KEY

First Name:_______________________________ Last Name:_______________________________

L13 – Worksheet – Photons

Textbook Questions

Pg 706 #1: What is the energy of a photon of light of frequency 4.00 x 10^{14} Hz?

$E = hf$

$= (6.63 \times 10^{-34}\ J \cdot s)(4.00 \times 10^{14}\ Hz)$

$= 2.652 \times 10^{-19}\ J$

Pg 706 #2: What is the energy of a green photon of light of wavelength 555 nm?

$\lambda = 555 \times 10^{-9}\ m$

$f = ?$

$c = 3.0 \times 10^{8}\ m/s$

$c = f\lambda$

$3.0 \times 10^{8}\ m/s = f\,(555 \times 10^{-9}\ m)$

$f = 5.405 \times 10^{14}\ Hz$

$E = hf$

$= (6.63 \times 10^{-34}\ J \cdot s)(5.405 \times 10^{14}\ Hz)$

$= 3.5838 \times 10^{-19}\ J$

Pg 707 #1: What is the frequency of a 10-nm photon?

$\lambda = 10 \times 10^{-9}\ m$

$c = 3.0 \times 10^{8}\ m/s$

$c = f\lambda$

$3.0 \times 10^{8}\ m/s = f\,(10 \times 10^{-9}\ m)$

$f = 3.0 \times 10^{16}\ Hz$

Pg 707 #2: What is the energy of a 10-nm photon?

$E = hf$

$= (6.63 \times 10^{-34}\ J \cdot s)(3.0 \times 10^{16}\ Hz)$

$= 1.989 \times 10^{-17}\ J$

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Pg 707 #3: How many photons of green light (λ = 550 nm) are required to deliver 10 J of energy?

$E_{tot} = 10 J$
$n = ?$
$\lambda = 550 nm$
$c = 3.0 \times 10^{8} m/s$
$f = ?$

$c = f\lambda$
$3.0 \times 10^{8} m/s = f(550 \times 10^{-9} m)$
$f = 5.4545 \times 10^{14} Hz$

$E = nhf$
$10 J = n(6.63 \times 10^{-34} J \cdot s)(5.4545 \times 10^{14} Hz)$
$n = 2.7652 \times 10^{19}$ photons

Pg 708 #1: How much energy is delivered by a beam of 1000 blue-light photons (λ = 400 nm)?

$E = ?$
$n = 1000$ photons
$\lambda = 400 \times 10^{-9} m$
$f = ?$
$c = 3.0 \times 10^{8} m/s$

$c = f\lambda$
$3.0 \times 10^{8} m/s = f(400 \times 10^{-9} m)$
$f = 7.50 \times 10^{14} Hz$

$E = nhf$
$= (1000)(6.63 \times 10^{-34} J \cdot s)(7.50 \times 10^{14} Hz)$
$= 4.9725 \times 10^{-16} J$

Pg 708 #2: How many 400-nm blue-light photons per second are required to deliver 10 W of power?

$P = \frac{\Delta E}{\Delta t}$

$\Delta t = 1 s$
$P = 10 W$

$10 W = \frac{\Delta E}{1 s}$

$\Delta E = 10 J$

$E = nhf$
$10 J = n(6.63 \times 10^{-34} J \cdot s)(7.50 \times 10^{14} Hz)$
$n = 2.011 \times 10^{19}$ photons per second

Diploma Questions – Photons (Basic Concepts)

Q636: A quantum of electromagnetic radiation is called

a. A proton
[✓ b.] A photon
c. An electron
d. A photoelectron

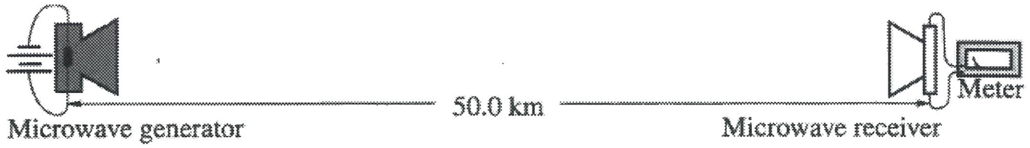
KEY

Diploma Questions – Photons (Photon Energy)

Use the following information to answer Q640– Q641:

Microwave Communication

A microwave generator emits photons that each have 4.37×10^{-23} J of energy. Some of these photons are detected by a microwave receiver placed 50.0 km away.



