1) The drawing at the right shows the energy levels of a hypothetical atom. List the wavelengths (in nm) of all the lines that will be seen in the line spectrum of this atom.

\[ E = hf = \frac{hc}{\lambda} \quad \lambda = \frac{hc}{E} \]

There are 3 possible lines, with energies 1.9 eV, 3.5 eV and 5.4 eV.

\[ \lambda_1 = \frac{(6.626 \times 10^{-34} \text{ J s})(3 \times 10^8 \text{ m/s})}{(1.9 \text{ eV})(1.602 \times 10^{-19} \text{ J/eV})} = 6.53 \times 10^{-7} \text{ m} = 653 \text{ nm} \]

\[ \lambda_2 = \frac{(\text{''} \text{''} \text{''}) (\text{''} \text{''})}{(3.5 \text{ eV}) (\text{''} \text{''})} = 354 \text{ nm} \]

\[ \lambda_3 = \frac{(\text{''} \text{''} \text{''}) (\text{''} \text{''})}{(5.4 \text{ eV}) (\text{''} \text{''})} = 230 \text{ nm} \]

653 nm, 354 nm, 230 nm

2) Ne has 10 electrons. List the quantum numbers \( n, l, m_l, m_s \) of each of the 10 electrons for Ne atoms in the ground state.

<table>
<thead>
<tr>
<th>( n )</th>
<th>( l )</th>
<th>( m_l )</th>
<th>( m_s )</th>
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<tr>
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</table>
3) The nucleus $^{110}\text{Ag}$ has a half-life of 2.4 minutes. 

$$2.4\,\text{min} = 144\,\text{s}$$

(a) Find the activity (decays per second) of a source consisting of $3 \times 10^{10}$ atoms of $^{110}\text{Ag}$. 

$$\lambda = \frac{693}{144} = 4.81 \times 10^{-3}/s$$

$$A = \lambda N = (4.81 \times 10^{-3}/s)(3 \times 10^{10}) = 1.44 \times 10^{8}/s$$

(b) What will the activity of the source be after 6 minutes have gone by? 

$$6\,\text{min} = 360\,\text{s}$$

$$N = N_0 e^{-\lambda t} = (3 \times 10^{10}) e^{-(4.81 \times 10^{-3})(360)} = 5.3 \times 10^{9}$$

$$A = \lambda N = 2.55 \times 10^{7}/s$$

4) Find the deBroglie wavelength of an electron with a kinetic energy of 20 eV. The electron mass is $9.11 \times 10^{-31}\,\text{kg}$. 

$$KE = \frac{1}{2}mv^2 = \frac{(m\gamma)^2}{2m} = \frac{p^2}{2m}$$

$$p = \left[2m \cdot KE\right]^{\frac{1}{2}} = \left[2 \left(9.11 \times 10^{-31}\,\text{kg}\right)(20\,\text{eV})(1.602 \times 10^{-19}\,\text{J/ev})\right]^{\frac{1}{2}}$$

$$p = 2.42 \times 10^{-24}\,\text{kg} \cdot \text{m/s}$$

$$\lambda = \frac{\hbar}{p} = \frac{6.626 \times 10^{-34}\,\text{J} \cdot \text{s}}{2.42 \times 10^{-24}\,\text{kg} \cdot \text{m/s}} = 2.74 \times 10^{-10}\,\text{m}$$

$$0.274\,\text{nm}$$
5) An unstable particle, $x$, at rest in the lab decays spontaneously into an electron and a positron (both of which have rest mass $9.11 \times 10^{-31}$ kg). In the decay the electron and the positron are emitted in opposite directions, each with speed 0.9c.

(a) What was the mass of particle $x$?

