Greg Pang

Ch. 7: 4, 6, 8   Ch. 8: 1, 9, 10

7.4 Estimate voltage for Geiger region of operation
3 excited atoms for every ion pair
De-excitation photons have prob. of $10^{-5}$ of creating additional avalanche

Details from problem 6.3
Anode radius = 0.003 cm
Cathode radius = 1.0 cm
P-10 gas @ 1 atm
Gas multiplication Factor?
$n_0' = 3$, $p = 10^{-5}$
Solve for M (multiplication factor) using condition of criticality for G-M

$$M n_0' p \geq 1$$
$$M(3)(10^{-5}) \geq 1$$
$$M \approx 10^5$$

Using...

$$\ln M = \frac{V}{\ln(b/a)} \cdot \frac{\ln 2}{\Delta V}\left(\ln \frac{V}{pa\ln(b/a)} - \ln K\right)$$

$M = 10^5$
$b = 1.0\text{ cm}$
$a = 0.003\text{ cm}$
$\Delta V = 23.6\text{ V}$
$p = 1\text{ atm}$
$K = 4.8 \times 10^4\text{ V/cm}\cdot\text{atm}$

$$\ln M = \frac{V}{\ln(b/a)}\left(\frac{\ln 2}{\Delta V}\right)\ln\left(\frac{V}{pa\ln(b/a)K}\right)$$

$$V\ln V = \frac{\ln(b/a)\ln M}{\ln 2}\Delta V + \ln(pa\ln(b/a)K)$$

$$V\ln V = 2277.1 + 6.7 = \cancel{2283.8}$$ Math?

$$\boxed{V = 383.8}$$

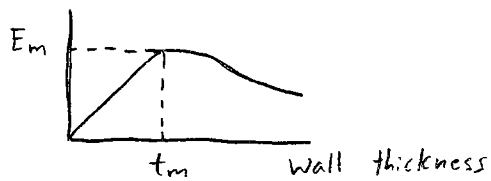
$$\ln(3.3\times10^{4}) = \frac{V_0}{\ln(1/0.003)}\left(\frac{\ln 2}{23.6}\right)\ln\left(\frac{V_0}{1\,(0.003)\ln\frac{1}{0.003}\,4.8\times10^{4}}\right)$$

$$10.40 = V_0\,(5.056\times10^{-3})\ln\left(V_0/836.5\right)$$

$$2.05\times10^{3} = V_0\left[\ln V_0 - \ln(836.5)\right]$$

solve $\rightarrow$ $V_0 = 2160$ Volts

7.6 Medium Energy Gamma Rays (1 MeV)




a) The shape of the wall can be explained by the gamma-ray interactions with the wall of the container. The gamma-ray counting efficiency rises to a maximum at $t_m$ because if the wall is ~~too~~ thin, the gamma-ray may not interact with the wall, but pass through it. The efficiency decreases as the thickness is increased beyond $t_m$ because the electons produced in the interaction may be stopped before reaching the gas.

b) Assume 1 MeV $e^-$ $\longrightarrow$ Typical range of $e^-$ in moderate density materials is approximately in mm/MeV

Estimated order of magnitude for wall thickness: $10^{-3}$m

7.8 $p = 0.5$ atm

$\mu = 1.5 \times 10^{-4}\ m^2 \cdot atm/V \cdot s$

Anode radius = 0.005 cm

Cathode radius = 2 cm

$V_{app} = 1500V$

$\mathcal{E}_{thresh} = 2 \times 10^6\ V/m$

$$\mathcal{E}(r) = \frac{V}{r\ln(b/a)}$$

$$\mathcal{E}_{thresh} = \frac{V}{r\ln(b/a)}$$

$$2 \times 10^6\ V/m = \frac{1500V}{r\ln(2/0.005)}$$

$$\boxed{r = 1.25 \times 10^{-4}\ m}$$

the real problem is that you need average field

v = drift velocity

$$v = \frac{\mu \mathcal{E}_{thresh}}{p}$$

$$v = \frac{(1.5 \times 10^{-4}\ m^2 \cdot atm/V \cdot s)(2 \times 10^6\ V/m)}{0.5\ atm}$$