Q640: The time it takes microwave photons to travel from the generator to the receiver is

a. 6.00 x 10^{-4} s
b. 5.10 x 10^{-4} s
c. 3.33 x 10^{-4} s
[✓ d.] 1.67 x 10^{-4} s

$v=\frac{d}{t}$ or $t=\frac{d}{v}=\frac{50\times10^{3}}{3.0\times10^{8}}=1.67\times10^{-4}$ s

Q641: The frequency of the microwave photons, expressed in scientific notation, is ***b*** x 10^{w} Hz. The value of ***b*** is _____.

(Record your **three digit** answer in the Numerical Response boxes below)

6	.	5	9

$E = hf$

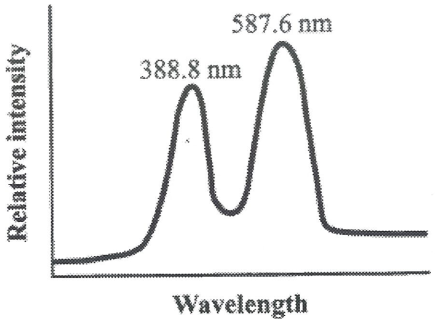
$4.37\times10^{-23} = (6.63\times10^{-34})f$

$f = 6.59\times10^{10}$ Hz

KEY

Use the following information to answer Q642:

A computer monitor displays the relative intensities of two emission lines of the helium spectrum, as shown below.



Q642: The difference in energy associated with the photons from the two lines of the helium spectrum is

a. 1.60 x 10^{-19} J
[✓ b.] 1.73 x 10^{-19} J
c. 4.07 x 10^{-19} J
d. 8.14 x 10^{-19} J

$$E_1 = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(388.8\times10^{-9})} = 5.11574\times10^{-19}\,J$$

$$E_2 = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(587.6\times10^{-9})} = 3.38495\times10^{-19}\,J$$

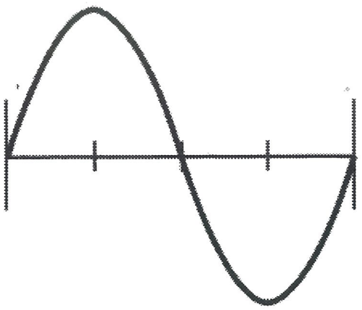
$$\Delta E = 1.73\times10^{-19}\,J$$

KEY

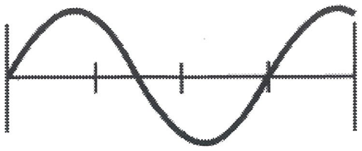
Use the following information to answer Q645:

Electromagnetic waves can be represented by the graphs of their electric fields. The following graphs represent the electric field of four electromagnetic waves over a fixed time interval.

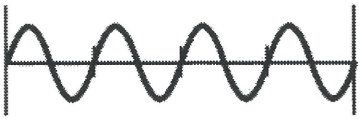
I.



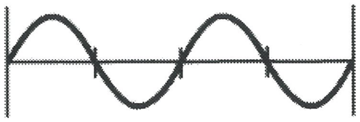
II.



III.



IV.



Q645: According to quantum theory, the electromagnetic wave that has the greatest amount of energy per photon is represented by graph

a. I

b. II

[✓ c.] III

d. IV

$E = hf$ so largest freq (smallest λ) has most energy.