Total energy is conserved

\[ E_i = E_f \]

\[ E_i = m_x c^2 \quad E_f = E_{e^+} + E_{e^-} \]

\[ E_{e^-} = E_0 + KE = m_0 c^2 + (\gamma - 1)m_0 c^2 = \gamma m_0 c^2 \]

\[ \gamma = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = \left(1 - \frac{1}{0.81}\right)^{-\frac{1}{2}} = 2.29 \]

\[ E_{e^-} = E_{e^+} = (2.29) m_0 c^2 \]

So

\[ m_x c^2 = 2 \times (2.29) m_0 c^2 \]

\[ m_x = (2.29) \times (2) \times (9.11 \times 10^{-31} \text{ kg}) \]

\[ m_x = 4.17 \times 10^{-30} \text{ kg} \]

(b) Suppose the electron enters a region in which there is a uniform magnetic field of 0.8 T (into the page in the drawing). As it moves through the field the electron will follow a circular path. Find the radius of the circle.

\[ R = \frac{mv}{qB} \]

But we need to use the relativistic mass of the electron

\[ m = \gamma m_0 \]

\[ R = \frac{(2.29)(9.11 \times 10^{-31} \text{ kg})(0.9)(2998 \times 10^8 \text{ m/s})}{(1.602 \times 10^{-19} \text{ C})(0.8 \text{ T})} \]

\[ R = 4.39 \times 10^{-3} \text{ m} \]

\[ 4.39 \text{ mm} \]
6) Two concentric hollow metal spheres have radii of 20 cm and 50 cm respectively. A charge of +100 μC is placed on the smaller sphere, and a charge of −80 μC is placed on the larger one. Find the magnitude of the electric field at point A (30 cm from the center of the spheres) and at point B (80 cm from the center).

At A there is no field from the outer charge

\[ E = \left( \frac{1}{4\pi\epsilon_0} \right) \frac{100 \times 10^{-6} \text{C}}{(0.3 \text{m})^2} = 9.99 \times 10^6 \text{ V/m} \]

At B we get fields from both spheres. The net charge is now +20 μC

\[ E = \left( \frac{1}{4\pi\epsilon_0} \right) \frac{20 \times 10^{-6} \text{C}}{(0.8 \text{m})^2} = 2.81 \times 10^5 \text{ V/m} \]

Point A: \[ 9.99 \times 10^6 \text{ V/m} \]

Point B: \[ 2.81 \times 10^5 \text{ V/m} \]

7) Find the total current supplied by the battery in the circuit shown.

\[ \frac{1}{R_{||}} = \frac{1}{20 \Omega} + \frac{1}{60 \Omega} \Rightarrow R_{||} = 15 \Omega \]

\[ R_{\text{Tot}} = 30 \Omega + 15 \Omega = 45 \Omega \]

\[ I = \frac{V}{R} = \frac{9 \text{ V}}{45 \Omega} = 0.2 \text{ A} \]

0.2 A
8) Unpolarized light of intensity 1 W/m² passes through a pair of linear polarizers. Find the intensity of the transmitted light if the axis of the second polarizer is rotated by 70° relative to the first.

The incident light is unpolarized, so the intensity is reduced by a factor of 2 in the 1st polarizer
⇒ \( S = \frac{1}{2} \text{ W/m}^2 \). After passing through the second polarizer

\[
S = S_0 \cos^2 \theta = (0.5 \text{ W/m}^2)(\cos^2 70°) = 0.0585 \text{ W/m}^2
\]

9) Suppose your near point is 90 cm. What focal length would your eyeglass lenses need to have in order to read a newspaper held 25 cm in front of your eyes. Assume that the lenses are 2 cm in front of your eyes.

We want the object to be 25 cm in front of our eye ⇒ 23 cm in front of the lens. We want the image to be formed at our near point, 90 cm from the eye ⇒ 88 cm from the lens. So with \( d_0 = 23 \text{ cm} \) we want \( d_i = 88 \text{ cm} \)

\[
\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{23 \text{ cm}} - \frac{1}{88 \text{ cm}}
\]

\[
f = 31.1 \text{ cm}
\]

10) A long straight wire carries a current of 15 A. A proton is moving parallel to the wire at a speed of \( 2 \times 10^5 \text{ m/s} \). The proton is 5 cm from the wire and directly below it. Find the magnitude of the force acting on the proton.

\[
B_{wire} = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7} \text{ T.m/A})(15 \text{ A})}{2\pi (0.05 \text{ m})} = 6.0 \times 10^{-5} \text{ T}
\]

\[
F = qvB\sin \theta = (1.602 \times 10^{-19} \text{ C})(2 \times 10^5 \text{ m/s})(6.0 \times 10^{-5} \text{ T}) = 1.92 \times 10^{-18} \text{ N}
\]