

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

\_\_\_\_\_

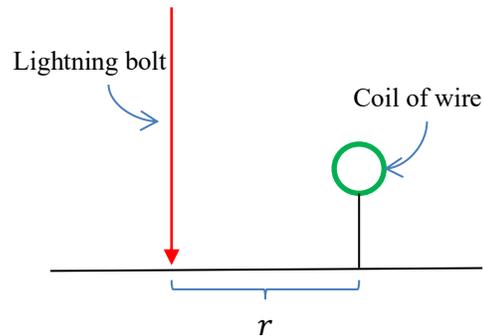
1. A  $N = 2000$  turn coil of copper wire is used in a Faraday's law experiment to study lightning. The copper wire is wound into a circle of radius  $2\text{cm}$ . The copper wire has cross-sectional diameter of  $0.5\text{mm}$  when viewed edge on, which corresponds to a cross-sectional area  $7.85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

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

$$R = \frac{\rho L}{A} = \frac{\rho N 2\pi R}{A} = \frac{1.68 \times 10^{-8}\Omega \cdot \text{m} \times 2000 \times 2\pi \times 0.02\text{m}}{7.85 \times 10^{-7}\text{m}^2} = 5.4\Omega$$

- 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  $r = 200\text{m}$  from the coil of wire and the current in the lightning bolt varies from  $0\text{A}$  when the bolt starts to form to a maximum current  $I_{max} = 3 \times 10^6\text{A}$  when the bolt is fully established. This current varies from  $0\text{A}$  to  $I_{max}$  over a time  $\Delta t = 1\mu\text{s}$  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.

As the lightning bolt builds up, the magnetic field points out of the page by the right-hand rule. To undo the increase in magnetic flux through the loop, the loop will generate a magnetic field pointing into the page. To generate this field, we need a clockwise current to flow.



$$I = \frac{\epsilon}{R} = \frac{NA \cos \theta}{R} \left| \frac{\Delta B}{\Delta t} \right| = \frac{N\pi r_{coil}^2 \cos \theta}{R\Delta t} \left| \frac{\mu_0 I}{2\pi r} \right|$$

$$I = \frac{2000 \times \pi(0.02\text{m})^2 \cos 0}{5.4\Omega \cdot 1 \times 10^{-6}\text{s}} \left| \frac{4\pi \times 10^{-7}\frac{\text{Tm}}{\text{A}} \times 3 \times 10^6\text{A}}{2\pi \times 200\text{m}} \right| = 1396.3\text{A}$$

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

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

$$\Delta E = (1396.3A)^2 \times 5.4\Omega \times 1 \times 10^{-6}s = 10.5J$$

- d. The energy from part c gets dissipated as heat in the wire. Suppose that the melting temperature of copper is  $T_{melt,Cu} = 1085^\circ\text{C}$  and the ambient temperature where the coil is in the field is  $T_{outside\ air} = 37^\circ\text{C}$ , 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  $\Delta T$ , by  $Q = mc\Delta T$ , where  $m$  is the mass of the copper wire and  $c = 385\frac{J}{kg^\circ\text{C}}$  is the specific heat. Be sure to explain your answer to earn full credit.

$$\rho = \frac{M}{V} \rightarrow m = \rho V = \rho N 2\pi R_{coil} A$$

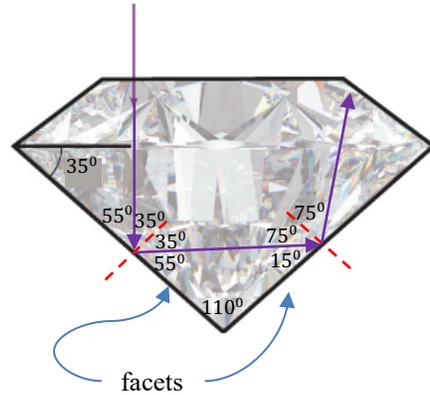
$$m = 8960\frac{kg}{m^3} \times 2000 \times 2\pi \times 0.02m \times 7.85 \times 10^{-7}m^2 = 1.77kg$$

$$Q = \Delta E = mc\Delta T \rightarrow \Delta T = \frac{\Delta E}{mc} = \frac{10.5J}{1.77kg \times 385\frac{J}{kg^\circ\text{C}}} = 1.5 \times 10^{-2}^\circ\text{C}$$

This change in temperature is milli-degrees Celsius. That will barely raise the temperature above the ambient temperature, let alone get the wire hot enough to melt. There may be a large current but it is transient and only lasts for  $1\mu s$ .