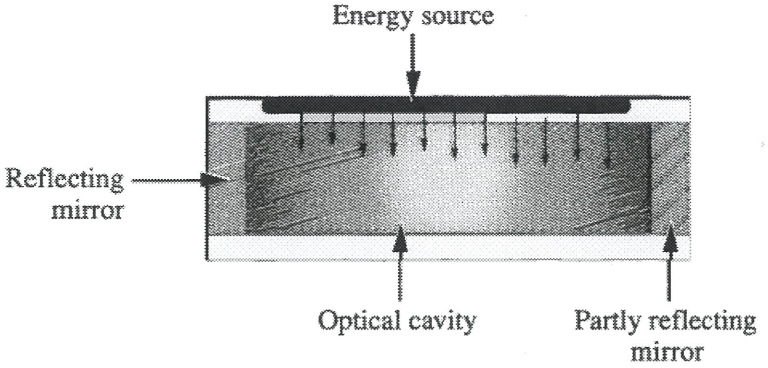
Quantum theory → Eregy not dependent on amplitude.

■ KEY ■

Diploma Questions – Photons (Power and Number of Photons)

Use the following information to answer Q646 – Q647:

A survey team uses 25.0 W lasers to map terrain. The laser is composed of three main parts: an energy source, an active medium, and an optical cavity. The optical cavity encloses the active medium and two mirrors. The active medium in the laser is a low-density helium–neon gas mixture.



Q646: The 25.0 W laser is only 0.0200% efficient in converting electric energy into photon energy. The output power of the laser is

[✓ a.] 5.00×10^{-3} W
b. 8.00×10^{-3} W
c. 1.25×10^{3} W
d. 3.14×10^{4} W

$$\text{Eff \%} = \frac{\text{Useful } E_{out}}{\text{Total } E_{in}} \times 100\%$$

$$0.0200\% = \frac{E_{out}}{25} \times 100\%$$

$$E_{out} = 0.005 \text{ J}$$
$$= 5.00 \times 10^{-3} \text{ J}$$

Q647: A beam of light from the laser has a wavelength of 633 nm. The number of photons per second emitted by the laser is

a. 9.99×10^{22}
b. 3.99×10^{21}
c. 2.55×10^{16}
[✓ d.] 1.59×10^{16}

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(633\times10^{-9})} = 3.14218\times10^{-19} \text{ J}$$
per photon

$$E_{TOTAL} = n(E_{photon})$$
$$5.00\times10^{-3} = n(3.14218\times10^{-19})$$
$$n = 1.59\times10^{16} \text{ photons}$$

KEY

Diploma Questions – Photons (X-Ray Production)

Q649: The maximum frequency of X-rays emitted from an electron tube operating at a potential difference of 4.0 x 10^4 V would be

a. 1.0 x 10^{19} Hz
[✓ b.] 9.7 x 10^{18} Hz
c. 4.3 x 10^{17} Hz
d. 1.6 x 10^{17} Hz

