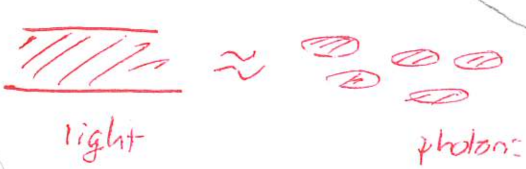
Weds: Review

Fri: Test 3 Waves, photon model

2022 Test Q1 → Q8
2023 Test Q1 → Q10

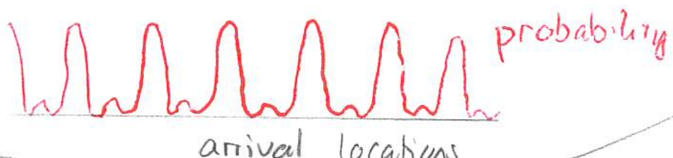
Photon model of light

In the photon model of light, a stream of light consists of individual particle like entities.



→ Predict where the photons will arrive using a wave associated with the photons.

→ Intensity of wave at screen/detectors gives probability of arrival



Additionally there is an energy associated with photons.

Given light with one frequency (or one wavelength) → The energy of a single photon is given by

$$\underbrace{\text{energy}}_{\text{Joules}} = 6.63\times10^{-34}\,\text{J}\cdot\text{s} \times \underbrace{\text{frequency}}_{\text{Hertz}}$$

$$E = h \times f$$

Given wavelength →

$$\text{frequency} = \frac{3.0\times10^{8}\,\text{m/s}}{\text{wavelength}}$$

Quiz 1 60% – 80%

Quiz 2 80%

DEMO: Spectrum Tube + Glasses

- Show different wavelengths (colors

Concepts of Physics: Group Exercise 7

11 November 2024

Names: ________________ ________________ ________________

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1 Photon energies and numbers, coin analogy

A particular light source can produce photons, each with energy 25×10^{-20} J. Consider a pulse of light produced by this source. Remember that the pulse consists of a number of individual photons.

a) Consider the total energy in the pulse. List the five lowest possible total energies that the pulse could have.

b) Is it possible that the pulse has total energy 175×10^{-20} J? Explain your answer.

c) Is it possible that the pulse has total energy 185×10^{-20} J? Explain your answer.

There is an analogy with money. In the following, suppose that the only cash one has is a collection of coins and that the only coins in the collection are quarters.

d) List the five lowest possible amounts of cash that one could have in the collection.

e) Is it possible that the amount of cash one has is \$1.75? Explain your answer.

f) Is it possible that the amount of cash one has is \$1.85? Explain your answer.

g) Suppose that the amount of cash is \$18.50. Determine the number of coins in this collection. How did you do this?

h) Now suppose that the collection of coins only consisted of dimes. List the five lowest possible amounts of cash in the collection. If the total amount of cash were \$18.50, how many coins would the collection contain? Which collection contains more coins? How did you determine this?

a)

number photons	total energy = number × energy one
0	0×10^{-20} J
1	25×10^{-20} J
2	50×10^{-20} J
3	75×10^{-20} J
4	100×10^{-20} J
5	125×10^{-20} J

b) yes it would require 7 photons

c) no 7 photons gives 175×10^{-20} J and 8 photons gives 200×10^{-20} J

185×10^{-20} J is between these d)

number of quarters	money
0	\$0.00
1	\$0.25
2	\$0.50
3	\$0.75
4	\$1.00
5	\$1.25

e) Yes, it requires 7 quarters

f) No, this is between 7 and 8 quarters.

g) $\text{number} = \dfrac{\text{total money value}}{\text{value one quarter}} = \dfrac{\$18.50}{\$0.25} = 74$ quarters.

h) \$0.00 \$0.30
\$0.10 \$0.40
\$0.20 \$0.50

$\text{number} = \dfrac{\$18.50}{\$0.10} = 185$ dimes. → collection of dimes ⇒ more coins

Now consider photons produced by different laser pointers, one red and the other green. The specifications of these are that the wavelength for the red is 6.35×10^{-7} m and the wavelength of the green is 5.20×10^{-7} m. The power produced by each is 0.005 W. We will use these to determine the number of photons that each laser produces in one second.

i) Determine the frequency of the light produced by each laser pointer.

j) Determine the energy of a single photon produced by each laser pointer.

k) The power specification means that in each second the laser produces a total energy of 0.005 J. Determine the number of photons that each laser produces in one second.

l) If you were to shine these lasers on a double slit, do you expect that you would notice individual photons in the pattern? Explain your answer.

red

i) $\text{freq} = \dfrac{3.0 \times 10^8}{\text{wavelength}} = \dfrac{3.0 \times 10^8 \text{ m/s}}{6.35 \times 10^{-7} \text{ m}} = 4.7 \times 10^{14} \text{ Hz}$

j) $\text{energy} = 6.63 \times 10^{-34} \times 4.7 \times 10^{14} \text{ Hz} = 3.1 \times 10^{-19} \text{ J}$

k) $\text{number} = \dfrac{\text{total energy}}{\text{energy one}} = \dfrac{0.005}{3.1 \times 10^{-19}} = 1.6 \times 10^{16}$

green

$\text{freq} = \dfrac{3.0 \times 10^8 \text{ m/s}}{5.2 \times 10^{-7} \text{ m}} = 5.8 \times 10^{14}$

$\text{energy} = 6.63 \times 10^{-34} \times 5.8 \times 10^{14} = 3.8 \times 10^{-19} \text{ J}$

$\text{number} = \dfrac{0.005}{3.8 \times 10^{-19} \text{ J}} = 1.3 \times 10^{16}$

l) No, there are more than 10^{16} photons and one could not distinguish a single one