

Physics 111

Exam #2

February 13, 2026

Name _____

Please read and follow these instructions carefully:

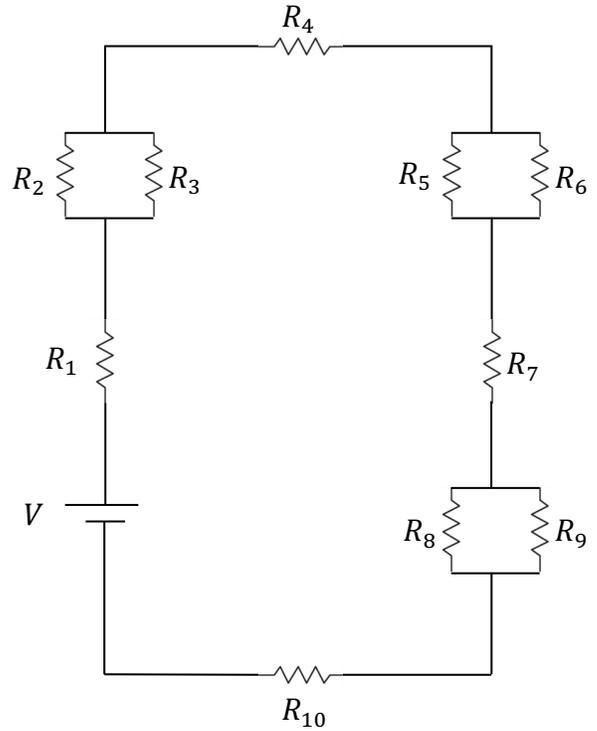
- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization clear.
- You must show all work, including correct vector notation.
- You will not receive full credit for correct answers without adequate explanations.
- You will not receive full credit 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,
 $|\vec{p}| \approx m|\vec{v}| = (5\text{kg}) \times (2\frac{\text{m}}{\text{s}}) = 10\frac{\text{kg}\cdot\text{m}}{\text{s}}$
- 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. Consider the circuit of resistors, each with resistance R , connected to a $100V$ battery shown on the right. All of the resistors in the circuit are constructed out of gold with a diameter $6\mu m$ and length $L = 1.3m$.

- a. What is the resistance R of a resistor?
 Hint: some useful data on gold: $\rho = 2.2 \times 10^{-8} \Omega \cdot m$, $\rho_m = 19300 \frac{kg}{m^3}$, and $M = 197 \frac{g}{mol}$.



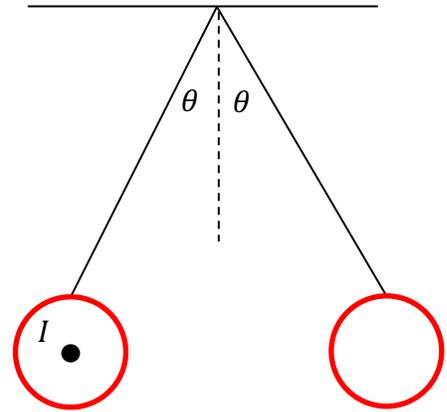
- b. What is the current produced by the battery?

c. What is the voltage (V_{R_6}) across resistor R_6 , the current (I_{R_6}) through resistor R_6 , and the energy dissipated across resistor R_6 if the circuit is powered for $1hr$?

d. What is the drift velocity of the charge carriers through resistor R_6 ? Assume that each gold atom donates 1 charge carrier to the current.

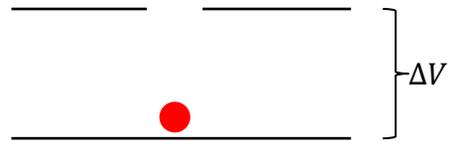
2. Two very long straight platinum wires are suspended from the ceiling using insulating strings of length $l = 50\text{cm}$ as shown on the right. Both wires have diameters 2mm , currents I flowing and the direction of the current in the left wire is shown.

- a. Due to the interactions of the currents, each wire makes an angle $\theta = 12^\circ$ measured with respect to the vertical when in equilibrium. What is the magnitude and direction of the current (be sure to explain how you got the direction) in the right wire? Hint: some useful data on platinum: $\rho = 1.1 \times 10^{-7}\Omega \cdot \text{m}$, $\rho_m = 21090\frac{\text{kg}}{\text{m}^3}$, and $M = 195\frac{\text{g}}{\text{mol}}$.

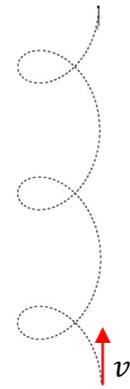


b. What is the net magnetic field at the midpoint between the two wires?

c. An electron is accelerated from rest using the particle accelerator below, where the voltage across the plates $\Delta V = 1500V$. The electron is fired *into the page* at the midpoint between the two wires in part a. What is the magnitude and direction of the initial force on the electron? Be sure to explain your choice for the direction of the electron's motion and how you arrived at that choice.

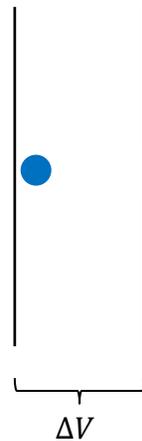


- d. As the electron moves into the page it interacts with the magnetic field everywhere in space created by the currents in the two wires. When viewed from above, the resulting motion of the electron as it interacts with the net magnetic field is shown on the right. Explain how this teardrop shaped motion is obtained.