$E_p \rightarrow E_K \rightarrow E_{photon}$

$q\Delta V \rightarrow \frac{1}{2}mv^2 \rightarrow hf$

$q\Delta V \longrightarrow hf$

$(1.60\times10^{-19})(4\times10^{4}) = (6.63\times10^{-34})f$

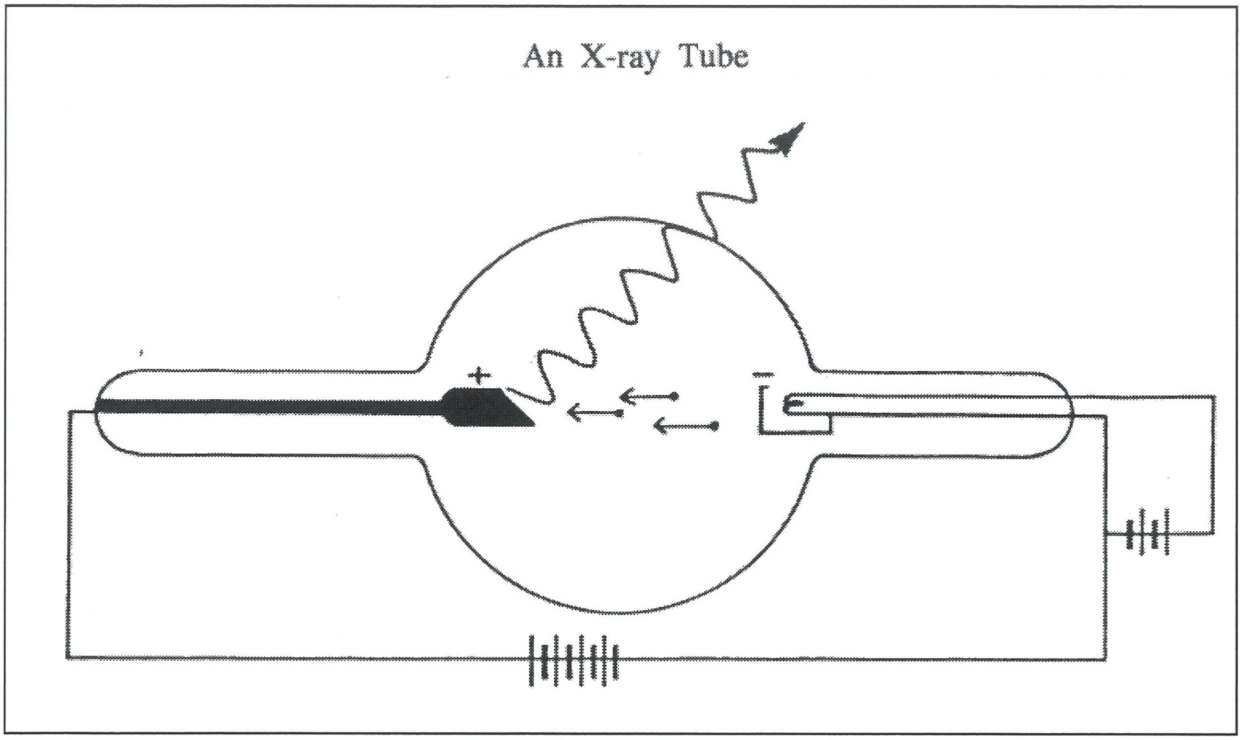
$f = 9.65 \times 10^{18} Hz$

Q650: A high-energy cathode ray is stopped by a tungsten target. This is the fundamental process involved in the production of

a. Beta radiation
b. Radar radiation
[✓ c.] X-ray radiation
d. Visible radiation

KEY

Use the following information to answer Q653:



Q653: Which of the following would **not** have an effect on the maximum frequency of the X-ray radiation produced?

$E_p \rightarrow E_k \rightarrow E_{photon}$

$q\Delta V \rightarrow \frac{1}{2}mv^2 \rightarrow hf$

- a. The speed of the electrons
- b. The kinetic energy of the electrons
- [✓ c.] The distance between the electrodes
- d. The potential difference across the electrodes

Q655: To produce X-rays of frequency 2.4 x 10^{17} Hz, an electron must have a speed of at least

- a. 9.9 x 10^3 m/s
- b. 5.8 x 10^6 m/s
- c. 1.3 x 10^7 m/s
- [✓ d.] 1.9 x 10^7 m/s

$E_p \rightarrow E_k \rightarrow E_{photon}$

$\frac{1}{2}mv^2 \rightarrow hf$

$\frac{1}{2}(9.11\times10^{-31})v^2 = (6.63\times10^{-34})(2.4\times10^{17})$

$v^2 = 3.4933\times10^{14}$

$v = 1.87\times10^{7}$ m/s

KEY

Q656: A television picture tube operates with a potential difference of 3.0×10^4 V. If X-rays are emitted from this picture tube, the minimum wavelength of the X-rays would be

