

Physics 111

Exam #3

November 4, 2024

Name _____

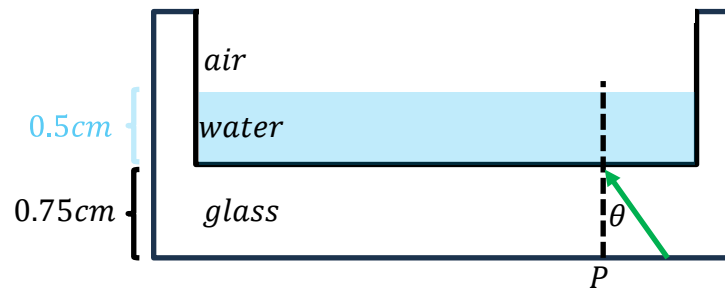
Please read and follow these instructions carefully:

- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization clear.
- You must show all work, including correct vector notation.
- You will not receive full credit for correct answers without adequate explanations.
- You will not receive full credit if incorrect work or explanations are mixed in with correct work. Erase or cross out anything you don't want graded.
- Make explanations complete but brief. Do not write a lot of prose.
- Include diagrams.
- Show what goes into a calculation, not just the final number. For example,
 $|\vec{p}| \approx m|\vec{v}| = (5\text{kg}) \times (2 \frac{\text{m}}{\text{s}}) = 10 \frac{\text{kg} \cdot \text{m}}{\text{s}}$
- Give standard SI units with your results unless specifically asked for a certain unit.
- Unless specifically asked to derive a result, you may start with the formulas given on the formula sheet including equations corresponding to the fundamental concepts.
- Go for partial credit. If you cannot do some portion of a problem, invent a symbol and/or value for the quantity you can't calculate (explain that you are doing this), and use it to do the rest of the problem.
- Each free-response part is worth 6 points.

Problem #1	/24
Problem #2	/24
Problem #3	/24
Total	/72

I affirm that I have carried out my academic endeavors with full academic honesty.

1. The figure below shows a container made from glass ($n_g = 1.5$) with a layer of water ($n_w = 1.33$) on top. Light is incident in the glass at an angle $\theta = \theta_1$ measured with respect to the normal. The bottom of the glass is frosted so that bright spots appear where light from the beam strikes this bottom surface and gets absorbed. You may assume that the reflection from this frosted surface is negligible.



- a. At this angle of incidence, θ_1 , two bright spots appear on the bottom surface of the glass. Let us label the spot that appears closer to point P in the diagram A , and the spot that appears farther from point P in the diagram B . The actual points A and B are not shown in the diagram. Explain the processes involved in the formation of the two spots at locations A and B and explain which spot is brighter, spot A or spot B .

- b. Suppose the glass has a thickness of 0.75cm , while the thickness of the water on top of the glass is 0.5cm . What is the horizontal distance along the bottom surface of the glass between the spots A and B if $\theta_1 = 30^\circ$?

- c. Suppose the angle of incidence in the glass is increased from θ_1 to θ_2 , where $\theta_2 > \theta_1$. In this case, the spots *A* and *B* move along the bottom surface of the glass and *one of the spots becomes brighter*. Explain which way the spots move, and which spot becomes brighter and why?

- d. Suppose that we further increase the angle of incidence of the light from θ_2 to θ_3 , where $\theta_3 > \theta_2$. At this angle θ_3 , the light becomes totally internally reflected in the glass. What is the angle of incidence θ_3 , in the glass so that the light will be totally internally reflected at the glass/water interface?

2. Two lenses are used in an experiment. Lens #1 has a power $P_1 = +7.9D$, while the power of lens #2 is unknown. An object is placed $100mm$ to the left of lens #1 and an image is seen on a screen $258mm$ to the right of lens #2.
- a. What is the type and power of the second (lens #2) if the lenses are separated by $188mm$?
- b. The image on the screen is measured to be $3.5cm$ in length. What was the height of the original object?

