

Physics 111

Exam #3

November 3, 2023

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. So 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.

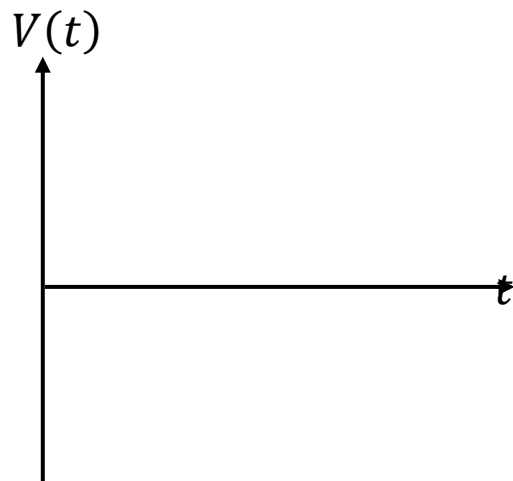
Problem #1	/24
Problem #2	/24
Problem #3	/24
Total	/72

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

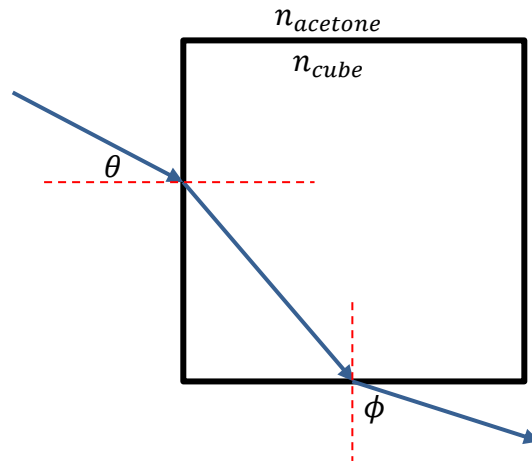
1. Suppose that you have a 251m long piece of copper wire ($\rho_{Cu} = 1.68 \times 10^{-8} \Omega\text{m}$). The copper wire has a 4mm diameter.
 - a. What is the resistance of this piece of copper wire and how many continuous circular coils of wire could you wind from this piece of wire if you wanted each coil to have a 40cm diameter? For the number of coils, round your answer to the nearest whole number.
 - b. Suppose that the circular coils of wire were made into a 40cm diameter belt that could be used to monitor the breathing of a patient in the hospital. The circular set of coils of N turns (found in part a) is slid around a patient's chest. The patient is lying horizontally on a table that is oriented north-south, with the patient's head pointing north and their feet pointing south. In this location, the earth's magnetic field (of magnitude $50\mu\text{T}$) has components that point both north and vertically down into the ground at an angle of 50° (measured with respect to the normal of the coil of wire which points north). The patient inhales and momentarily holds their breath before exhaling. During the inhalation phase, which takes a time of 2s , the diameter of the belt increases to 41cm in diameter. What is the magnitude and direction of the induced current in the coils of wire? To determine the direction assume you are standing at the patient's feet and looking north.

c. Over the inhalation phase, how much energy is dissipated as heat in the coils of wire?

d. The patient continuously inhales and exhales pausing momentarily between each inhalation and exhalation. On the axes below, what would an approximate voltage versus time graph look like for one breathing cycle (inhale – hold – exhale – hold)? To earn full credit, you need to explain the plot and why you drew it as you did. Make sure to note which parts of the plot are the inhalation, holding, exhalation and holding. This plot is what the breathing monitor would show.