a. 7.2×10^{18} m
[✓ b.] 4.1×10^{-11} m
c. 2.4×10^{10} m
d. 1.0×10^{-4} m

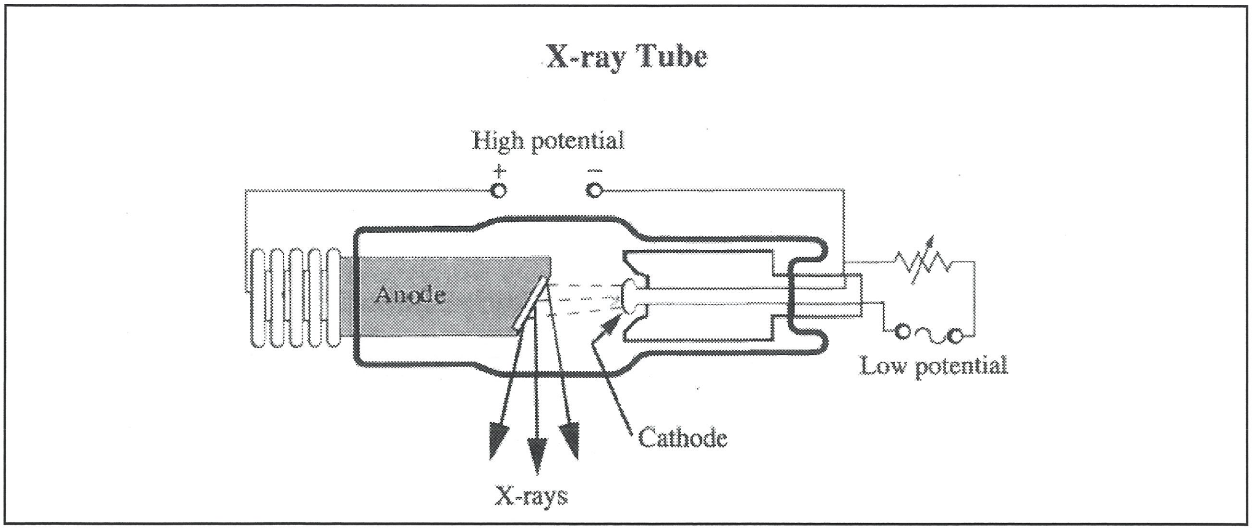
$E_p \rightarrow E_k \rightarrow E_{ph}$

$q\Delta V \longrightarrow \frac{hc}{\lambda}$

$(1.60\times10^{-19})(3.0\times10^{4}) = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{\lambda}$

$\lambda = 4.14 \times 10^{-11}$ m

Use the following information to answer Q660:



Q660: If the potential difference between the anode and the cathode is increased, the X-rays produced will have

[✓ a.] Shorter wavelengths and greater penetrating power
~~b.~~ Longer wavelengths and greater penetrating power
c. Shorter wavelengths and less penetrating power
~~d.~~ Longer wavelengths and less penetrating power

$E_p \rightarrow E_k \rightarrow E_{photon}$

$q\Delta V \longrightarrow hf$ or $q\Delta V \longrightarrow \frac{hc}{\lambda}$

Increase ΔV, then increase f
decrease λ

$E = \frac{hc}{\lambda}$ so smaller λ, more energy, more penetrating.

KEY

Use the following information to answer Q666:

X-rays were discovered in 1895 by Roentgen. In the cathode ray tube that he used, a high electrical potential difference between the anode and the cathode accelerated the electrons. The electrons then collided with a copper target.

Three Types of Energy

1	electrical potential energy
2	electromagnetic energy
3	kinetic energy

Q666: In the production of X-rays, the three types of energy listed above occur in order from ___ to ___ to ___.

(Record your **three digit** answer in the Numerical Response boxes below)

1	3	2	

$E_p \rightarrow E_K \rightarrow E_{photon}$

$1 \longrightarrow 3 \longrightarrow 2$

KEY

Diploma Questions – Photons (Tabulated Data and Graph Analysis)

Use the following information to answer Q670:

X-rays are produced when a metal target is bombarded by a stream of electrons. The table shows the wavelength of X-rays produced as a function of accelerating voltage.

