Home Work 4

1) 50 m Ci Source, emits α w/ 5 MeV

- assume: α lose all energy in the detector
  - energy to create e + ion pair = 30 eV
  - Collection efficiency for charge: 89%

1. How many α/s?
   $1\ Ci = 3.7 \times 10^{10}\ Bq$, $1\ Bq = 1\ \text{decay}/s$

   $\rightarrow 50 \times 10^{-3}\ Ci \cdot 3.7 \times 10^{10} \frac{Bq}{Ci} = 185 \times 10^{7}\ Bq$ or α/s

2. How many e-ion pairs per α?
   5 MeV αs → assume all converted to ioniz.
   → 30 eV to ionize

   $\rightarrow 5\ MeV / 30\ eV$ = # electrons from ionization
   $5 \times 10^{6}\ eV / 30\ eV = 1.67 \times 10^{5}$ electrons

3. Charge of electrons:
   for each electron $q = 1.602 \times 10^{-19}\ C$
   $\rightarrow q_{tot} = 1.67 \times 10^{5}$ electrons $\times 1.602 \times 10^{-19}$ C/elect.
   $= 2.7 \times 10^{-14}\ C$

4. Current, including efficiency:
   $I = 185 \times 10^{7}\ \alpha/s \times 2.7 \times 10^{-14}\ C \times 0.89$
   $= 444 \times 10^{7} \times 10^{-14} = \boxed{4.44 \times 10^{-5}\ A}$

1) b. 5 MeV particle stopped in ionization chamber
Voltage undergoes step change of 2mV.

What is the capacitance?
Assume electronics/chamber time constant is long compared to charge deposition by αs.

$C = Q/V$

where $Q = 2.7 \times 10^{-14}\ C \times 0.89$ → take detection efficiency into account

$= 2.4 \times 10^{-14}\ C$

$$C = \frac{2.4 \times 10^{-14} C}{2 \times 10^{-3} V} = \boxed{1.2 \times 10^{-11}\ F = C}$$

2) a. $f = 30$ MHz, accelerates to v_i. What is l?

$l = v \Delta t$, $\Delta t = 1/2f$ → half cycle

$$\boxed{l = v_i/2f}$$

b. Assume particles are O^{16} ions, acc. to $80\ MeV/c = p$

$v = \beta c$, where $\beta = p/E$

Assume $E = m$ → $p = 80\ MeV/c$ much smaller than mass of ^{16}O

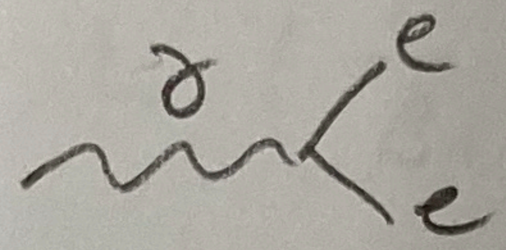
→ $E = m = 16u = 16 \times 930\ MeV = 14,880\ MeV$

$$\rightarrow v = \frac{pc}{E} = \frac{80 MeV \times 3 \times 10^8 m/s}{14,880\ MeV} = \boxed{1.6 \times 10^6\ m/s = v}$$

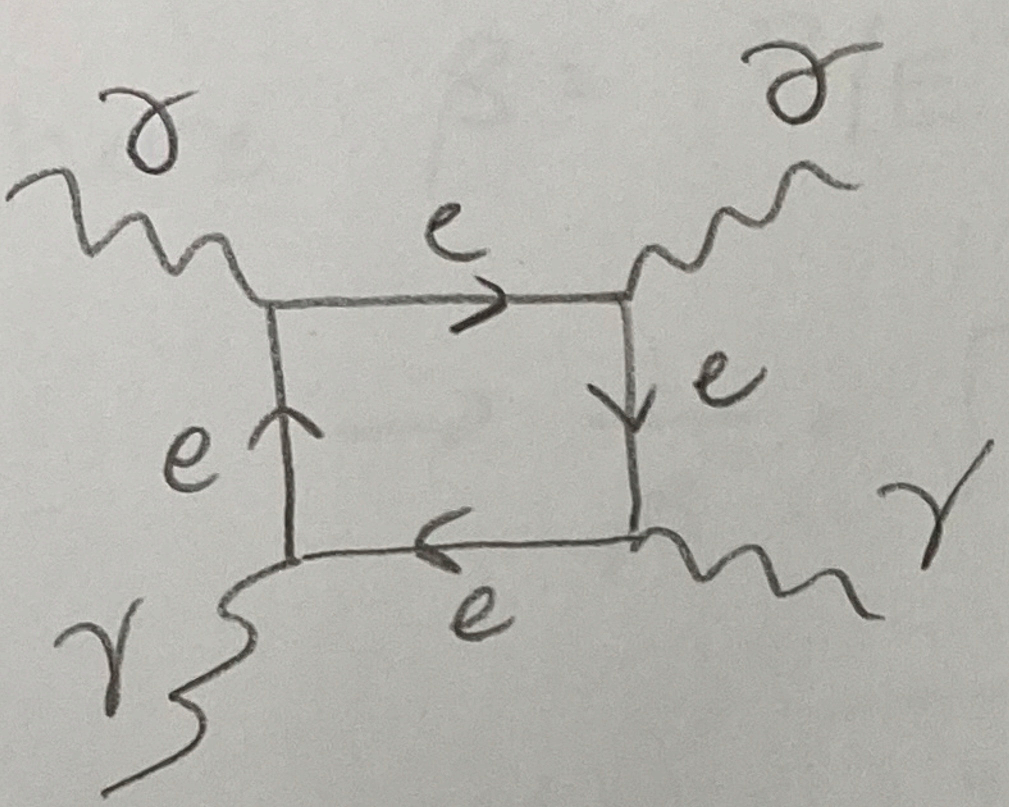
2) b. cont:

$$\ell = \frac{v_i}{2f} = \frac{1.6 \times 10^6 \text{ m/s}}{2 \cdot 30 \times 10^6 \, 1/s} = 0.0267\text{m} = 2.7\text{cm}$$

3.) a. $\gamma + \gamma \rightarrow \gamma + \gamma$

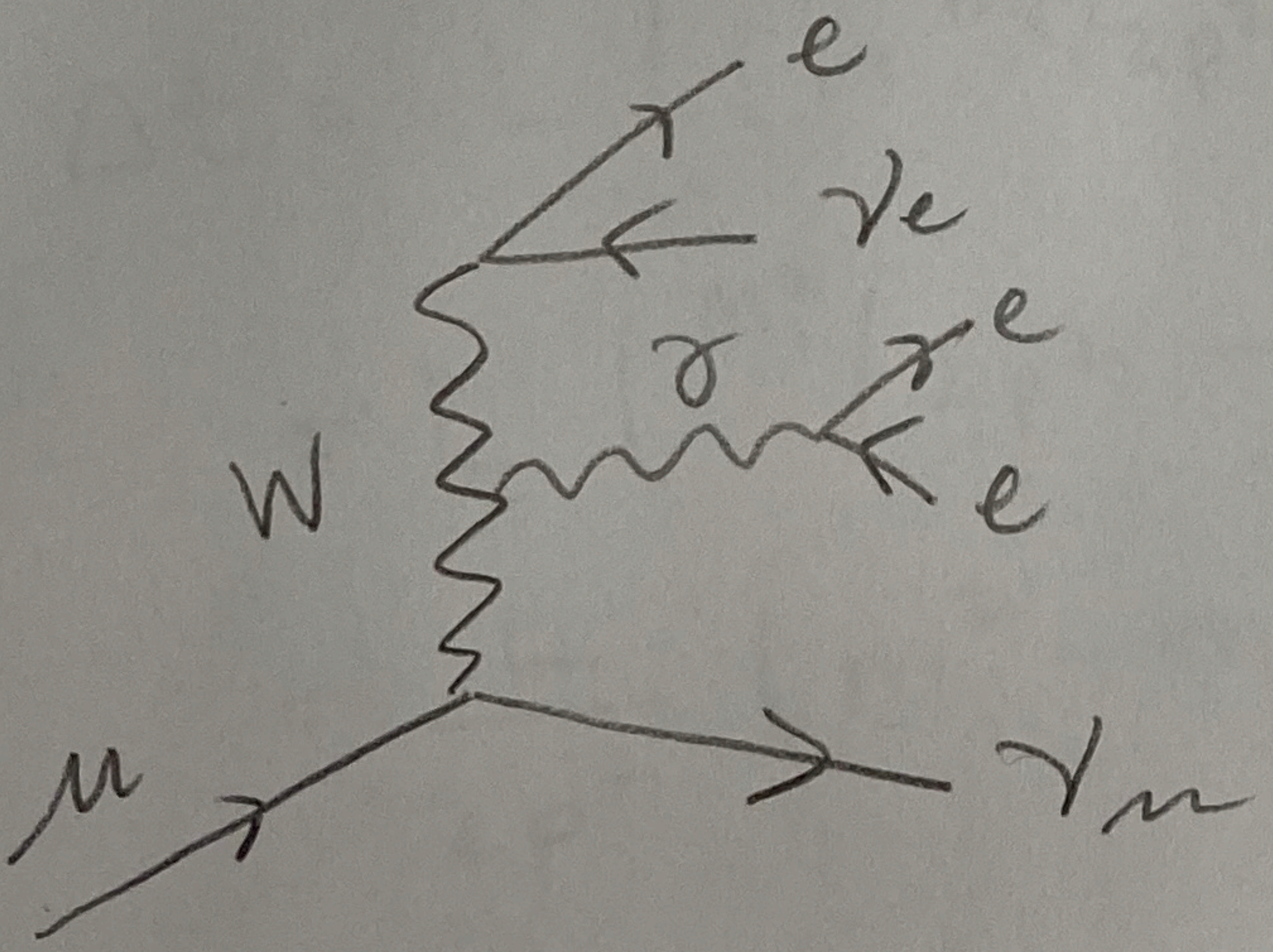
Base vertex: 

