BPT-401 Date- 16/04/2021

Planck's Radiation Formula :

Wave and particle nature

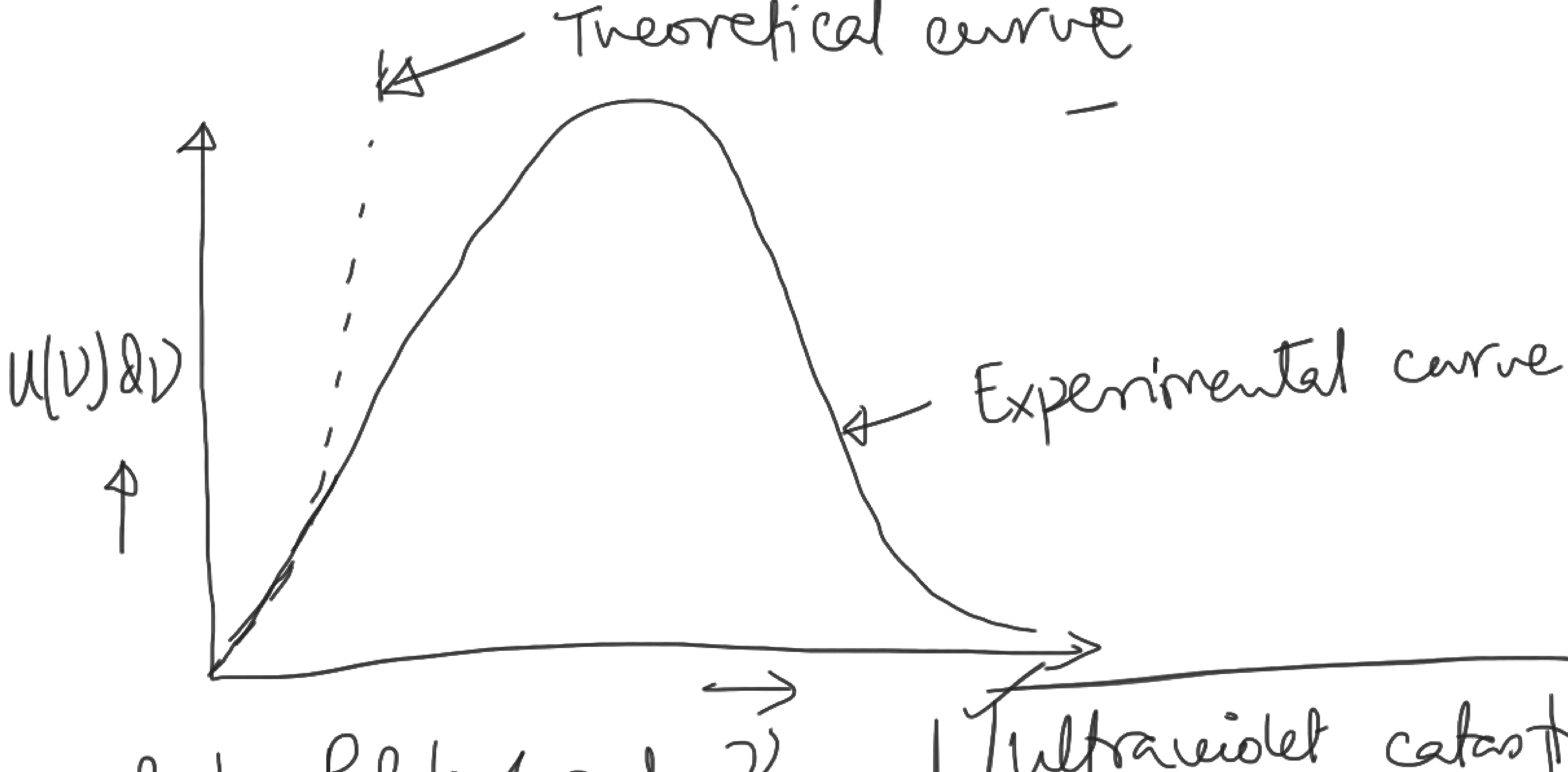
✓ In microscopic world →

✓ em wave ⇒

Radiation by hot bodies ⇒

⇓

Blackbody radiation ⇒



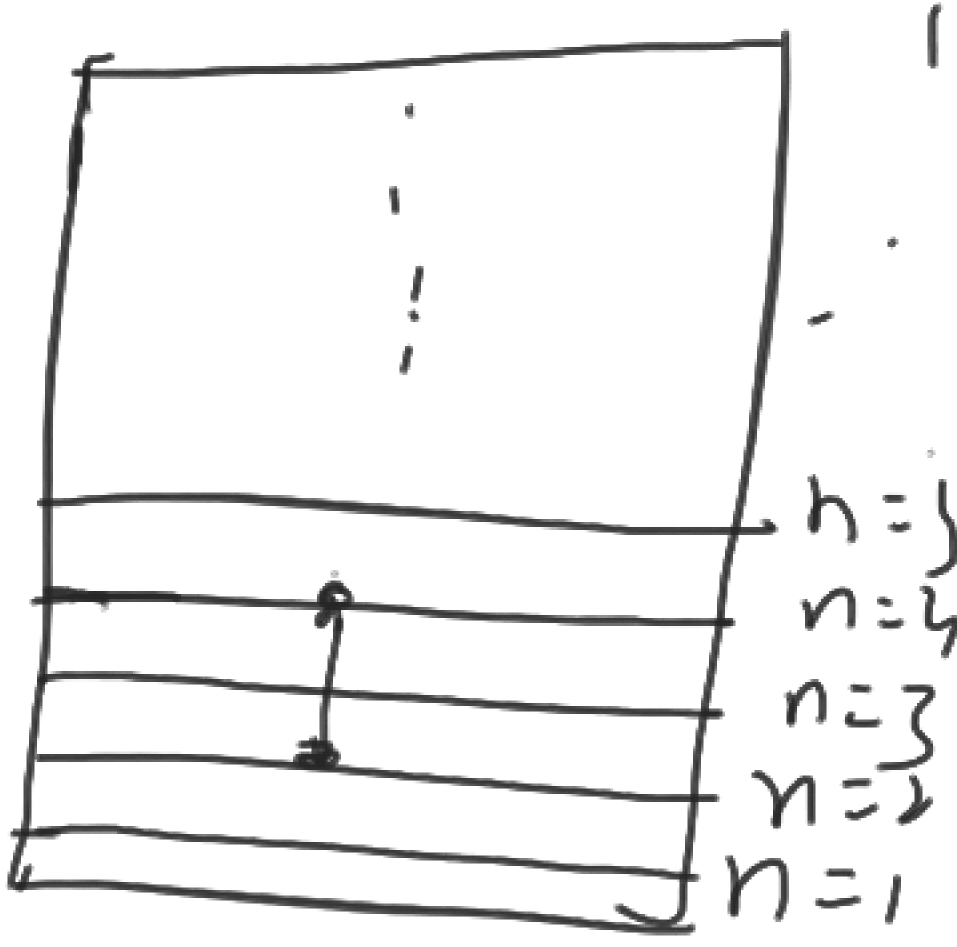
used by Ralyleigh and Jeans
em wave theory =>