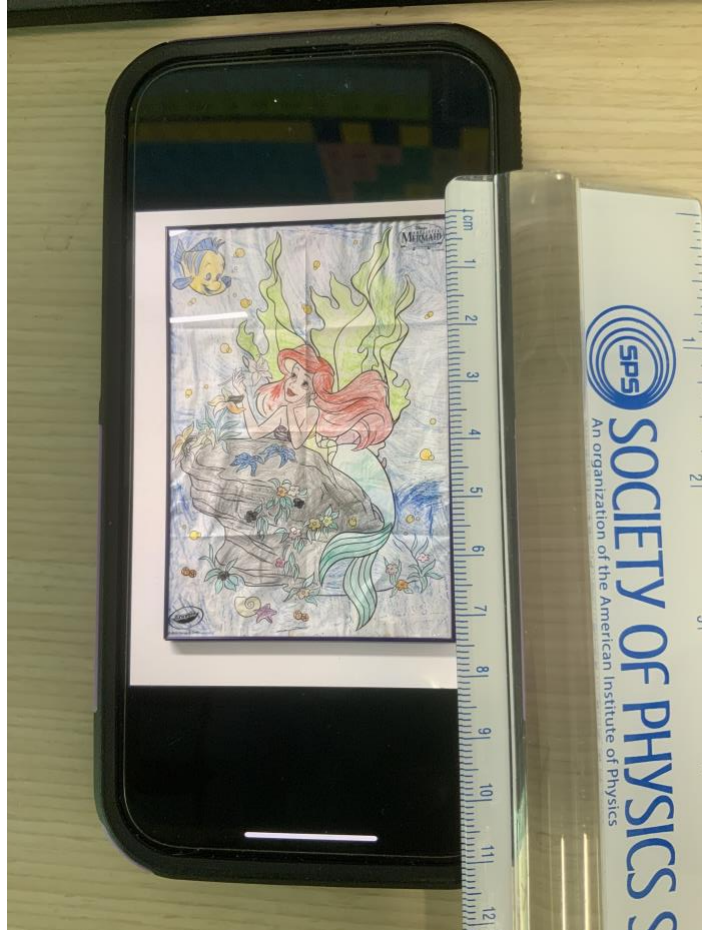
2. A small cube of material has sides of length $L = 20\text{cm}$. The cube of material is submerged in acetone where the speed of light in acetone is $v_{\text{acetone}} = 0.73c$, where c is the speed of light.



- a. The light is incident on the left face of the cube at $\theta = 65^\circ$ and exits the from the lower face at $\phi = 75^\circ$. What are the indices of refraction of acetone and of the cube material? Hint: $\sin(90 - \delta) = \cos \delta$.

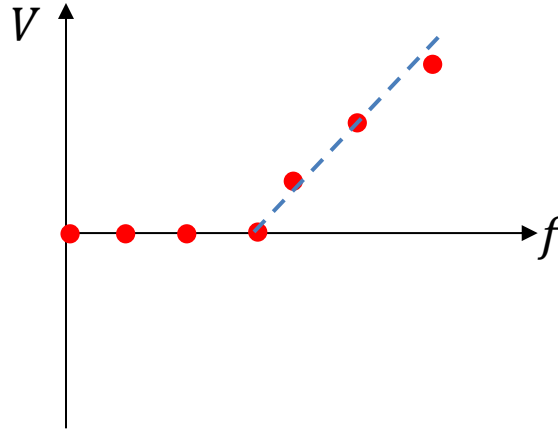
- b. Suppose that the light that was incident on the cube submerged in acetone was blue with a wavelength λ_B . Of the following scenarios below, explain fully which can or cannot happen. Simply saying it can or cannot, will earn no credit, even if the choice was correct.
1. For the light that was incident on the cube submerged in acetone, there is a reflected beam from the cube but no transmitted beam of light into the cube.
 2. For the light that was incident on the cube submerged in acetone, there is a transmitted beam of light into the cube but no reflected beam of light from the cube.
 3. If the blue light were to be transmitted into the cube from the acetone its speed would increase.
 4. If the blue light were to be transmitted into the cube from the acetone, its frequency would increase.

- c. The newest iPhone (the iPhone15) can take amazing photographs. Suppose that you are standing at a distance of $0.9m$ from a priceless piece of art that is $99cm$ tall and you take a picture of the art with your iPhone15. The photograph that you took is shown below. What is the focal length of the camera on the iPhone15 and what explain what type of lens is in the phone?