- c. Suppose that the experiment was repeated, but this time we replaced the first lens with a lens of power $P_1 = -7.9D$. With everything else the same, would we have to move the screen closer to lens #2, farther from lens #2, or make no change at all to the location of the screen, to see the clear image? Hint: This probably requires a calculation and everything else the same means that the object's location with respect to lens #1 does not change, the focal length of lens #2 does not change, and the distance between the lenses does not change.
- d. Suppose that you look at lens #1 from **part 2a** and notice that the shape of the lens is a circle of radius R . Further, suppose that you were to paint lens #1 in **part 2a** so that only a small circle of radius r , where $r < R$, near the center of the lens allowed light to pass. In this situation, what would happen to the image on the screen if everything else remained the same? Explain your answer fully. Hint: everything else the same means that the object's location with respect to lens #1 does not change, the focal length of lenses #1 and #2 do not change, and the distance between the lenses does not change. We just allow less light to pass through lens #1.

3. Light with a single wavelength $\lambda = 98nm$ is emitted from a source. The light is incident on a piece of platinum metal whose work function is ϕ . The beam makes a circular spot on the metal and electrons ejected from the metal are observed on a collector.
- a. If the electrons were ejected with a speed of $v = 0.005c$, what voltage (V_{stop}) would be needed to stop the electrons from striking the collector and what is the work function ϕ (in eV) of the metal?
- b. If the beam of light made a circular spot on the metal with a radius $r = 1cm$ and the rate at which electrons were incident on the collector was $8.2 \times 10^{20}s^{-1}$, what was the intensity of the incident beam of light? Hint: the efficiency of the emitter is 100%, meaning that for every incident photon, we get an ejected electron.

- c. Suppose the intensity in part b were too large and further that we want to lower the intensity of the incident beam by using two polarizers. Initially unpolarized light from the source passes through the first polarizer with its transmission axis vertical. At what angle would you have to set the second polarizer to reduce the intensity of the emerging beam by 99%?
- d. The light that emerges from the polarizers is again incident on the metal surface. If the beam makes the same spot size on the platinum metal, what can you say about the kinetic energy of the ejected electrons that strike the collector, in this case? Explain your answer.

Physics 111 Formula Sheet

Electrostatics

$$F = k \frac{q_1 q_2}{r^2}$$

$$\vec{F} = q\vec{E}; \quad E_{pc} = k \frac{q}{r^2}; \quad E_{plate} = \frac{q}{\epsilon_0 A}$$

$$E = -\frac{\Delta V}{\Delta x}$$

$$V_{pc} = k \frac{q}{r}$$

$$U_e = k \frac{q_1 q_2}{r} = qV$$

$$W = -q\Delta V = -\Delta U_e = \Delta K$$

Electric Circuits - Capacitors

$$Q = CV; \quad C = \frac{\kappa \epsilon_0 A}{d}$$

$$C_{parallel} = \sum_{i=1}^N C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^N \frac{1}{C_i}$$

$$Q_{charging}(t) = Q_{max} \left(1 - e^{-\frac{t}{\tau}}\right)$$

$$Q_{discharging}(t) = Q_{max} e^{-\frac{t}{\tau}}$$

$$I(t) = I_{max} e^{-\frac{t}{\tau}} = \frac{Q_{max}}{\tau} e^{-\frac{t}{\tau}}$$

$$\tau = RC$$

$$U_C = \frac{1}{2}qV = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$$

Light as a Wave

$$c = f\lambda$$

$$S(t) = \frac{\text{Energy}}{\text{time} \times \text{Area}} = c\epsilon_0 E^2(t) = c \frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \frac{1}{2}c\epsilon_0 E_{max}^2 = c \frac{B_{max}^2}{2\mu_0}$$

$$P = \begin{cases} \frac{S}{c}; & \text{absorbed} \\ \frac{2S}{c}; & \text{reflected} \end{cases}$$

$$S = S_0 \cos^2 \theta$$

$$v = \frac{c}{n}$$

$$\theta_{incident} = \theta_{reflected}$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$P = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$M = \frac{d_i}{d_o}; \quad |M| = \frac{h_i}{h_o}$$

