Physics 205 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.

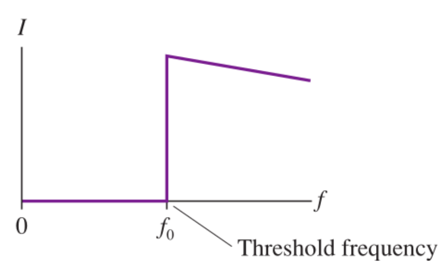
1. Waves from two slits S and Q will destructively interfere and cancel at a point P if the distance between P and S is larger than the distance between P and Q by

   A. $(n + \frac{1}{2})\lambda$ (integer n)
   B. λ
   C. $\frac{1}{2}n\lambda$ (n is an integer)
   D. $n\lambda$ (n is an integer)
   E. Other (specify).

   Explain.

2. The Rutherford cross section formula $d\sigma/d\Omega$ is related to the intensity of scattering particles to different angles in a collision. Was this expression successful in describing the Davisson-Germer results for electrons scattering from ^{58}Ni? Explain why it succeeded or failed.

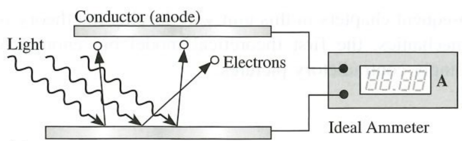
3. The figure below shows current versus frequency of the incident light for a photoelectric effect measurement. How would the figure change if classical physics (the swimming pool model of light) provided the correct description of the photoelectric effect? Explain.



4. For experiments using the apparatus shown in the figure, which of the following possible results (if seen) about the value displayed on the ammeter would probably *not* be consistent with the wave model of light?

   A. It is zero for some time after the light starts shining.
   B. It increases as the light's intensity increases.
   C. It varies as the light's wavelength changes.
   D. It is zero if the wavelength is larger than a certain value.

   Explain.



5. An electron beam shining on a nickel crystal is preferentially reflected in certain directions instead of being scattered uniformly in all directions. Classify this experimental result according to the choices shown below and explain your choice.

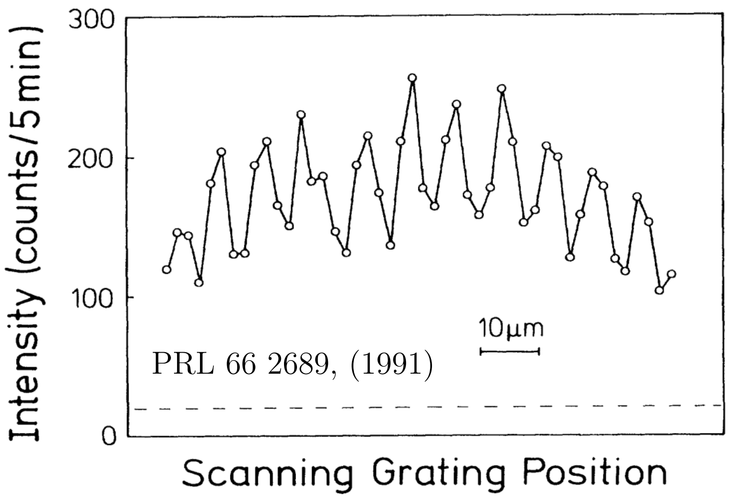
   A. Results are consistent with a pure wave model.
   B. Results are consistent with a pure particle model.
   C. Results are consistent with either model and do not distinguish between them.
   D. Cannot be explained by either model alone.

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

1. 15 pts. The value of the photoelectric work function W for zinc is about $4.24\ eV$. What is the maximum wavelength that light falling on a zinc cathode can have if it is to be able to eject electrons.

2. 20 pts. In a head-on collision, the distance of closest approach (DOCA) of a ^{4}He nucleus with energy $E = 6.47$ MeV $= 1.04 \times 10^{-12}\ J$ to the center of a nucleus is $DOCA = 8.0\ fm = 8.0 \times 10^{-15}\ m$. The nucleus is an atom of what element? Assume the nucleus remains at rest and the interaction is non-relativistic. The ^{4}He nucleus consists of two protons and two neutrons.

