

1/ Caesium-133 produces radiation of frequency

$$f = 9,192,631,770 \text{ Hz} = 9.1926 \times 10^9 \text{ Hz}$$

$$(i) \lambda = \frac{c}{f} = \frac{2.998 \times 10^8}{9.1926 \times 10^9} = 3.261 \times 10^{-2}$$

$$\text{i.e. } \lambda \approx \boxed{3.26 \text{ cm}}$$

This type of radiation is **Microwave**  
 (1 MHz  $\rightarrow$  10 GHz)  
 300m  $\rightarrow$  0.1 cm

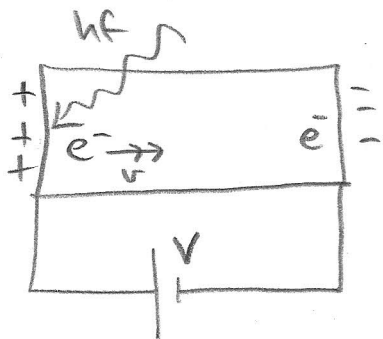
(ii)  $eV = hf$  {  $V$  is equivalent accelerating voltage acting on one electron }

So energy in electron-volts is  $\frac{hf}{e} = \frac{6.63 \times 10^{-34} \times 9.1926 \times 10^9}{1.60 \times 10^{-19}} = \boxed{3.81 \times 10^{-5} \text{ eV}}$

Now the ionization energy of Hydrogen is 13.6 eV, and typical photoelectric effect work functions for metals are  $\sim 5 \text{ eV}$ .

So this transition is **electronic** between two possibly large quantum number orbitals. Nuclear transitions are  $\sim \text{MeV}$

2/ (i) Photoelectric effect



Energy of electron emitted due to absorption of a photon of frequency  $f$  is

$$E = hf - W$$

Work function of metal

$\therefore$  If "stopping potential" is  $V$

$$\boxed{eV = hf - W}$$

(i) when  $\boxed{hf < W}$ , no electrons are emitted.

If  $f_{\min} = \frac{c}{300 \times 10^9} = 9.993 \times 10^{14} \text{ Hz}$ ,  $\boxed{hf_{\min} = W}$

(ii)  $\Rightarrow W = \frac{2.998 \times 10^8 \times 6.63 \times 10^{-34}}{300 \times 10^9 \times 1.60 \times 10^{-19}} = \boxed{4.14 \text{ eV}}$

(iii)  $P = 100\text{W}$  (laser power) 6% efficiency  
 $\lambda = 200\text{nm}$  (laser wavelength)

Energy per laser photon is  $hf = \frac{hc}{\lambda}$

Energy of photoelectron is  $\frac{hc}{\lambda} - W$

( $W$  from above is  $4.141\text{eV}$ )

If 10% efficient, 10W results in photoelectrons

$\therefore$  # electrons per second =  $\frac{10}{\frac{hc}{\lambda} - W}$

$\therefore$  Current is  $\boxed{\frac{10e}{\frac{hc}{\lambda} - W} = I}$

$$I = \frac{10 \times 1.6 \times 10^{-19}}{\frac{6.63 \times 10^{-34} \times 2.998 \times 10^8}{200 \times 10^{-9}} - 4.141 \times 1.6 \times 10^{-19}}$$

$\boxed{I = 4.83\text{ A}}$

3/

$$\lambda = \frac{h}{p}$$

kinetic energy of  $\text{H}_2\text{O}$   
 $\frac{p^2}{2m} = 3 \times \frac{1}{2} k_B T \leftarrow$  Average KE of  $\text{H}_2\text{O}$

$$p = \sqrt{3k_B T m}$$

$$\therefore \lambda = \frac{h}{\sqrt{3k_B T m}}$$

Now  $m \approx \underbrace{2 \times m_p}_{2 \times \text{H}} + \underbrace{8 \times m_p + 8 \times m_n}_{16 \times \text{O}}$

$$m \approx 2 \times 1.6726 \times 10^{-27} + 8 \times 1.6726 \times 10^{-27} + 8 \times 1.6749 \times 10^{-27}$$

2)