→ need 2 to get 2 γ in/out

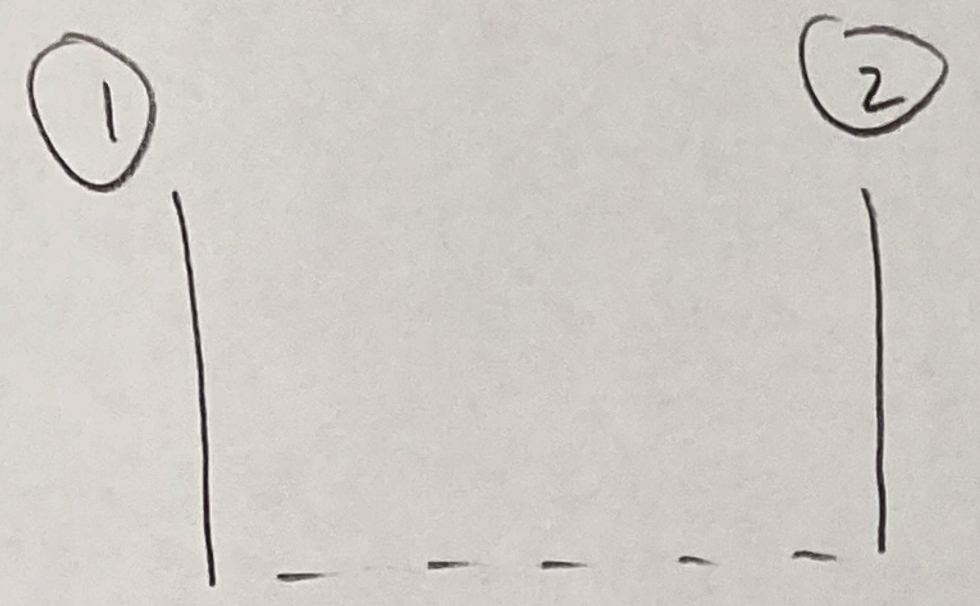


b. $\mu^- \rightarrow e^- + e^- + e^+ + \nu_\mu + \bar{\nu}_e$

neutrinos → must be weak + charged, since not $\nu_{in} + \nu_{out}$ of interaction w/ flavor conservation



4)



$\Delta X = L$

$$\Delta t = \frac{L}{v_1} - \frac{L}{v_2} = L\left(\frac{1}{\beta_1} - \frac{1}{\beta_2}\right)$$

where $\beta = P/E = \dfrac{P}{\sqrt{p^2+m^2}}$

$$\rightarrow \frac{1}{\beta} = \sqrt{1 + m^2/p^2}$$

Approximate: $\sqrt{1+\alpha} \approx 1 + \alpha/2$

$$\rightarrow \frac{1}{\beta} \approx 1 + m^2/2p^2$$

So $\Delta t = L\left(\left(1 + m_1^2/2p^2\right) - \left(1 + m_2^2/2p^2\right)\right)$

$$= L\left(m_1^2/2p^2 - m_2^2/2p^2\right)$$

$$= \frac{L}{2p^2}\left(m_1^2 - m_2^2\right)$$

b. $\Delta t = 200$ ps, $p = 3$ GeV/c

From a:

$$L = \frac{2p^2 \Delta t}{c\left(m_1^2 - m_2^2\right)} = \frac{2 \times 3000 \times c \times 200 \times 10^{-12}}{493.7^2 - 139.6^2} = \boxed{4.82\ m}$$