3. 25 pts. Consider the double-slit interference of helium atoms shown in the figure. The center-to-center separation between the slits is $d = 8.0\ \mu m$ and the detection screen is a distance $L = 0.64\ m$ from the slits. The helium atoms have a wavelength $\lambda = 0.103\ nm$. The helium nucleus consists of two protons and two neutrons (the electron mass is tiny). (a) What is their speed? (b) What is the expected theoretical distance y_{th} between the adjacent interference maxima on the detection screen?



DO NOT WRITE BELOW THIS LINE.

Physics 205 Equations

$$\vec{F}_{net} = \sum \vec{F}_i = m\vec{a} = \frac{d\vec{p}}{dt} \quad v = \frac{dx}{dt} \quad v = \frac{\Delta x}{\Delta t} \quad x = \frac{1}{2}at^2 + v_0 t + x_0 \quad v = at + v_0 \quad a_g = -g \quad a_c = \frac{v^2}{r}$$

$$\vec{F}_{Earth} = -mg\hat{\jmath} \quad KE = \frac{1}{2}mv^2 \quad KE_0 + PE_0 = KE_1 + PE_1 \quad PE_{Earth} = mgh \quad PE_V = qV$$

$$\vec{p}_i = \vec{p}_f \quad \vec{p} = m\vec{v} \quad \vec{F}_C = k_e \frac{q_1 q_2}{r^2}\hat{r} \quad \vec{E} \equiv \frac{\vec{F}}{q_0} \quad d\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{s} \times \hat{r}}{r^2} = \frac{\mu_0}{4\pi}\frac{qd\vec{v} \times \hat{r}}{r^2} \qquad \vec{F}_B = q\vec{v} \times \vec{B} \qquad |\vec{F}_B| = |qvB\sin\theta|$$

Galilean Transformation SI units	Lorentz Transformation SI units	Lorentz Transformation SR units
$x' = x - vt$	$x' = \gamma(x - vt)$	$x' = \gamma(x - \beta t)$
$y' = y$	$y' = y$	$y' = y$
$z' = z$	$z' = z$	$z' = z$
$t' = t$	$t' = \gamma(t - vx/c^2)$	$t' = \gamma(t - \beta x)$
$v'_x = v_x - v_O$	$v'_x = \frac{v_x - v_O}{1 - v_x v/c^2}$	$v'_x = \frac{v_x - \beta}{1 - v_x \beta}$

Coordinate Time	Proper Time	Spacetime Interval
Time between two events in an inertial frame measured with synchronized clocks	Time between two events measured by the same clock at both events.	Time between two events measured by the same, inertial clock at both events.
$c\Delta t$,Δt	$\Delta\tau_{SI}$, $\Delta\tau_{SR}$	Δs_{SI}, Δs_{SR}
Frame dependent	Frame independent	Frame independent

$$\Delta s_{SI}^2 = c^2\Delta t^2 - \Delta d^2 = {\Delta s'_{SI}}^2 \quad \text{or} \quad \Delta s_{SR}^2 = \Delta t^2 - \Delta d^2 = {\Delta s'_{SR}}^2$$

$$\Delta\tau_{SI} = \int_{t_A}^{t_B} \sqrt{1 - \frac{v^2}{c^2}}\, dt \quad \text{or} \quad \Delta\tau_{SR} = \int_{t_A}^{t_B} \sqrt{1 - \beta^2}\, dt$$

$$\Delta\tau_{SI} = \sqrt{1 - v^2/c^2}\,\Delta t \quad \text{or} \quad \Delta\tau_{SR} = \sqrt{1 - \beta^2}\,\Delta t$$

$$L_{SI} = L_R\sqrt{1 - v^2/c^2} \quad \text{or} \quad L_{SR} = L_R\sqrt{1 - \beta^2}$$

$$v'_x = \frac{v_x - v}{1 - v_x v/c^2} \quad v'_y = \frac{v_y\sqrt{1 - v_x^2/c^2}}{1 - v_x v/c^2} \quad KE = E - mc^2 \quad \text{SI units}$$

$$v'_x = \frac{v_x - \beta}{1 - v_x \beta} \quad v'_y = \frac{v_y\sqrt{1 - \beta^2}}{1 - v_x \beta} \quad KE = E - m \quad \text{SR units}$$

$$\underset{\sim}{p}_i = \underset{\sim}{p}_f \quad \underset{\sim}{p}_1 \cdot \underset{\sim}{p}_2 = \underset{\sim}{p}_3 \cdot \underset{\sim}{p}_4$$