- d. We've been using an equation in class that relates the object and image distances to the focal length of the lens. This called the thin lens equation and was first written algebraically by Sir Edmond Halley (of the comet fame) around 1693. Not to be outdone, Sir Isaac Newton also wrote a version of the thin lens equation (around 1694) that related the distance from the focal point of the lens to the object location (x), the distance from the focal point of the lens to the image location (x') to the focal length of the lens f by $xx' = f^2$. Using these definitions, show that the Newtonian form of the thin lens equation can be given by $xx' = f^2$.

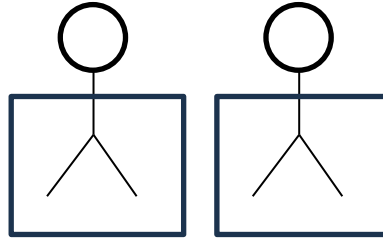
3. Monochromatic (one color) light of frequency f shines on a metal. The frequency of the light can be varied, and the maximum kinetic energy of the electrons ejected from the metal surface is measured by recording the stopping voltage of a circuit needed to stop the ejected electrons from striking the collector. The data collected were plotted below and a fit to the data gives an equation of the form $f = AV + B$, where A and B are experimental constants.



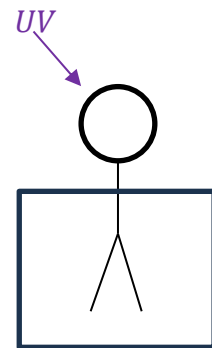
- a. Explain the features plot above making sure to identify all the major parts. In addition, what is the physical interpretation of the coefficients A and B and what do they correspond to in the figure?

- b. Suppose x-rays of frequency $f = 3 \times 10^{19} \text{s}^{-1}$ were shown onto a piece of samarium metal ($\phi = 2.73 \text{eV}$). What voltage would you need to set to stop the ejected electrons from striking the collector and what was the speed of the ejected electrons expressed as a fraction of the speed of light?

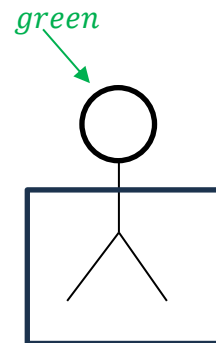
- c. X-rays are not an ideal light source to conduct a photoelectric effect experiment since they pose an exposure and radiation hazard to the users/experimenters. Instead, suppose that you have some other light sources available and that one of those was an ultraviolet light source with frequency f_{UV} while another was a green light source with frequency f_g , where $f_g < f_{UV}$. Consider two individual identical negatively charged electroscopes shown below, where the leaves are initially separated by the same amount due to the electrostatic repulsion between the negative charges on the leaves. Now, consider the situations described below and provide an explanation for the observations seen.



1. The ultraviolet light is shone onto one electroscope and the leaves were observed *to move closer together*. Using as many physics ideas as possible, explain how this could happen.



2. The green light is shone onto the other electroscope and the leaves are observed *not to move*. Using as many physics ideas as possible, explain how this could happen.



- d. Suppose that after the experiment, you notice that the intensity of the ultraviolet light source was greater than the intensity of the green light source. Wondering if this difference matters, you increase the intensity of the green light source until it matches that of the ultraviolet light source and redo the experiment. Fully explain what happens to the electroscope and why when the higher intensity green light is shown onto the system.

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

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

$$I = neAv_d; \quad n = \frac{\rho N_A}{m}$$

$$V = IR$$

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

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

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

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

Light as a Particle/Relativity

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

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

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

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

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

$$p = \gamma mv$$

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

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

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

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	2 He Helium 4.0026																
3 Li Lithium 6.94	4 Be Beryllium 9.0122																
11 Na Sodium 22.990	12 Mg Magnesium 24.305																
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 Caesium 132.91	56 Ba Barium 137.33	57-71 Lanthanoids	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 Actinoids	104 Db Dubnium (267)	105 Nh Nihonium (286)	106 Ds Darmstadtium (281)	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)			