Magnetism

$$\vec{F} = q\vec{v} \times \vec{B} \rightarrow F = qvB \sin \theta$$

$$\vec{F} = I\vec{L} \times \vec{B} \rightarrow F = ILB \sin \theta$$

$$V_{Hall} = wv_d B$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\mathcal{E} = \Delta V = -N \frac{\Delta \phi_B}{\Delta t}$$

$$\phi_B = BA \cos \theta$$

Electric Circuits - Resistors

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = neAv_d$$

$$n = \left(\frac{\rho_m N_A}{m}\right) \times \frac{\text{charge carriers donated}}{\text{atom}}$$

$$V = IR$$

$$R = \frac{\rho L}{A}$$

$$R_{series} = \sum_{i=1}^N R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^N \frac{1}{R_i}$$

$$P = \frac{\Delta E}{\Delta t} = IV = I^2 R = \frac{V^2}{R}$$

Light as a Particle/Relativity

$$E = hf = \frac{hc}{\lambda}$$

$$K_{max} = hf - \phi$$

$$\Delta \lambda = \lambda' - \lambda = \frac{h}{mc} (1 - \cos \phi)$$

$$\frac{1}{E'} = \frac{1}{E} + \frac{(1 - \cos \phi)}{E_{rest}}; \quad E_{rest} = mc^2$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$p = \gamma m v$$

$$E_{total} = E_{rest} + K = \gamma mc^2$$

$$K = (\gamma - 1)mc^2$$

$$E_{total}^2 = p^2 c^2 + m^2 c^4$$

Nuclear Physics

$$N = N_0 e^{-\lambda t}$$

$$m = m_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$

$$A = \lambda N$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Constants

$$g = 9.8 \frac{m}{s^2}$$

$$1e = 1.6 \times 10^{-19} C$$

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$1eV = 1.6 \times 10^{-19} J$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A}$$

$$c = 3 \times 10^8 \frac{m}{s}$$

$$h = 6.63 \times 10^{-34} Js = 4.14 \times 10^{-15} eVs$$

$$N_A = 6.02 \times 10^{23}$$

$$1u = 1.66 \times 10^{-27} kg = 931.5 \frac{MeV}{c^2}$$

$$m_p = 1.67 \times 10^{-27} kg = 937.1 \frac{MeV}{c^2}$$

$$m_n = 1.69 \times 10^{-27} kg = 948.3 \frac{MeV}{c^2}$$

$$m_e = 9.11 \times 10^{-31} kg = 0.511 \frac{MeV}{c^2}$$

Physics 110 Formulas

$$\vec{F} = m\vec{a}; \quad F_G = \frac{GM_1 m_2}{r^2}; \quad F_s = -ky; \quad a_c = \frac{v^2}{r}$$

$$W = -\Delta U_g - \Delta U_s = \Delta K$$

$$U_g = mgy$$

$$U_s = \frac{1}{2}ky^2$$

$$K = \frac{1}{2}mv^2$$

$$\vec{r}_f = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a_r \Delta r$$

Common Metric Units

$$\text{nano (n)} = 10^{-9}$$

$$\text{micro (\mu)} = 10^{-6}$$

$$\text{milli (m)} = 10^{-3}$$

$$\text{centi (c)} = 10^{-2}$$

$$\text{kilo (k)} = 10^3$$

$$\text{mega (M)} = 10^6$$

Geometry/Algebra

$$\text{Circles:} \quad A = \pi r^2 \quad C = 2\pi r = \pi$$

$$\text{Spheres:} \quad A = 4\pi r^2 \quad V = \frac{4}{3}\pi r^3$$

$$\text{Triangles:} \quad A = \frac{1}{2}bh$$

$$\text{Quadratics:} \quad ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.008	Atomic # Symbol Name Weight																2 He Helium 4.0026
3 Li Lithium 6.94	4 Be Beryllium 9.0122																
5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180												
11 Na Sodium 22.990	12 Mg Magnesium 24.305																
13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948												
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89-103	104 Rf Rutherfordium (261)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (277)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (282)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (290)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																	
																	
57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.05	71 Lu Lutetium 174.97			
89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)			

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