$$\underset{\sim}{p} = m\, d\underset{\sim}{s}/d\tau = [m\frac{dt}{d\tau}, m\frac{dx}{d\tau}, m\frac{dy}{d\tau}, m\frac{dz}{d\tau}] = \frac{m}{\sqrt{1 - |\vec{v}|^2}}[1, \vec{v}] \quad \underset{\sim}{p} \cdot \underset{\sim}{p} = E_r^2 - |\vec{p}|^2 = m^2 \qquad \text{SR units}$$

$$\underset{\sim}{p} = m\, d\underset{\sim}{s}/d\tau = [mc\frac{dt}{d\tau}, m\frac{dx}{d\tau}, m\frac{dy}{d\tau}, m\frac{dz}{d\tau}] = \frac{m}{\sqrt{1 - v^2/c^2}}[c, \vec{v}] \quad \underset{\sim}{p}c \cdot \underset{\sim}{p}c = E_r^2 - |\vec{p}c|^2 = (mc^2)^2 \qquad \text{SI units}$$

$$y = A\sin(kx - \omega t + \phi) \quad k\lambda = \omega T = 2\pi \quad E = E_m \sin(kx - \omega t + \phi) \quad B = B_m \sin(kx - \omega t + \phi) \quad \phi = k\delta$$

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B} \quad E = cB \quad \langle|\vec{S}|\rangle = I = \frac{E^2}{2\mu_0 c} = \frac{\text{energy}}{\text{area} \cdot \text{time}} \quad c = \frac{\lambda}{T} = \lambda f$$

$$\delta = d\sin\theta = m\lambda\,(m = 0, \pm 1, ...) \quad \text{(bright)} \quad \delta = a\sin\theta = m\lambda\,(m = \pm 1, ...) \quad \text{(dark)} \quad \sin\theta \approx \frac{y_m}{L}$$

$$I_{int} = I_m \cos^2\left(\frac{\pi d}{\lambda}\sin\theta\right) \quad I_{diff} = I_m\left[\frac{\sin\left(\frac{\pi a}{\lambda}\sin\theta\right)}{\frac{\pi a}{\lambda}\sin\theta}\right]^2 \quad E = hf \quad KE_{max} = eV_{stop} = hf - W \quad c = \lambda f$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{4E}\right)^2 \frac{1}{\sin^4\left(\frac{\theta_s}{2}\right)} = \frac{\text{area}}{\text{steradian}} \quad d\Omega = r^2 \sin\theta d\theta d\phi \quad ME = \frac{1}{2}mv^2 + PE \quad ME_i = ME_f$$

$$PE = qV \quad PE = \frac{Z_1 Z_2 e^2}{r} = \frac{k_e q_1 q_2}{r} \quad p = \frac{h}{\lambda} \quad KE = \frac{p^2}{2m} \quad KE_i = KE_f \text{ (elastic)} \quad \vec{p}_i = \vec{p}_f \quad \vec{p} = m\vec{v}$$

$$\frac{d}{dx}(f(u)) = \frac{df}{du}\frac{du}{dx} \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int \frac{1}{x}dx = \ln x \quad \vec{A}\cdot\vec{B} = AB\cos\theta \quad |\vec{A}\times\vec{B}| = |AB\sin\theta|$$

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

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

$$\frac{df(x)}{dx} = \lim_{\Delta x \to 0} \frac{f(x+\Delta x) - f(x)}{\Delta x} \qquad \int_a^b f(x)dx = \lim_{\Delta x \to 0} \sum_{n=1}^{N} f(x)\Delta x$$

Physics 205 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	$932\ MeV/c^2$
$1\ u$	$1.67 \times 10^{-27}\ kg$	MeV/c^2	$1.78 \times 10^{-30}\ kg$
g	$9.8\ m/s^2$	Earth's radius	$6.37 \times 10^6\ m$
$1\ nm$	$10^{-9}\ m$	$1\ \mu m$	$10^{-6}\ m$
Gravitation constant	$6.67 \times 10^{-11}\ N-m^2/kg^2$	Electron mass	$0.511\ MeV/c^2$
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)	$1.60 \times 10^{-19}\ C$	$e^2 = \hbar c \alpha$	$197\ MeV - fm/137$
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)	$4.14 \times 10^{-15}\ eVs$
Planck's constant ($\hbar c$)	$197\ MeV - fm$	Planck's constant ($\hbar c$)	$1970\ eV - \text{Å}$
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]