Accelerating Voltage (10^5 V)	Wavelength (10^{-12} m)
1.8	4.6
2.0	4.4
3.5	2.5
4.5	1.9

From the data above, the following inferences may be drawn.

✗ I Wavelength is directly proportional to accelerating voltage.
✓ II Wavelength is inversely proportional to accelerating voltage.
✓ III Frequency is directly proportional to accelerating voltage.
✗ IV Frequency is inversely proportional to accelerating voltage.

Q670: The inferences that are consistent with the data are

a. I and III
b. I and IV
[✓ c.] II and III
d. II and IV

$E_p \rightarrow E_k \rightarrow E_{photon}$

$q\Delta V \longrightarrow \frac{hc}{\lambda}$ or $\lambda = \frac{hc}{q\Delta V}$ or $\lambda \propto \frac{1}{\Delta V}$

$\uparrow \Delta V$ then $\downarrow \lambda$

$E_p \rightarrow E_{photon}$

$q\Delta V \rightarrow hf$

$f = \frac{q\Delta V}{h}$ or $f \propto \Delta V$

KEY

Cumulative Review from Previous Units

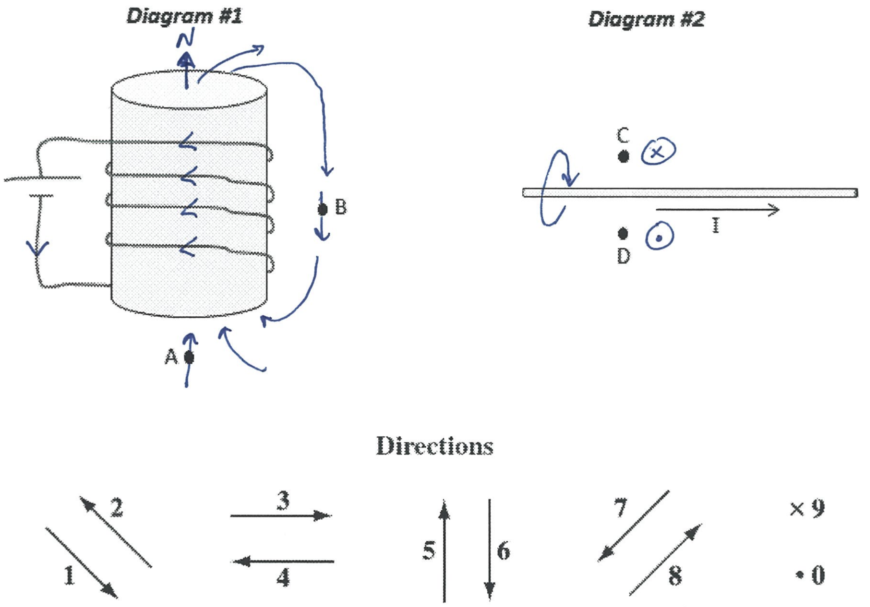
Q1: Coulomb started with two identically charged spheres separated by a distance *r*. The force between the spheres was *F*. If he changed the separation to $\frac{2}{3}r$, then the force between the spheres would have become

$$F_{new} = \frac{kq_1q_2}{(\frac{2}{3}r)^2} = \frac{kq_1q_2}{\frac{4}{9}r^2} = \frac{9}{4}\left(\frac{kq_1q_2}{r^2}\right)$$

a. $\frac{4}{9}F$
b. $\frac{2}{3}F$
c. $\frac{3}{2}F$
[✓ d.] $\frac{9}{4}F$

Use the following information to answer Q2:

Magnetic Fields around Current in a Wire



Q2: The directions of magnetic fields at various locations can be described using the numbers given above.

Direction:	↑ 5	↓ 6	⊗ 9	⊙ 0
Field:	**Direction of magnetic field at *Position A***	**Direction of magnetic field at *Position B***	**Direction of magnetic field at *Position C***	**Direction of magnetic field at *Position D***

*(Record your **four digit** answer in the Numerical Response boxes below)*

5	6	9	0