2. Gemstones are cut in such a way as to maximize the light generated by light reflecting off of the facets (or such facets are in the diamond gemstone shown below)

- a. Diamond has an index of refraction  $n_d = 2.4$  and is surrounded on all sides by air. What is the critical angle from a diamond/air interface and is the light totally internally reflected? To answer whether light is internally reflected, determine the angles of incidence of the light on the facets and why or why not the light is internally reflected.



The critical angle:

$$n_d \sin \theta_c = n_{air} \sin 90^\circ \rightarrow \theta_c = \sin^{-1} \left( \frac{n_{air}}{n_d} \right) = \sin^{-1} \left( \frac{1.0}{2.4} \right) = 24.6^\circ$$

If the light strikes a facet at an angle greater than the critical angle the light will be internally reflected.

Using the geometry the light strikes the left facet at an angle  $55^\circ$  measured with respect to the surface. This makes the angle with respect to the normal  $90^\circ - 55^\circ = 35^\circ$ . Since this is greater than the critical angle, the light will be internally reflected from the left facet.

The light reflects off of the left facet at  $35^\circ$  by the law of reflection. This makes the angle with respect to the surface  $90^\circ - 35^\circ = 55^\circ$ . The sum of the angles in the lower triangle must add to  $180^\circ$ . The lower vertex angle is determined from  $180^\circ - 2(35^\circ) = 110^\circ$  from the large triangle in the diamond. This makes the light strike the right facet at  $180^\circ - 55^\circ - 110^\circ = 15^\circ$  measured with respect to the surface. This makes the light strike the right facet at an angle  $90^\circ - 15^\circ = 75^\circ$  measured with respect to the normal. Since this is greater than the critical angle, the light will be internally reflected from the left facet.

In fact, most of the light that is incident through the upper surface of the diamond will be internally reflected back toward the observer who would see the gemstone sparkle.

- b. Suppose that you had a diamond lens ( $f = 10\text{cm}$ ) that you were using for an experiment. A  $1.0\text{cm}$  tall object is placed in front of the lens and the image is formed on a screen a distance  $D = 100\text{cm}$  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.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightarrow \frac{1}{d_o} + \frac{1}{D - d_o} = \frac{1}{f} \rightarrow d_o^2 - Dd_o + Df = 0$$

$$d_o = \frac{D \pm \sqrt{D^2 - 4Df}}{2}$$

$$d_{o1} = \frac{D + \sqrt{D^2 - 4Df}}{2} = \frac{100\text{cm} + \sqrt{(100\text{cm})^2 - 4 \times 100\text{cm} \times 10\text{cm}}}{2} = 88.7\text{cm}$$

$$d_{o2} = \frac{D - \sqrt{D^2 - 4Df}}{2} = \frac{100\text{cm} - \sqrt{(100\text{cm})^2 - 4 \times 100\text{cm} \times 10\text{cm}}}{2} = 11.3\text{cm}$$

- c. Suppose that you now use two diamond lenses for an experiment. The first diamond lens has 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.

For lens 1:

$$\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{f_1} = P_1 \rightarrow d_{i1} = \left(P_1 - \frac{1}{d_{o1}}\right)^{-1} = \left(13.3D - \frac{1}{0.050m}\right)^{-1} = -0.149m$$

The image of the first lens becomes the object for the second lens. Since the image distance is negative for lens 1, we have a virtual image and the object distance is this image distance plus the separation between the lenses.

For lens 2:

$$\frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{f_2} = P_2 \rightarrow P_2 = \frac{1}{0.149m + 0.500m} + \frac{1}{0.400m} = +4.04D$$

Since the power of the lens is positive the second lens must be a converging lens.