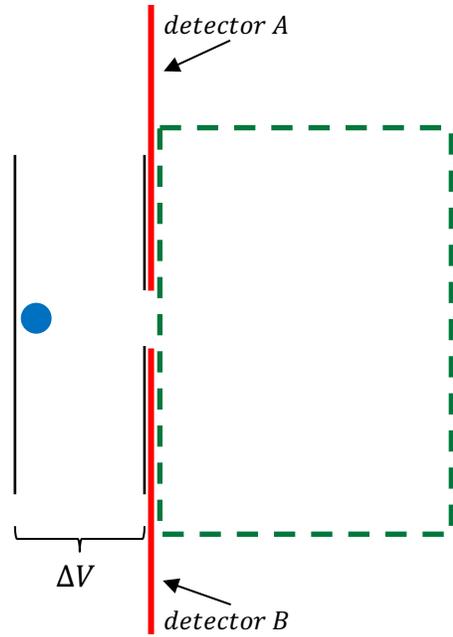


3. Technetium is primarily a synthetic (human made) element being found in very trace amounts on earth and throughout the universe. Technetium has several isotopes, with technetium-99m being the most useful. Technetium-99m is a radioactive isotope of technetium that is used in medical procedures to image many things, such as blood flow in the heart (myocardial perfusion imaging), bone cancers (osteosarcomas), and the kidneys (renal scintigraphy). However, when technetium-99m is being made, other isotopes of technetium are also produced. Suppose you have two isotopes of technetium produced, ${}^{99}_{43}\text{Tc}$ and ${}^{97}_{43}\text{Tc}$ and that you need to separate the technetium-99m from the technetium-97. To do this we use a mass spectrometer. Singly ionized atoms are sent through the mass spectrometer and are separated in space due to their interaction with an externally applied magnetic field.

- a. To get the ions into the mass spectrometer, we ionize the sample and accelerate the ions using a potential difference as shown on the right. Suppose that we accelerate singly charged ions (with charge $+1e$) through a potential difference of $\Delta V = 5000\text{V}$. What are the speeds of ${}^{99}_{43}\text{Tc}^+$ and ${}^{97}_{43}\text{Tc}^+$ ions? Hint: $1u = 1.66 \times 10^{-27}\text{kg}$. Do not round your answers. Keep all the decimal places.



- b. When the ions exit the accelerator in part a, they encounter a region of space (the green box) with only a magnetic field present. The net magnetic field in this region of space can be varied. Assume here that the magnetic field points out of the page perpendicular to the velocity of the ions and has a magnitude $B = 2T$. Which detector, A or B will the technetium ions strike (be sure to explain your choice and why you chose this detector) and what is the ratio of the orbital radii of ${}^{99}_{43}\text{Tc}^+$ to ${}^{97}_{43}\text{Tc}^+$? Again, don't round. Keep at least 4 decimal places in your answer.



- c. Suppose someone misaligns the magnetic field in the green box in such a way that the magnetic field no longer points out of the page, but is rotated toward the right (in the direction of the velocity of the ions) by an angle $\phi = 15^\circ$. What are the orbital radius and pitch of a ${}_{43}^{99}\text{Tc}^+$ ion?
- d. From the time a ${}_{43}^{99}\text{Tc}^+$ ion leaves the accelerator until it strikes either detector *A* or *B*, how long is it in flight?

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

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

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

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

$$A = \lambda N$$

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

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

$$\vec{F} = m\vec{a}; \quad F_G = \frac{GM_1m_2}{r^2}; \quad F_s = -ky; \quad a_c = \frac{v^2}{r}$$

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

$$U_g = mgy$$

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

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

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

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

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

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											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 28.085	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 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 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.																																																												
<table border="1"> <thead> <tr> <th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th> </tr> </thead> <tbody> <tr> <td>57 La Lanthanum 138.91</td> <td>58 Ce Cerium 140.12</td> <td>59 Pr Praseodymium 140.91</td> <td>60 Nd Neodymium 144.24</td> <td>61 Pm Promethium (145)</td> <td>62 Sm Samarium 150.36</td> <td>63 Eu Europium 151.96</td> <td>64 Gd Gadolinium 157.25</td> <td>65 Tb Terbium 158.93</td> <td>66 Dy Dysprosium 162.50</td> <td>67 Ho Holmium 164.93</td> <td>68 Er Erbium 167.26</td> <td>69 Tm Thulium 168.93</td> <td>70 Yb Ytterbium 173.05</td> <td>71 Lu Lutetium 174.97</td> </tr> <tr> <td>89 Ac Actinium (227)</td> <td>90 Th Thorium 232.04</td> <td>91 Pa Protactinium 231.04</td> <td>92 U Uranium 238.03</td> <td>93 Np Neptunium (237)</td> <td>94 Pu Plutonium (244)</td> <td>95 Am Americium (243)</td> <td>96 Cm Curium (247)</td> <td>97 Bk Berkelium (247)</td> <td>98 Cf Californium (251)</td> <td>99 Es Einsteinium (252)</td> <td>100 Fm Fermium (257)</td> <td>101 Md Mendelevium (258)</td> <td>102 No Nobelium (259)</td> <td>103 Lr Lawrencium (260)</td> </tr> </tbody> </table>																		6	7	8	9	10	11	12	13	14	15	16	17	18	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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