$\boxed{\text{ultraviolet catastrophe}}$

classical physics
fails.

In 1900, Max Planck used his 'lucky guess' to explain this descrepancy —

The oscillators in the cavity have decrete energy level ϵ.



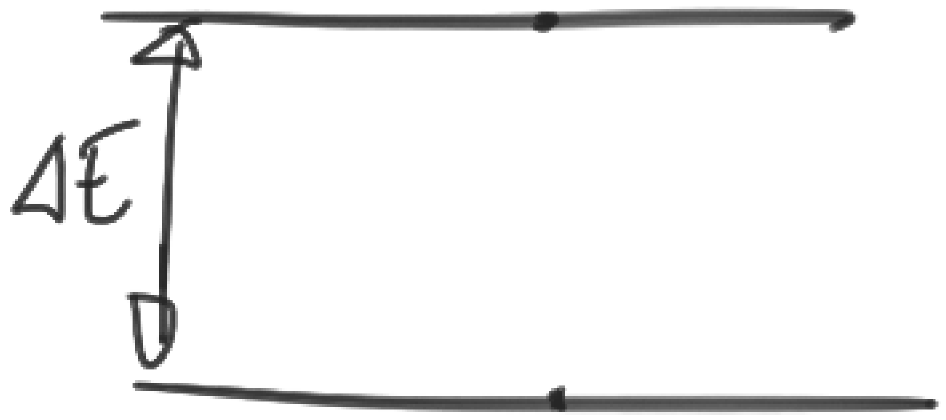
$$\epsilon_n = nh\nu \quad \text{where } n = 0, 1, 2, 3, \ldots$$

