FYS3500 Problem set 1

Problem 1

a) Parity is multiplicative

$$\hat{P}(\pi^+) = \hat{P}(u) \cdot \hat{P}(\bar{d})$$

Per definition, intrinsic parity of a fermion is +1 and anti-fermion is −1

$$\hat{P}(\pi^+) = \hat{P}(u) \cdot \hat{P}(\bar{d}) = (+1) \cdot (-1) = \underline{\underline{-1}}$$

The intrinsic parity of π^+ is −1.

b) $\hat{P}(f) \cdot \hat{P}(f) \cdot (-1)^{\ell=1}$

$= (+1) \cdot (+1) \cdot (-1)$

$= \underline{\underline{(-1)}}$

Though the intrinsic parity of the fermions are +, the angular momentum contributes & gives negative parity.

c) 1.2 in M&S:

$$Y_1^1 = \sqrt{\frac{3}{8\pi}} \sin\vartheta \, e^{i\varphi}$$

Eigenfunction of parity if $\hat{P} Y_1^1 = P Y_1^1$, $P = \pm 1$

Know that:

$$\hat{P}: \begin{cases} r \to r \\ \vartheta \to \pi - \vartheta \\ \varphi \to \varphi + \pi \end{cases}$$

$$\hat{P} Y_1^1 = \hat{P}\left(\sqrt{\frac{3}{8\pi}} \sin\vartheta \, e^{i\varphi}\right)$$

$$= \sqrt{\frac{3}{8\pi}} \sin(\pi - \vartheta) \, e^{i(\pi+\varphi)}$$

$$\sin(\pi - \vartheta) = \underbrace{\sin\pi}_{0} \cos(-\vartheta) + \underbrace{\cos(\pi)}_{-1} \underbrace{\sin(-\vartheta)}_{-\sin\vartheta}$$

$$\underline{= \sin\vartheta}$$

$$e^{i(\pi+\varphi)} = e^{i\pi} e^{i\varphi}$$

Euler's formula: $e^{i\pi} + 1 = 0 \Rightarrow e^{i\pi} = -1$

$$\hat{P} Y_1^1 = \sqrt{\frac{3}{8\pi}} \sin\vartheta \cdot (-1) \cdot e^{i\varphi}$$

$$\underline{\underline{= (-1) \cdot Y_1^1}}$$

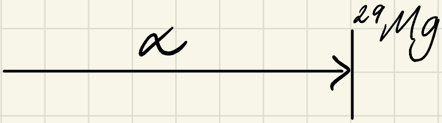
$\Rightarrow Y_1^1$ is an eigenfunction of parity with eigenvalue (-1).

Problem 2

a) Lots of things, so including (but not limited to):

- The intensity of the particle beam
- The density of the target
- The cross section of the reaction
- The detector efficiency

b) : Exercise 1.15 in M&S



Use eq. 1.57c) :

cross section $\sigma = \dfrac{W \cdot M_A}{I \cdot N_A \cdot \rho \cdot t}$

W : reaction rate

M_A : atomic mass of target

I : beam intensity

ρ : density of target

N_A : Avogadro's number

t : target thickness

Must find value of each component:

$M_A = 24.3\,u = 24.3\ g/mole$ remember from chemistry (or Google)

$N_A = 6.022 \cdot 10^{23}\ mol^{-1}$

I, beam intensity in particles/s :

10nA of α particles

1 Ampère = 1 Coulomb/s

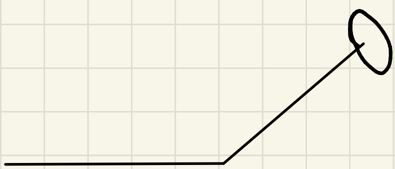
1 elementary charge $\sim 1.6 \cdot 10^{-19}$ C

$$\frac{10 \cdot 10^{-9}\ C/s}{2 \cdot 1.6 \cdot 10^{-19}\ C/\text{particle}} = \underline{3.125 \cdot 10^{10}\ \alpha/s}$$

$\rho \cdot t$: "mass thickness", mass per area

$= 10^{-3}\ g/cm^2$

W, reaction rate :



$2 \cdot 10^{-3}$ sr

A detector covering $2 \cdot 10^{-3}$ sr of the solid angle detects 20 protons/s.

Assume 100% detector efficiency & isotropic (= same in all angles) scattering

total # protons produced per second:

$$W = \frac{20}{2\cdot 10^{-3}\,sr}\cdot 4\pi = \underline{1.257\cdot 10^{5}}\ \text{protons/s}$$

(interaction rate)

Input all values into formula:

$$\sigma = \frac{W\, M_A}{I \cdot N_A \cdot \rho t}$$

$$= \frac{1.257\cdot 10^{5}\,\#p/s \cdot 24.3\ g/mol}{3.125\cdot 10^{10}\,\#\alpha/s \cdot 6.022\cdot 10^{23}\,mol^{-1}\cdot 10^{-3}\,g/cm^2}$$

$$= 1.62\cdot 10^{-25}\,cm^2 = 0.162\cdot \underbrace{10^{-24}\,cm^2}_{\text{unit: barn, } b}$$

$$= \underline{\underline{162\ mb}}$$