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 ^{14}C in living organisms has been at least roughly constant for many thousands of years. How can this be if the ^{14}C is constantly decaying away?

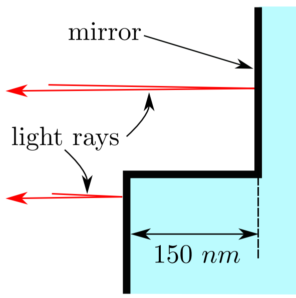
3. Recall the discussion of Newton's corpuscular theory of light in the laboratory on interference. Does the data you collected for that lab support Newton's theory or the wave theory? Why?

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 λ, and m is the order of the bright spot. Generate an expression for the distance Δy 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 δ 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.

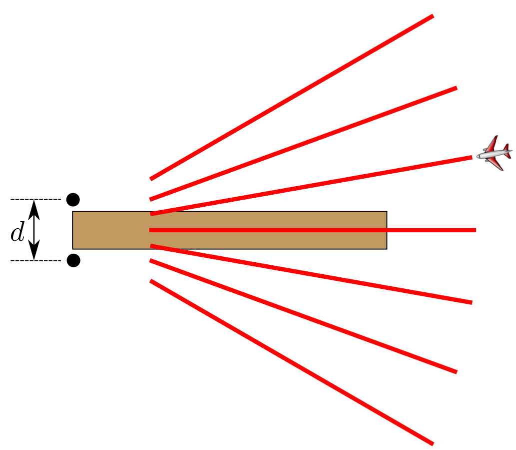
1. 15 pts. There are radioactive substances all around us. Consider the radioactivity of milk we studied in a problem on the Chernobyl nuclear accident. The radioactivity is due to the presence of potassium. Assume that one liter of milk contains a mass $m_K = 2.6\ g$ of potassium, of which a fraction $f = 0.012\%$ is the isotope ^{40}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

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

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

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

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

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

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

$$\vec{E} \equiv \frac{\vec{F}}{q_0} \quad \vec{E} = k_e \sum_i \frac{q_i}{r_i^2}\hat{r}_i \quad \vec{E} = \int \frac{k_e dq}{r^2}\hat{r} \quad V = k_e \sum_n \frac{q_n}{r_n} \quad V = k_e \int \frac{dq}{r} \quad V = \frac{PE}{q} \quad V = Ed$$

$$\vec{F}_B = q\vec{v} \times \vec{B} \qquad |\vec{F}_B| = |qvB\sin\alpha| \qquad |\vec{F}_c| = m\frac{v^2}{r}$$

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

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

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

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

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

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

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

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

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

Physics 132-2 Test 3 Constants and Conversions

Avogadro's number (N_A)	6.022×10^{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 (ϵ_0)	$8.85 \times 10^{-12} \frac{kg^2}{N-m^2}$	1.0 eV	$1.6 \times 10^{-19} \ J$
1 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 (μ_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)	$3.7 \times 10^{10} \ Bq$

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

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

The Periodic Chart.