h = Planck's constant

$= 6.626 \times 10^{-34}$ J.s

$$\Delta E = nh\nu$$

$$\downarrow$$



Each decrete bundle of energy $h\nu$ is called a quantum

According to Planck's Theory,

Average energy, $\bar{\epsilon} = \dfrac{h\nu}{e^{\frac{h\nu}{k_B T}} - 1}$

The Planck's radiation formulla then

$$u(\nu)\,d\nu = \frac{8\pi h}{c^3} \frac{\nu^3\,d\nu}{e^{\frac{h\nu}{k_B T}} - 1}$$

✓ At high frequency, $\frac{h\nu}{k_B T} \gg 1$,

then, $e^{\frac{h\nu}{k_B T}} \rightarrow \infty$

then $u(\nu)\,d\nu \rightarrow 0$

$T_r = 300\,K$

$k_B T_r \simeq 0.02$ ev

UV, $h\nu = 2$ ev

$\frac{h\nu}{k_B T_r} =$

For low frequencies, $\frac{h\nu}{k_B T} << 1$ $\quad x = \frac{h\nu}{k_B T}$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots$$

$$e^x \approx 1 + x$$

$$\frac{1}{e^{\frac{h\nu}{k_B T}} - 1} \approx \frac{k_B T}{h\nu}$$

we recover, Rayleigh-Jeans formula

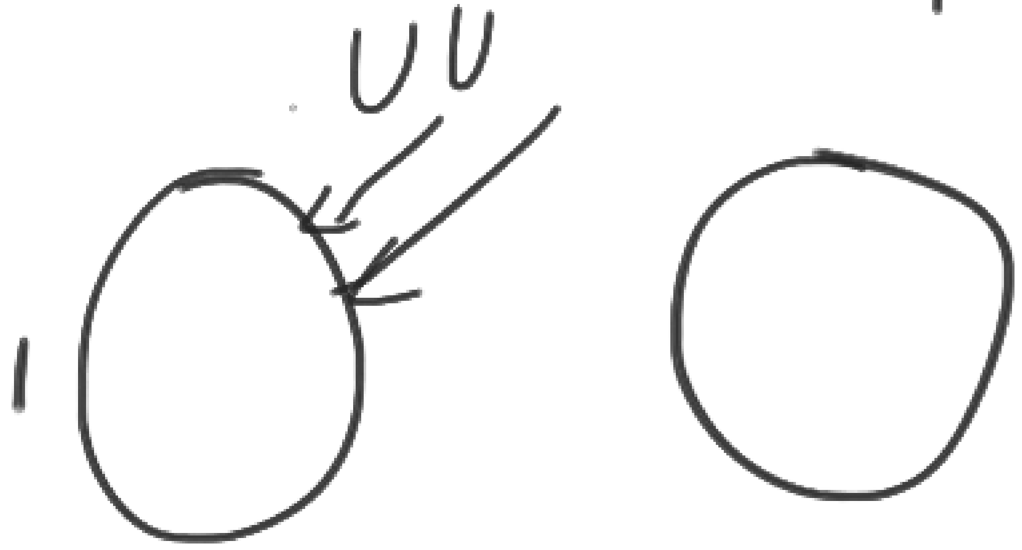
$$u(\nu)d\nu = \frac{8\pi k_B T}{c^3} \nu^2 d\nu$$

