Physics 111

Exam #3

March 6, 2026

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, $|\vec{p}| \approx m|\vec{v}| = (5kg)\times(2\frac{m}{s}) = 10\frac{kg\cdot m}{s}$
- 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

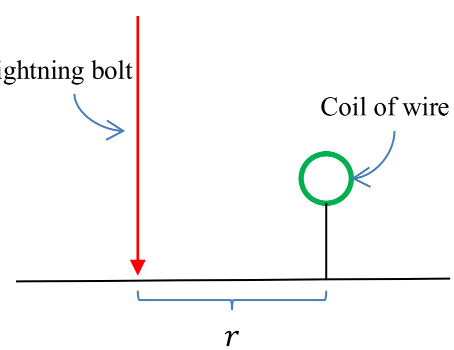
I affirm that I have carried out my academic endeavors with full academic honesty.

____

1. A $N = 2000$ turn coil of copper wire is used in a Faraday's law experiment to study lightning. The copper wire is wound into a circle of radius $2cm$. The copper wire has cross-sectional diameter of $0.5mm$ when viewed edge on, which corresponds to a cross-sectional area $7.85 \times 10^{-7}m^2$.

    a. What is the resistance R of the coil of copper wire? Hint: some useful data on copper: $\rho = 1.68 \times 10^{-8}\Omega \cdot m$, $\rho_m = 8960\frac{kg}{m^3}$, and $M = 63.6\frac{g}{mol}$.

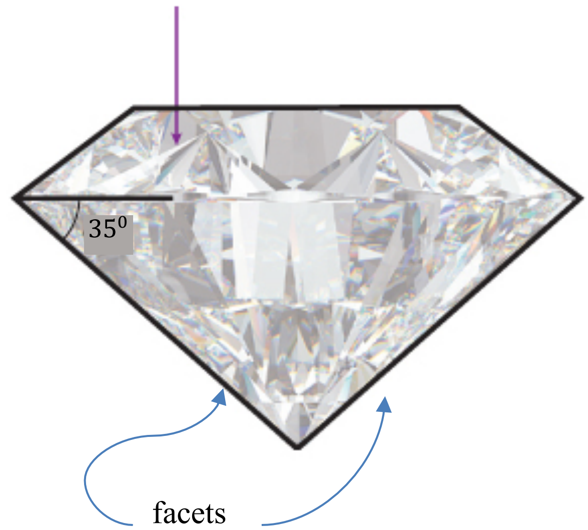
    b. The coil of copper wire is taken out into the field and set up as shown below, where we wait for lightning to strike somewhere. A bolt of lightning strikes a distance $r = 200m$ from the coil of wire and the current in the lightning bolt varies from $0A$ when the bolt starts to form to a maximum current $I_{max} = 3 \times 10^6 A$ when the bolt is fully established. This current varies from $0A$ to I_{max} over a time $\Delta t = 1\mu s$ and can be modeled as a long straight wire. What is the magnitude and direction of the current induced in the $N = 2000$ turn coil of copper wire? To earn full credit, be sure to explain how you arrived at the direction of the induced current.



c. How much energy is dissipated as heat across the coil of copper wire as the current builds from $0A$ to I_{max}?

d. The energy from part c gets dissipated as heat in the wire. Suppose that the melting temperature of copper is $T_{melt,Cu} = 1085°\text{C}$ and the ambient temperature where the coil is in the field is $T_{outside\ air} = 37°\text{C}$, will the coil of copper wire melt? Hint: The heat Q that needs to be dissipated raises the temperature of the system by an amount ΔT, by $Q = mc\Delta T$, where m is the mass of the copper wire and $c = 385\frac{J}{kg\cdot°\text{C}}$ is the specific heat. Be sure to explain your answer to earn full credit.

2. Gemstones are cut in such a way as to maximize the gemstones sparkle. The sparkle is generated by light reflecting off of the facets (or faces) of the gemstones and two such facets are in the diamond gemstone shown below.



   a. Diamond has an index of refraction $n_d = 2.4$ and the diamond gemstone here is surrounded on all sides air. What is the critical angle for total internal reflection from a diamond/air interface and is the light totally internally reflected from the left and right facets? To answer whether light is internally reflected you will need to determine the angles of incidence of the light on the left and right facets and explain why or why not the light is internally reflected.

b. Suppose that you had a diamond lens ($f = 10cm$) that you were using for an experiment. A $1.0cm$ tall object is placed in front of the lens and the image is formed on a screed a distance $D = 100cm$ from the object. At what location(s) could the lens be placed so that you could see a sharp image of the object on the screen? You must show all of the work and steps involved to earn full credit. Using solvers on your calculator to solve the problem will earn you some but not all of the credit.

c. Suppose that you now use two diamond lenses for an experiment. The first diamond lens as a power $P_1 = +13.3D$ and is placed a distance $D = 500mm$ from the second diamond lens of unknown power, P_2. An object is placed $50mm$ to the left of the first lens and an image of the object is seen $400mm$ to the right of the second lens. What is the power and type of the second lens used in the experiment. Be sure to justify your answer for the type.

d. If the image seen on a screen is $40cm$ tall, what was the size of the original object?

3. Ultraviolet light photons are directed at a platinum surface with work function $\phi = 5.6eV$ at a rate $3 \times 10^{15} s^{-1}$. Electrons are ejected from the platinum surface in a narrow beam with a 95% efficiency and are stopped at the collector by applying a potential difference of $10.2V$ across the system.

   a. What was the speed of the ejected electrons from the platinum surface? Do not assume that the ejected electron is non-relativistic and express your answer as a fraction of the speed of light.

   b. What was the wavelength of the light (in nm) used and what was the intensity of the photons on the platinum surface if the ultraviolet light beam makes a circular spot with a $0.5cm$ diameter?

c. What are the maximum values of the electric and magnetic fields in the ultraviolet beam of light incident on the platinum surface?

d. Suppose that the beam of light was instead incident on a piece of platinum foil suspended along one edge. The beam makes a circular spot in diameter on the platinum foil. If the density of platinum is $\rho_{Pt} = 21450\frac{kg}{m^3}$ and the dimensions of the platinum foil are $L \times W \times T = 10cm \times 10cm \times 1\mu m$, what is the magnitude of the acceleration of the platinum foil if the beam of light were completely reflected?

Physics 111 Formula Sheet

Electrostatics

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

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

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

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

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

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

Magnetism

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

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

$V_{Hall} = wv_d B$

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

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

$\phi_B = BA\cos\theta$

Electric Circuits - Capacitors

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

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

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

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

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

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

$\tau = RC$

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

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 Wave

$c = f\lambda$

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

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

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

$S = S_0\cos^2\theta$

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

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

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

$P = \frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$

$M = \frac{d_i}{d_0}; \quad |M| = \frac{h_i}{h_0}$

Light as a Particle/Relativity

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

$K_{max} = hf - \phi$

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

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

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

$p = \gamma mv$

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

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

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

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

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

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

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

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

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

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

Geometry/Algebra

Circles:	$A = \pi r^2$	$C = 2\pi r = \pi$
Spheres:	$A = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$
Triangles:	$A = \frac{1}{2}bh$	
Quadratics:	$ax^2 + bx + c = 0 \rightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$