Light Equation Worksheet **Name** Key **Period**________

Max Planck theorized that energy was transferred in chunks known as **quanta**, equal to $h\nu$. The variable h is a constant equal to 6.63×10^{-34} J·s and the variable ν represents the frequency in 1/s. This equation allows us to calculate the energy of photons, given their frequency. If the wavelength is given, the energy can be determined by first using the wave equation ($c = \lambda\nu$) to find the frequency, then using Planck's equation to calculate energy.

$1\ nm = 1 \times 10^{-9}\ m$

speed of light = wavelength x frequency $c = \lambda\nu$

(speed of light = $c = 3.00 \times 10^8$ m/s) $E = h\nu$ h = Planck's constant = 6.626×10^{-34} J·s

Color	Wavelength λ	Frequency ν $= c/\lambda$	Energy E $= h\nu$
Violet	400 nm = 400×10^{-9} m	$= 3.00 \times 10^8$ m/s ÷ 4.00×10^{-7} m $= 7.50 \times 10^{14}$ /s (Hz)	$= 6.626 \times 10^{-34}(7.5 \times 10^{14}/s)$ $= 49.695 \times 10^{-20}$ $= 4.97 \times 10^{-19}$ JS
Indigo	445 nm $= 445 \times 10^{-9}$ m	$= 3.00 \times 10^8$ m/s $/ 445 \times 10^{-9}$ $= 0.00674 \times 10^{17}$ $= 6.74 \times 10^{14}$ /s	4.47×10^{-19}
Blue	475 nm $= 475 \times 10^{-9}$	$= 3.00 \times 10^8 / 475 \times 10^{-9}$ $= 6.32 \times 10^{14}$ /s	4.19×10^{-19}
Green	510 nm 510×10^{-9} m	$= 3 \times 10^8 / 510 \times 10^{-9}$ $= 5.88 \times 10^{14}$ /s	3.90×10^{-19}
Yellow	570 nm 570×10^{-9} m	$= 3 \times 10^8 / 570 \times 10^{-9}$ $= 5.26 \times 10^{14}$ /s	3.49×10^{-19}
Orange	590 nm 590×10^{-9}	$= 3 \times 10^8 / 590 \times 10^{-9}$ $= 5.08 \times 10^{14}$ /s	3.37×10^{-19}
Red	650 nm 650×10^{-9}	$= 3 \times 10^8 / 650 \times 10^{-9}$ $= 4.62 \times 10^{14}$ /s	3.06×10^{-19}
Hydrogen – red line	656 nm 656×10^{-9}	$= 3 \times 10^8 / 656 \times 10^{-9}$ $= 4.58 \times 10^{14}$ /s	3.03×10^{-19}

Rank these bands of light from lowest energy (1) to highest (7):

Gamma	Infrared	Microwave	Radio	Visible	Ultraviolet	X-ray
7	3	2	1	4	5	6

Rank these parts of the electromagnetic spectrum from lowest frequency (a) to highest (g):

Gamma	Infrared	Microwave	Radio	Visible	Ultraviolet	X-ray
g	c	b	a	d	e	f

Rank these types of light from the shortest wavelength (A) to the longest wavelength (G):

Gamma	Infrared	Microwave	Radio	Visible	Ultraviolet	X-ray
A	E	F	G	D	C	B

Electromagnetic Radiation Light as Waves Worksheet

Use the following equation to solve the following problems:

$c = \lambda v$

c = the speed of light (2.998×10^8 m/sec)

λ= wavelength measured in meters.

v= frequency (unit is sec^{-1} or hertz (Hz))

Conversions

1nm = 10^{-9} m

10^9 = 1m

10^2 cm = 100cm = 1m

1. What is the frequency in hertz of red light having a wavelength of 710 nm? 710×10^{-9} m

$v = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/sec}}{710 \times 10^{-9} \text{ m}} = 4.23 \times 10^{14} \text{ /sec}$

2. Ozone protects the earth's inhabitants from the harmful effects of ultraviolet light arriving from the sun. This shielding is a maximum for UV light having a wavelength of 295 nm. What is the frequency in hertz of this particular wavelength of UV light?