$$v = 600\ m/s$$

distance from cathode to multiplying region

$(2\ cm - 0.0125\ cm) = 1.9875\ cm = 0.019875\ m$

$0.019875\ m / (600\ m/s) = \boxed{3.31\ s}$

↳ $33\ \mu s$ but this is too short for reason above

$$\text{drift time} = \frac{\Delta S}{\frac{\mu}{p}\bar{\mathcal{E}}} = \frac{(b - r_c)}{\frac{\mu}{p}\frac{V_0}{\ln b/a}\left[\text{Int}\right]} \qquad \bar{\mathcal{E}} = \left\{\frac{V_0}{\ln b/a}\int_{r_c}^{b}\frac{1}{r}\,dr\right\}\Big/ b - r_c$$

$$\text{time} = \frac{(b-r_c)}{\left(\frac{\mu}{p}\right)\frac{V_0}{\ln b/a\,(b-r_c)}\left(\ln b - \ln r_c\right)} \qquad \int \frac{1}{r}\,dr = \ln r$$

$$\text{time} = \frac{(0.02 - 1.25\times10^{-4}\,m)^2 \ln\left(.02/5\times10^{-5}\right)}{\left(\frac{1.5\times10^{-4}}{0.5}\frac{m^2\,atm}{V\cdot sec\;atm}\right)1500\,V\left(\ln .02 - \ln 1.85\times10^{-4}\right)}$$

$$= 1.0\ m\,sec$$

8.1 Scintillation eff.

1 MeV of particle energy loss → 20,300 photons

$\lambda = 447$ nm

$$c = \lambda\nu$$
$$\nu = 6.7 \times 10^{14}\,s^{-1}$$

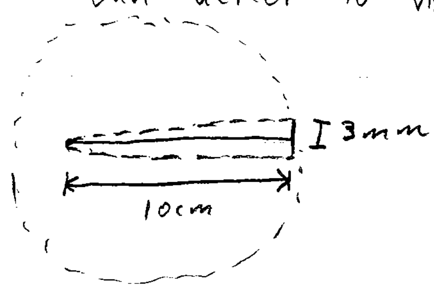
$$E = h\nu$$
$$E = 4.45 \times 10^{-19}\,J \Rightarrow 2.78\,eV$$

$$20{,}300 \text{ photons} \times 2.78\,\frac{eV}{\text{photon}} = 56434\,eV$$

$$\frac{56434\,eV}{1 \times 10^{6}\,eV} = 0.056 \rightarrow \boxed{5.6\%}$$

8.9 1 MeV $\beta$ in NaI(Tl)

can detect 10 visible photons



Light yield for NaI(Tl) $\rightarrow$ 1 MeV produces 38,000 photons

Surface area $= 4\pi r^2 = 4\pi(0.1\,m)^2 = 0.126\,m^2$

Area of eye $= \pi r^2 = 7.07 \times 10^{-6}\,m^2$

$$\frac{\text{Eye Area}}{\text{Surface Area (emitted)}} = \frac{7.07 \times 10^{-6}\,m^2}{0.126\,m^2} = 5.6 \times 10^{-5}$$

# of photons reaching eye $= (5.6 \times 10^{-5})(38{,}000 \text{ photons})$

# of photons = 2.1 photons

unable to detect

PREPARED BY

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8.10

a) 1 MeV fast $e^-$ 0.3 mm diametr plastic fiber

Estimate 1mm/MeV → ~0.3 MeV energy loss

from where? 2mm/MeV → ~0.6 MeV energy loss (too large)

b) Assuming 8-10 photons/keV

And 0.3 MeV energy deposited

$$300\text{keV}\left(9\ \frac{\text{photons}}{\text{keV}}\right) = 2700 \text{ photons}$$

c) core = 1.58

cladding = 1.49

attenuation length = 2m

# of scint. photons arriving at one end of fiber 1 m from point of interaction

$$F = \frac{1}{2}\left(1 - \frac{n_1}{n_0}\right)$$

$n_1$ = refractive indices of cladding
$n_0$ = refractive indices of core

$$F = \frac{1}{2}\left(1 - \frac{1.49}{1.58}\right)$$

Fraction of rays captured in one direction

$$F = 0.0285$$

$$\frac{I}{I_0} = e^{-x/L}$$

x = distance from point of interaction
L = attenuation length

$$\frac{I}{I_0} = e^{-1/2}$$

$$\frac{I}{I_0} = 0.607$$

$$(0.0285)(0.607)(2700 \text{ photons}) = \boxed{46.7 \text{ photons}}$$