Photoelectric effect

Maxwell theoretically shown that light is em wave

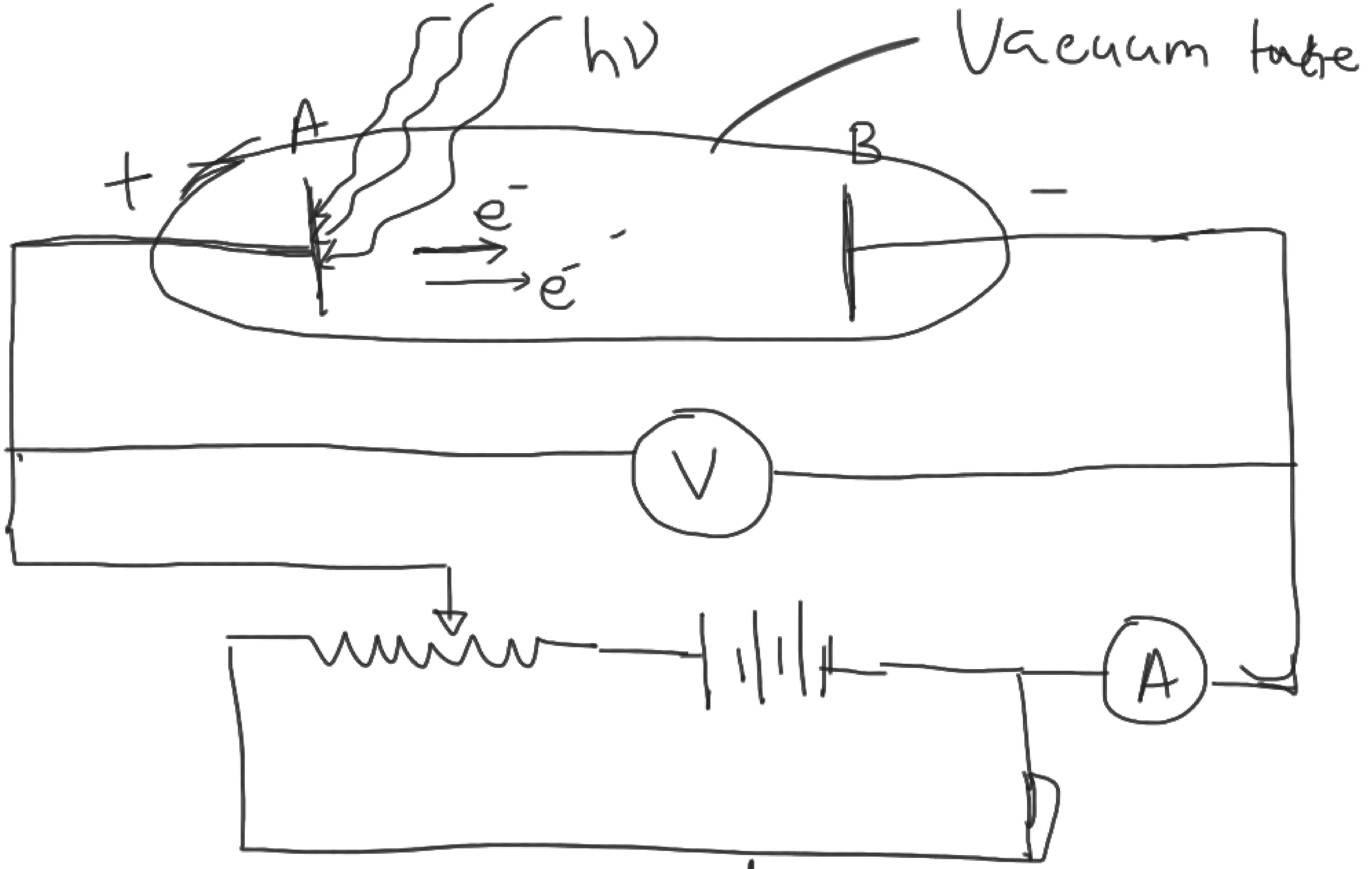
$\Downarrow$

Hertz experimentally verified



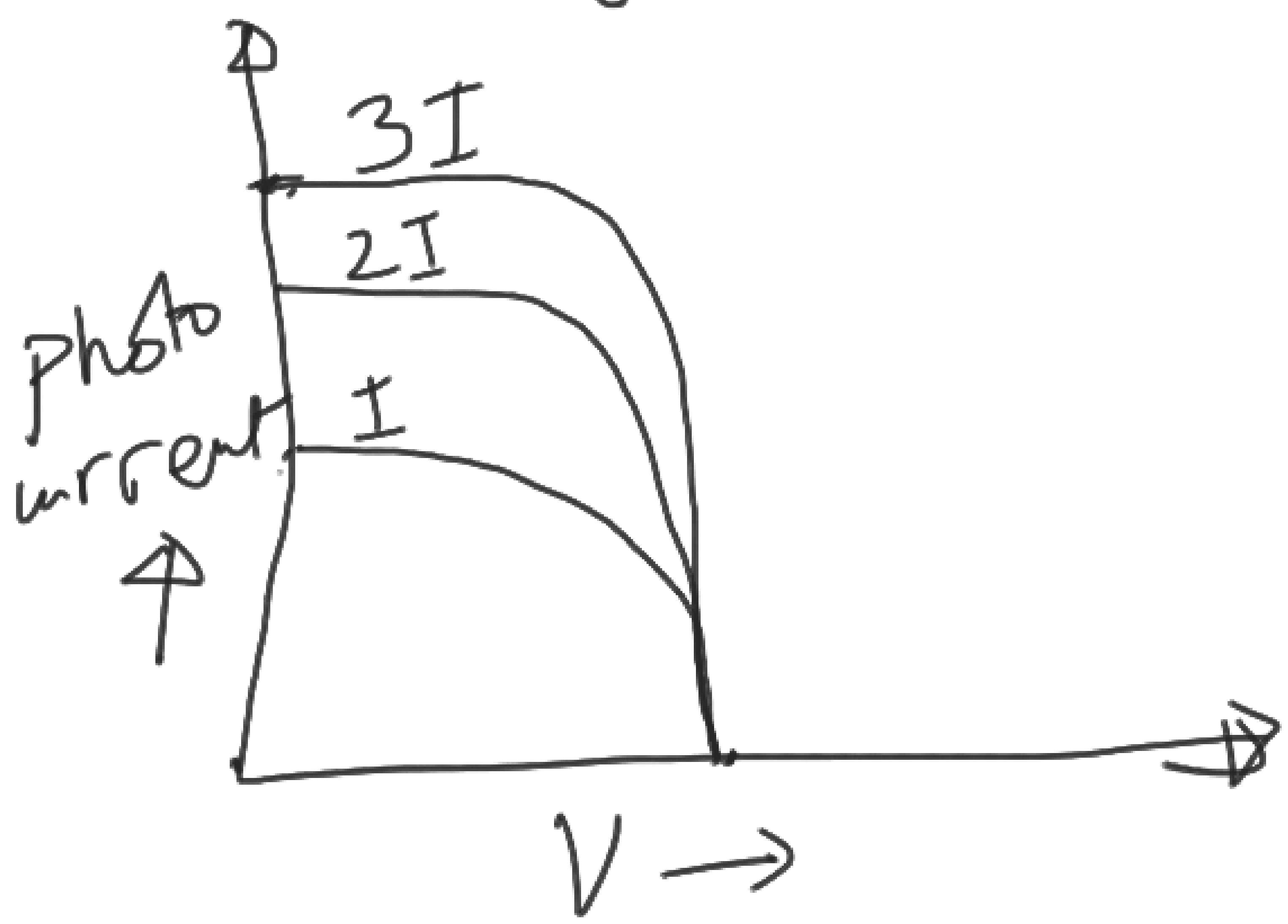
Photoelectron

✓

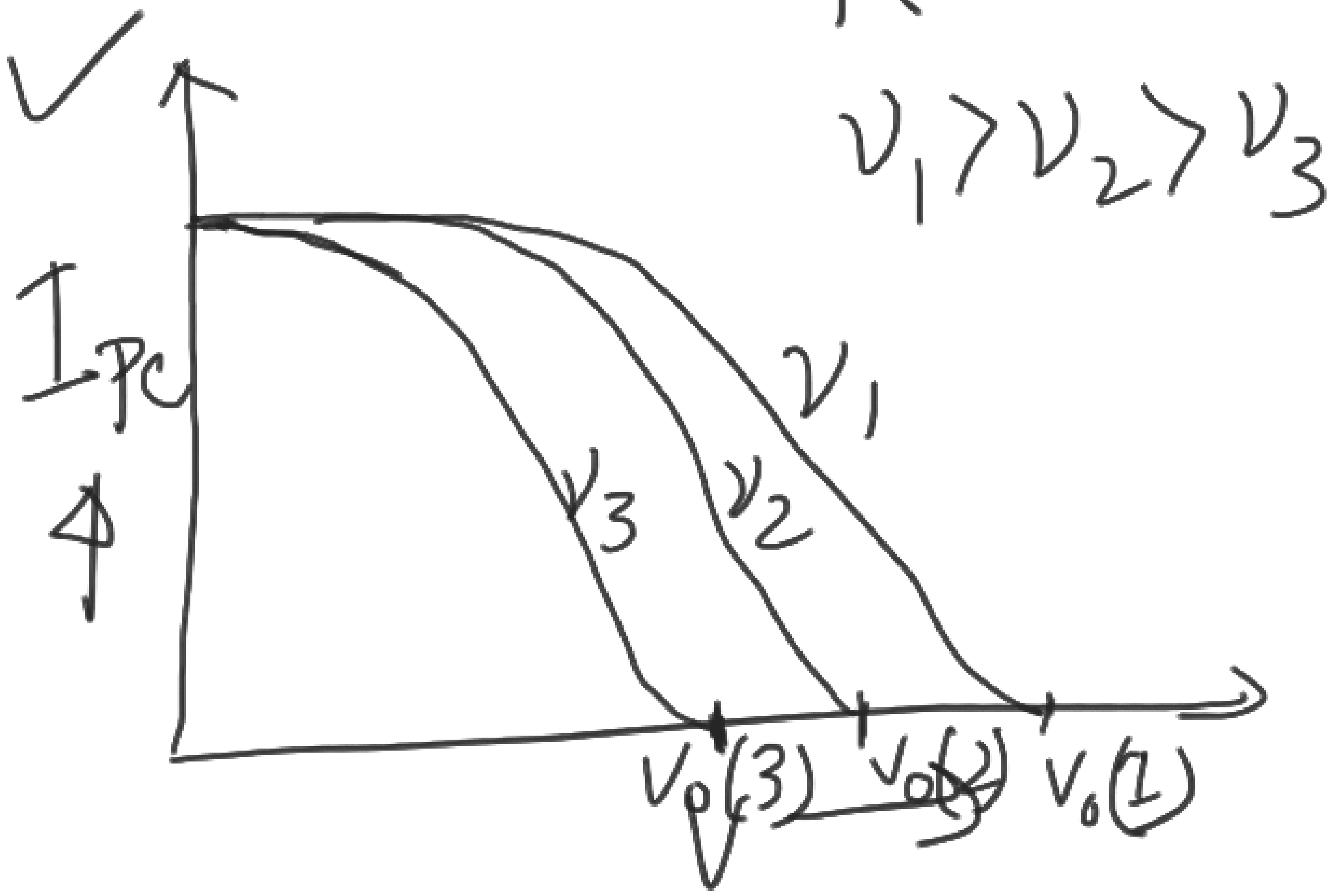