$v = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/sec}}{295 \times 10^{-9} \text{ m}} = 1.02 \times 10^{15} \text{ /sec} = 10.2 \times 10^{14} \text{ /sec}$

$295 \text{ nm} = 295 \times 10^{-9} \text{ m}$

3. Radar signals are also part of the electromagnetic spectrum in the microwave region. A typical radar signal has a waveleng of 3.19 cm. What is the frequency in hertz?

$3.19 \text{ cm} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 0.0319 \text{ m}$

$v = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/sec}}{0.0319 \text{ m}} = 94 \times 10^8 \text{ /sec}$ $\quad \frac{3 \times 10^8}{3.19 \times 10^{-2}} = 94.04 \times 10^{10} \text{ Hz}$

4. AM radio dials are calibrated in frequency. A certain AM Brockville radio station broadcasts at a frequency of 830 kHz. What is the wavelength of these radio waves expressed in meters? $c = \lambda v$ $\quad \lambda = \frac{c}{v} = \frac{2.998 \times 10^8 \text{ m}}{\text{sec}} \left(\frac{\text{sec}}{830{,}000}\right) = 361 \text{ m}$

$830 \text{ KHz} \left(\frac{1000 \text{ Hz}}{1 \text{ KHz}}\right) = 830{,}000 \text{ Hz} = 830{,}000 \text{ /sec}$

Use the following equations to solve the following problems:

$E = nhv$

E = energy in Joules (J)

h = plank's constant 6.626×10^{-34} J s

n = integer (number of photons)

$c = \lambda v$

c = the speed of light (2.998×10^8 m/sec)

λ = wavelength measured in meters.

v = frequency (unit is sec^{-1} or hertz (Hz))

5. Sodium vapor lamps are used to sometimes light streets. If the frequency of the light coming from them is 5.09 x 1014 Hz what is the energy in each photon? $n = 1$ for one photon

$E = nhv = 1(6.626 \times 10^{-34} \text{ Js})(5.09 \times 10^{14} \text{ Hz}) = 33.73 \times 10^{-20} \text{ J}$

6. What is the energy of each photon of red light that has a frequency of 4.0 x 10^{14} Hz?

$E = hv = (6.626 \times 10^{-34} \text{ Js})(4.0 \times 10^{14} \text{ Hz}) = 26.5 \times 10^{-20} \text{ J}$

7. Calculate the energy in joules/photon for green light having a wavelength of 550 nm. 550×10^{-9} m

$E = hv, \quad v = \frac{c}{\lambda} \quad v = \frac{3 \times 10^8 \text{ m/s}}{550 \times 10^{-9} \text{ m}} = 0.005545 \times 10^{17} = 5.45 \times 10^{14} \text{ Hz}$

$E = (6.626 \times 10^{-34} \text{ Js})(5.45 \times 10^{14}) = 36.11 \times 10^{-20} \text{ J} = 3.61 \times 10^{-19}$

8. Microwaves are used to heat food in microwave ovens. The microwave radiation is absorbed by moisture in the food. This heats the water, and as water becomes hot, so does the food. How many photons having a wavelength of 3.00 mm would hav to be absorbed by 1.00 g of water to raise its temperature by 1oC? It takes 4.184 J of energy to heat this much water.

$E = 4.184 \text{ J}$ $\quad \lambda = 3 \text{ mm} = 3 \times 10^{-3} \text{ m}$ $\quad 1000 \text{ mm} = 1 \text{ m}$ $\quad 3 \text{ mm} \left(\frac{1 \text{ m}}{1000 \text{ mm}}\right) = 0.003 \text{ m}$ $\quad v = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/s}}{0.003 \text{ m}} = 1000 \times 10^8$

$n = ?$ $\quad E = nhv$ $\quad n = \frac{E}{hv} = \frac{4.184 \text{ J}}{(6.626 \times 10^{-34} \text{ Js})(1000 \times 10^8)} = \frac{4.184 \times 10^0}{6626 \times 10^{-26}} = 0.000631 \times 10^{26}$

$= 6.31 \times 10^{22}$

9. What is the relationship between frequency and wavelength? (Direct or Inverse)

10. What is the relationship between frequency and energy? (Direct or Inverse)