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

$$M_T = M_1 M_2 \rightarrow M_{total} = M_1 M_2 = \frac{h_{if}}{h_o} \rightarrow h_o = \frac{h_{if}}{M_1 M_2} = \frac{h_{if}}{\left(\frac{d_{i1}}{d_{o1}}\right)\left(\frac{d_{i2}}{d_{o2}}\right)}$$

$$h_o = \frac{h_{if}}{\left(\frac{d_{i1}}{d_{o1}}\right)\left(\frac{d_{i2}}{d_{o2}}\right)} = \frac{40cm}{\left(\frac{149mm}{50mm}\right)\left(\frac{400mm}{649mm}\right)} = 21.8cm$$

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.

$$K_e = eV_{stop} = (\gamma - 1)mc^2 \rightarrow \gamma = \frac{eV_{stop}}{mc^2} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \rightarrow v = \sqrt{1 - \frac{1}{\gamma^2}} c$$

$$v = \sqrt{1 - \frac{1}{(1.000019961)^2}} c = 0.0063c$$

Where,

$$\gamma = \frac{10.2eV}{(5.11 \times 10^5 \frac{eV}{c^2})c^2} + 1 = 1.000019961$$

- 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?

$$K_e = \frac{hc}{\lambda} - \phi \rightarrow \lambda = \frac{hc}{K_e + \phi}$$

$$\lambda = \frac{6.63 \times 10^{-34} J \cdot s \times 3 \times 10^8 \frac{m}{s} \times \frac{1eV}{1.6 \times 10^{-19} J}}{10.2eV + 5.6eV} = 7.9 \times 10^{-8} m = 79nm$$

$$S = \frac{energy}{time \cdot area} = \frac{N(K_e + \phi)}{\pi r^2}$$

$$S = \frac{3 \times 10^{15} s^{-1} \times (10.2eV + 5.6eV) \times \frac{1.6 \times 10^{-19} J}{1eV}}{\pi(0.25 \times 10^{-2} m)^2} = 386.3 \frac{W}{m^2}$$

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

$$S = \frac{1}{2}c\epsilon_0 E_{max}^2 \rightarrow E_{max} = \sqrt{\frac{2S}{c\epsilon_0}} = \sqrt{\frac{2 \times 386.3 \frac{W}{m^2}}{3 \times 10^8 \frac{m}{s} \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2}}} = 539.4 \frac{N}{C}$$

And,

$$E_{max} = cB_{max} \rightarrow B_{max} = \frac{E_{max}}{c} = \frac{539.4 \frac{N}{C}}{3 \times 10^8 \frac{m}{s}} = 1.8 \times 10^{-6} T$$

Or calculating the maximum value of the magnetic field first,

$$S = \frac{c}{2\mu_0} B_{max}^2 \rightarrow B_{max} = \sqrt{\frac{2\mu_0 S}{c}} = \sqrt{\frac{2 \times 4\pi \times 10^{-7} \frac{T \cdot m}{A} \times 386.3 \frac{W}{m^2}}{3 \times 10^8 \frac{m}{s}}}$$

$$B_{max} = 1.8 \times 10^{-6} T$$

And,

$$E_{max} = cB_{max} = 3 \times 10^8 \frac{m}{s} \times 1.8 \times 10^{-6} T = 539.4 \frac{N}{C}$$

- 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?

$$P = \frac{2S}{c} = \frac{F}{A} = \frac{ma}{A} \rightarrow a = \frac{2SA}{mc} = \frac{2 \times 386.3 \frac{W}{m^2} \times (0.1m)^2}{2.14 \times 10^{-5} kg \times 3 \times 10^8 \frac{m}{s}} = 1.2 \times 10^{-3} \frac{m}{s^2}$$

Where the mass is determined from the density and the volume:

$$\rho = \frac{m}{V} \rightarrow m = \rho V = 21450 \frac{kg}{m^3} \times (0.1m \times 0.1m \times 1 \times 10^{-6} m) = 2.14 \times 10^{-5} kg$$

## 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"> <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>																		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)
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)																																	