✓ photoelectric effect set up schematic

Frequency (ν) = constant



Intensity (I) constant



em wave theory =>

em wave theory could not explain the following points ⇒

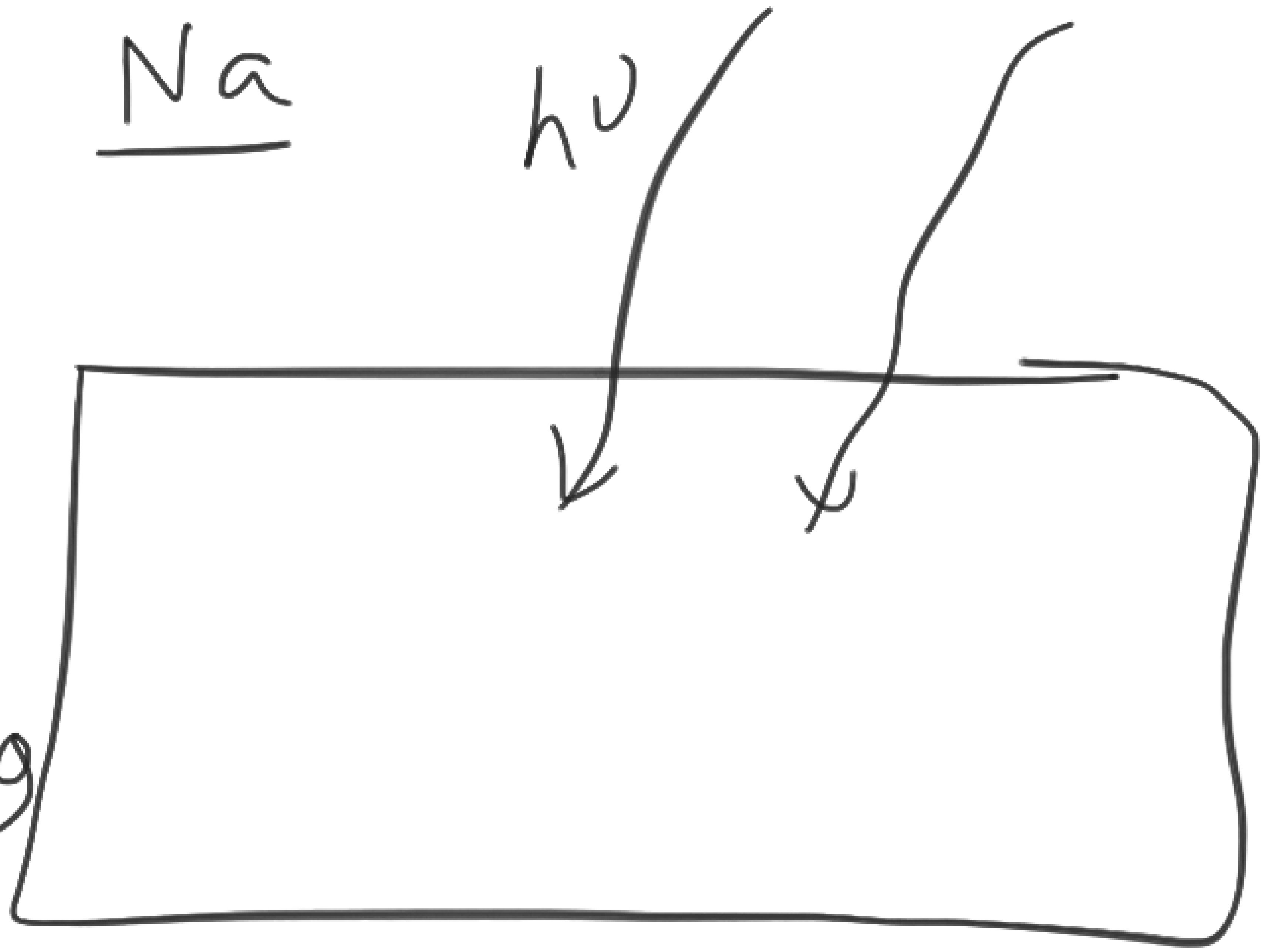
① No delay between the arrival of light and emission of electrons.

$(10^{-9}\ s)$

em wave is correct for this case

$I = 10^{-6}\ w/m^2$

Na



$1\ m^2$ area of 1 layer thick atom,

number of atoms $\simeq 10^{+19}$

Only e^- will escape if it gather few eV

$\simeq 1\ eV$

$\simeq 1.6 \times 10^{-19}\ J$

$$\text{Time required} = \frac{1.6 \times 10^{-19}}{10^{-25}}\, s = 10^{6}\, s$$

$$\approx 11 \text{ days}$$

(2) Photo current $\propto$ Intensity $\Rightarrow$ experimental

$\Rightarrow$ em theory says, electron K.E $\propto$ Intensity

3