	Rydberg constant $(R_H)$	$1.097 \times 10^7 \ m^{-1}$
Becquerel $(Bq)$	$1 \ decay/s$	Curie $(Ci)$	$3.7 \times 10^{10} Bq$

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39.098 rubidium	40.078 strontium		44.956 vttrium	47.867 zirconium	50.942 niohium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546 silver	65.39 cadmium	69.723 indium	72.61	74.922 antimony	78.96 tellurium	79.904 iodine	83.80 xenon
39.098 rubidium 37	40.078 strontium 38		44.956 yttrium <b>39</b>	47.867 zirconium 40	50.942 niobium <b>41</b>	51.996 molybdenum 42	54.938 technetium <b>43</b>	55.845 ruthenium <b>44</b>	58.933 rhodium 45	58.693 palladium <b>46</b>	63.546 silver 47	65.39 cadmium <b>48</b>	69,723 Indium <b>49</b>	72.61 tin <b>50</b>	74.922 antimony 51	78.96 tellurium <b>52</b>	79.904 lodine 53	83.80 xenon 54
39.098 rubidium 37 Rh	40.078 strontium 38		44.956 yttrium 39	47.867 zirconium 40 <b>7 r</b>	50.942 niobium 41	51.996 molybdenum 42	54,938 technetium 43	55.845 ruthenium 44	58.933 rhodium 45 <b>Rh</b>	58.693 palladium 46 <b>Dd</b>	63.546 silver 47	65.39 cadmium 48	69.723 Indium 49	72.61 tin 50	74.922 antimony 51	78.96 tellurium 52	79.904 Iodine 53	83.80 xenon 54
39.098 rubidium 37 Rb	40.078 strontium 38 Sr		44.956 yttrium <b>39</b> <b>Y</b>	47.867 zirconium 40 Zr	50.942 niobium 41 Nb	51.996 molybdenum 42 Mo	43 technetium 43	44 AU AU AU AU AU AU AU AU	58.933 rhodium 45 <b>Rh</b>	58.693 palladium 46 Pd	63.546 silver 47 <b>Ag</b>	65.39 cadmium 48 <b>Cd</b>	69.723 Indium 49 In	72.61 tin 50 <b>Sn</b>	74.922 antimony 51 <b>Sb</b>	78.96 tellurium 52 <b>Te</b>	79.904 lodine 53	83.80 xenon 54 Xe
39.098 rubidium 37 <b>Rb</b> 85.468 caesium	40.078 strontlum 38 Sr 87.62 barium		44.956 yttrium <b>39</b> <b>Y</b> 88.906 lutetium	47.867 zirconium 40 Zr 91.224 hafnium	50.942 niobium 41 Nb 92.906 tantalum	51.996 molybdenum 42 Mo 95.94 tungsten	54.938 technetium 43 TC [98] rhenium	55.845 ruthenium 44 Ru 101.07 osmium	58.933 rhodium 45 Rh 102.91 iridium	58.693 palladium 46 Pd 106.42 platinum	63.546 silver 47 Ag 107.87 gold	65.39 cadmium 48 Cd 112.41 mercury	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead	74.922 antimony 51 Sb 121.76 bismuth	78.96 tellurium 52 Te 127.60 polonium	79.904 Iodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55	40.078 strontium 38 Sr 87.62 barium 56	57-70	44.956 yttrium 39 Y 88.906 lutetium 71	47.867 zirconium 40 Zr 91.224 hafnium 72	50.942 niobium 41 Nb 92.906 tantalum 73	51,996 molybdenum 42 Mo 95,94 tungsten 74	54.938 technetium 43 TC [98] rhenium 75	55,845 ruthenium 44 Ru 101.07 osmium 76	58.933 rhodium 45 Rh 102.91 iridium 77	58.693 palladium 46 Pd 106.42 platinum 78	63.546 silver 47 Ag 107.87 gold 79	65.39 cadmium 48 Cd 112.41 mercury 80	69.723 Indium 49 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82	74.922 antimony 51 <b>Sb</b> 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 Iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55 <b>Cs</b>	40.078 strontium 38 Sr 87.62 barium 56 Ba	57-70 <del>X</del>	44.956 yttrium 39 Y 88.906 lutetium 71 Lu	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantatum 73 Ta	51,996 molybdenum 42 Mo 95,94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 <b>Re</b>	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58,693 palladium 46 Pd 106,42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65,39 cadmium 48 Cd 112,41 mercury 80 Ha	69.723 Indium 49 <u>In</u> 114.82 thailium 81 <b>TI</b>	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurlum 52 Te 127.60 potonium 84 PO	79.904 Iodine 53 I 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55 <b>Cs</b> 132.91	40.078 strontlum 38 Sr 87.62 barium 56 Ba 137.33	57-70 <del>X</del>	44.956 yttrium 39 Y 88.906 lutetium 71 Lu 174.97	