9.3) $\delta = \frac{\text{number of secondary electrons emitted}}{\text{primary incident electron}}$

overall gain $= \alpha\, \delta^N$

$\alpha \sim 1$ for well designed tubes

$N = 6$ stages

overall gain $= 10^6$

$\Rightarrow \delta = 10$

From figure 9.3, when $\delta = 10$, the total applied voltage is around 200V.

9.4) dark current $= 2\,nA = 2\times10^{-9}\,\frac{C}{s}\;\frac{1\text{ electron}}{1.6\times10^{-19}C}$

$= 1.25\times10^{10}\,\frac{\text{electrons}}{s}$

PM tube gain $= 10^6$

$$\frac{1.25\times10^{10}\,\frac{\text{electrons}}{s}}{10^6} = 1.25\times10^4\,\frac{\text{electrons}}{s}$$

emitted at the photocathode

9.5) PMT voltage of 1000V over 10 stages implies 100V per stage.

The gain per dynode varies as $V^{0.6}$;

for 10 stages $[V^{0.6}]^{10} = 10^{12}$ or $u = V^6$, $\frac{\partial u}{\partial V} = 6V^5$.

(3.37) $\sigma_u^2 = \left(\frac{\partial u}{\partial V}\right)^2 \sigma_V^2$ where $\sigma_u = 1\%$ of 10^{12}

$$\sigma_x = \frac{\sigma_u}{\left(\frac{\partial u}{\partial V}\right)} = \frac{10^{10}}{6\,V^5} = \frac{10^{10}}{6(100V)^5} = 0.17$$

The HV supply 1000 ± 0.17 V.

9.8) Number of electrons at the photocathode:

$$(1.2\ \text{MeV})(38{,}000\ \frac{\text{photons}}{\text{MeV}})(70\%)(20\%\ \frac{\text{electrons}}{\text{photon}})$$

$$= 6{,}384 \text{ electrons.}$$

Number of electrons at the anode:

$$6{,}384 \text{ electrons} \times 10^5$$

$$= 6.384 \times 10^8 \text{ electrons.}$$

Total charge:

$$Q = 6.384 \times 10^8\ e^- \quad 1.6 \times 10^{-19}\ \frac{C}{e^-} = 1.02 \times 10^{-10}\ C$$

Time constant of the light $= 230\text{ns}$
$= 0.23\mu S$

Anode time constant:

$$RC = 10^5\ \Omega\ (100\text{pF}) = 10\mu s.$$

$$\theta = \frac{1}{RC} = 1 \times 10^5 / S$$

$\theta \ll \lambda$ so voltage pulse:

$$V = \frac{Q}{C}$$

$$= \frac{1.02 \times 10^{-10} C}{100\text{pF}}$$

$$= 1.02\ V$$

9.11)

(4.2) $I = rQ = r \frac{E}{W} q$

where r = event rate

E = energy per event

W = energy to produce charge pair $= h\frac{\lambda}{c} = 2.95\,eV$

$q = 1.6 \times 10^{-19} C$

$$I = \frac{10^6}{s} \frac{5\,MeV}{2.95\,eV} (1.6 \times 10^{-19} C)(3.0\%)(75\%)(80\%)$$

$= \underline{4.9\,nA}$