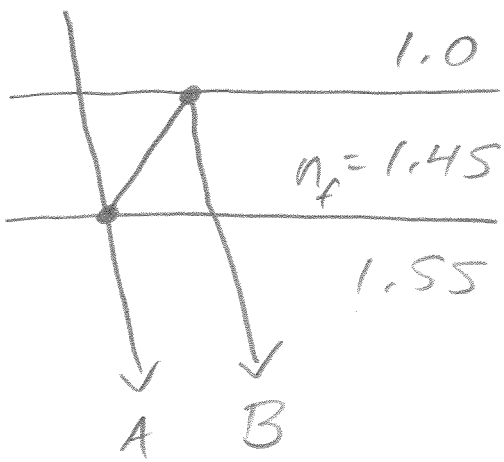
Physics 10164 - Exam 4B

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (35 pts) White light passes through a 420-nm film (n = 1.45) on top of glass (n = 1.55). Determine all wavelengths of visible light (ranging from 400-700 nm) that will strongly transmit through the film and into the ~~water~~ glass.

Remember to show all work, including calculations of phase shifts for different beams of light, or you will lose points.



$\delta_A = 0$

$\delta_B = \frac{1}{2} + 0 + \frac{2tn_f}{\lambda_0}$

$\delta_B - \delta_A = \frac{2tn_f}{\lambda_0} + \frac{1}{2} = 0, 1, 2, \ldots$

$\frac{2tn}{\lambda_0} + \frac{1}{2} = 0 \quad \frac{2tn}{\lambda_0} = -\frac{1}{2}$ ×

$\frac{2tn}{\lambda_0} + \frac{1}{2} = 1 \quad \frac{2tn}{\lambda_0} = \frac{1}{2}, \quad \lambda_0 = 4tn = 4(420)(1.45)$
$= 2440\,nm$ ×

$\frac{2tn}{\lambda_0} + \frac{1}{2} = 2 \quad \frac{2tn}{\lambda_0} = \frac{3}{2}, \quad \lambda_0 = \frac{4tn}{3} = 812\,nm$ ×

$\frac{2tn}{\lambda_0} + \frac{1}{2} = 3 \quad \frac{2tn}{\lambda_0} = \frac{5}{2}, \quad \lambda_0 = \frac{4tn}{5} = 487\,nm$ ✓

$\frac{2tn}{\lambda_0} + \frac{1}{2} = 4 \quad \frac{2tn}{\lambda_0} = \frac{7}{2}, \quad \lambda_0 = \frac{4tn}{7} = 348\,nm$ ×

2. (30 pts) An alpha particle with a charge of +2e and mass of 4.002602 amu is fired at a fixed gold nucleus target with a charge of +79e. The alpha particle has an initial kinetic energy of 4.5 MeV and is fired from very far away. To what minimum distance does the particle approach the gold nucleus before turning around?

$q_1 = +2e$

$W_E = \Delta K$

$-\Delta U_E = \Delta K$

$U_i - U_f = K_f - K_i$

$U_i = 0 \quad (r = \infty)$

$U_f = \dfrac{k q_1 q_2}{r_{min}}$

$K_i = 4.5\,MeV = 7.2 \times 10^{-13}\,J$

$K_f = 0$ (stops at r_{min})

$$-\frac{k q_1 q_2}{r_{min}} = -7.2 \times 10^{-13}\,J$$

$$r_{min} = \frac{k q_1 q_2}{7.2 \times 10^{-13}} = \frac{(9 \times 10^9)(2)(1.6 \times 10^{-19})(79)(1.6 \times 10^{-19})}{7.2 \times 10^{-13}}$$

$$= 5.1 \times 10^{-14}\,m$$

3. (40 pts) Polonium-210 has been used by Russia as a poison to slowly kill targets over the past few decdes, such as prominent dissident and former KGB agent Alexander Litvinenko. The victim was administered a dose of 10.0 micrograms of Polonium-210, which has a half-life of 138.4 days and a mass of 210 amu. He died within a few months of severe radiation poisoning (it is an interesting story if you want to Google it).

What is the activity of 10.0 micrograms of Po-210, in Curies?

How many years would it take for the activity to fall to a less-than-lethal level of 200 microCuries?

$$T_{1/2} = 138.4\,d \cdot \frac{86400\,s}{day} = 1.2 \times 10^7\,s$$

a) $$\lambda = \frac{0.693}{T_{1/2}(sec)} = 5.8 \times 10^{-8}\,s^{-1}$$

$$N = \frac{m_{TOT}}{m_{Po}} = \frac{10 \times 10^{-9}\,kg}{210\,u \cdot \frac{1.66 \times 10^{-27}\,kg}{u}} = 2.9 \times 10^{16}\,atoms$$

$$a = \lambda N = (2.9 \times 10^{16})(5.8 \times 10^{-8})$$

$$= 1.66 \times 10^{9}\,Bq \cdot \frac{1\,Ci}{3.7 \times 10^{10}\,Bq}$$

$$= 0.045\,Ci$$

b) $a = 200 \times 10^{-6}\,Ci$

$a_0 = .045\,Ci$

$\lambda = 5.8 \times 10^{-8}$

$a = a_0 e^{-\lambda t}$

$\ln\left(\frac{a}{a_0}\right) = -\lambda t$

$-5.416 = -(5.8 \times 10^{-8})t$

$t = 9.34 \times 10^7\,s \cdot \frac{1\,yr}{3.16 \times 10^7\,s}$

$= 2.96\,yrs$