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95	51,996 molybdenum 42 Mo 95,94 tungsten 74 W 183,84	54.938 technetium 43 <b>TC</b> [98] rhenium 75 <b>Re</b> 186.21	55.845 ruthenium 44 Ruu 101.07 osmium 76 OS 190.23	58.933 rhodium 45 <b>Rh</b> 102.91 iridium 77 <b>Ir</b> 192.22	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08	63,546 silver 47 AG 107.87 gold 79 AU 196,97	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59	69,723 indium 49 Inn 114.82 thailium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Tee 127.60 potonium 84 Po [209]	79.904 lodine 53 1 126.90 astatine 85 <b>At</b> [210]	83.80 xenon 54 Xee 131.29 radon 86 Rn [222]
39,098 rubidium 37 <b>Rb</b> 85,468 caesium 55 <b>Cs</b> 132,91 francium 97	40.078 strontlum 38 Sr 87.62 barium 56 Baa 137.33 radium	57-70 ★	44.966 yttrium 39 Y 88.906 lutetium 71 Luu 174.97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51,996 molybdenum 42 Mo 95,94 tungsten 74 W 183,84 seaborgium 106	54.938 technetium 43 <b>TC</b> [98] rhenium 75 <b>Re</b> 186.21 bohrium 107	55.845 ruthenium 44 Ruu 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 <b>Rh</b> 102.91 iridium 77 <b>Ir</b> 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnillum 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 ununnum	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 unumbium 112	69,723 indium 49 In 114.82 thailium 81 TI 204.38	72.61 Un 50 Sn 118.71 lead 82 Pb 207.2 Ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Tee 127.60 potonium 84 POO [209]	79.904 lodine 53 126.90 astatine 85 At [210]	83.80 xenon 54 Xee 131.29 radon 86 Rn [222]
39,098 rubidium 37 <b>Rb</b> 85,468 caesium 55 <b>CS</b> 132,91 francium 87	40.078 strontlum 38 Sr 87.62 barlum 56 Baa 137.33 radium 88	57-70 ★ 89-102	44.966 yttrium <b>39</b> <b>Y</b> 88.906 lutetium <b>71</b> <b>LU</b> 174.97 lawrencium <b>103</b>	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51,996 molybdenum 42 Mo 95,94 tungsten 74 W 183,84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ruu 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodlum 45 Rh 102.91 iridlum 77 Ir 192.22 meltnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69,723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sbb 121.76 bismuth 83 Bi 208.98	78.96 tellurlum 52 Te 127.60 polonium 84 PO [209]	79.904 iodine 53 I 126.90 astatine 85 At [210]	83.80 xenon 54 Xe 131.29 radon 86 Rn [222]
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55 <b>Cs</b> 132.91 francium 87 <b>Fr</b>	40.078 strontlum 38 Sr 87.62 barlum 56 Baa 137.33 radium 88 Ra	57-70 ★ 89-102 ★ ★	44.966 yttrium 39 Y 88.906 lutetium 71 Luu 174.97 lawrencium 103 Lr	47.867 zirconium 40 Zr 91.224 hatnium 72 Hf 178.49 rutherfordium 104 Rf	50.942 niobium 41 Nb 92.906 tantaium 73 Ta 180.95 dubnium 105 Db	51,996 molybdenum 42 MO 95,94 tungsten 74 W 183,84 seaborgium 106 Sg	54.938 technetium 43 Tc [98] rhenium 75 Re 186.21 bohrium 107 Bh	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108 HS	58.933 rhodlum 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109 Mt	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110 Uun	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111 Uuuu	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112 Uub	69,723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 Un 50 Sn 118.71 Iead 82 Pb 207.2 Ununquadum 114 Uuq	74.922 antimony 51 Sbb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 PO [209]	79.904 iodine 53 I 126.90 astatine 85 At [210]	83.80 xenon 54 Xe 131.29 radon 86 Rn [222]

*Lanthanida sorios	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium <b>64</b>	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
,	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

The Periodic Chart.