

First Name: \_\_\_\_\_

Last Name: \_\_\_\_\_

120 - Worksheet - EMR Unit Review

**L01 - EMR**

**Q1:** An ultraviolet source emits electromagnetic waves with a frequency of  $2.47 \times 10^{15}$  Hz. Its wavelength, expressed in scientific notation, is  $b \times 10^{-w}$  m. The value of  $b$  is \_\_\_\_\_.

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

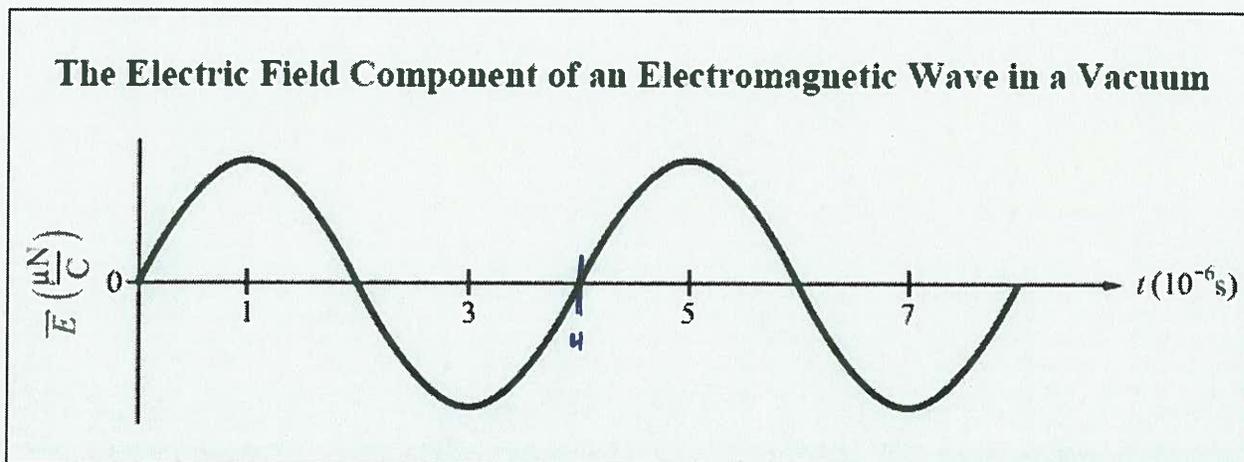
1	.	2	1
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$$c = f\lambda$$

$$(3.0 \times 10^8) = (2.47 \times 10^{15})\lambda$$

$$\lambda = 1.21 \times 10^{-7} \text{ m}$$

Use the following information to answer Q2:



**Q2:** The wavelength of this electromagnetic wave is

- a.  $6.0 \times 10^2$  m
- b.  $1.2 \times 10^3$  m
- c.  $2.5 \times 10^5$  m
- d.  $7.5 \times 10^{13}$  m

$$T = \frac{1}{f} \quad f = \frac{1}{4 \times 10^{-6}} = 2.50 \times 10^5 \text{ Hz}$$

$$c = f\lambda$$

$$(3.0 \times 10^8) = (2.50 \times 10^5)\lambda$$

$$\lambda = \frac{1200 \text{ m}}{1} = 1.2 \times 10^3 \text{ m}$$

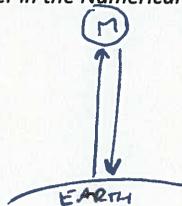
Q3: Electromagnetic radiation is produced by charged particles that are moving

- a. At the speed of light
- b. With zero acceleration
- c. With a changing velocity**
- d. Parallel to a fixed magnetic field

Q4: An electromagnetic wave is sent from Earth to the Moon and reflected back to Earth. If the total time taken is 2.48 s, then the distance from Earth to the Moon, expressed in scientific notation, is  $b \times 10^w$  m. The value of  $b$  is \_\_\_\_\_.

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

3	.	7	2
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$$v = \frac{d}{t}$$

$$3.0 \times 10^8 = \frac{d}{2.48}$$

$$d_{\text{roundtrip}} = 7.44 \times 10^8 \text{ m}$$

$$d_{1/2} = 3.72 \times 10^8 \text{ m}$$

Q5: Which of the following types of radiation has the longest period?

- a. Radio waves**
- b. Infrared light
- c. Ultraviolet light
- d. Gamma radiation

$$c = f\lambda$$

$$\text{and } T = \frac{1}{f}$$

Low f                      High f  
 R M I V U X G  
 Big T                      Small T

Q6: Which of the following properties is a property of X-rays not of radio waves?

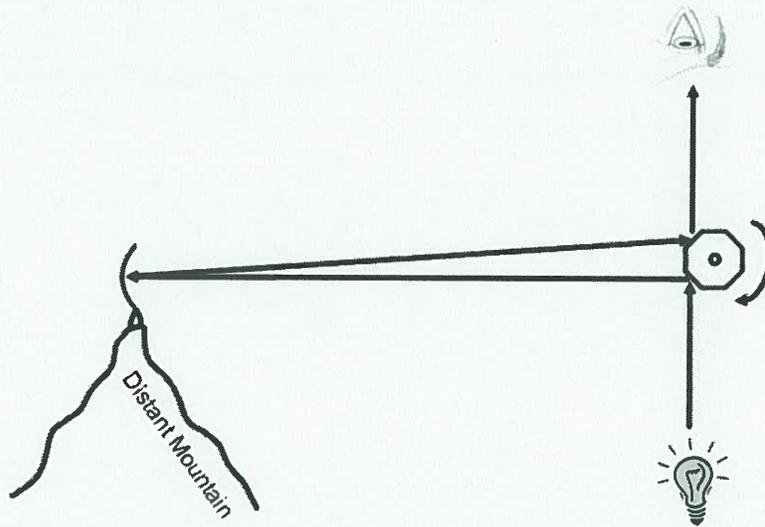
- a. Reflection
  - b. Refraction
  - c. Interference
  - d. Gas ionization** by process of elimination
- } Properties of all waves, not just EMR

L02 – Speed of Light

Use the following information to answer Q7:

A student is curious about how far away a distant mountain is. She drives to the distant mountain, climbs to the top, and sets up a reflecting mirror. Back at her residence, the student recreates Michelson's experiment, per the diagram below.

The student finds that light is able to successfully travel from the light source to her eye when the octagonal mirror has a rotational frequency of 525 Hz.



Q7: Using the experiment described above, how far away is the mountain from the student's household?

- a) 35.7 km
- b) 71.4 km
- c) 142.9 km
- d) 571.4 km

$$f = 525 \text{ Hz}$$

$$T = \frac{1}{f} = 1.90476... \times 10^{-3} \text{ s}$$

1/8<sup>th</sup> of a rotation in 1/8<sup>th</sup> of a period

$$\text{time for } 1/8^{\text{th}} \text{ of a rotation} = 2.38095... \times 10^{-4} \text{ s}$$

$$v = \frac{d}{t}$$

$$3.0 \times 10^8 = \frac{d_{\text{round trip}}}{2.38095... \times 10^{-4}}$$

$$d_{\text{round trip}} = 7.1428 \times 10^4 \text{ m}$$

$$d^{1/2} = 3.5714 \times 10^4 \text{ m}$$

$$\approx 35.7 \text{ km}$$

L03&04 – Reflection Ray Diagrams and Equations

Use the following information to answer Q8-Q10:

A 2cm tall object is placed 15cm from the vertex of a concave mirror. A real image appears 20cm from the vertex.

Q8: The focal length of the concave mirror is \_\_\_\_ cm.

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

8 . 5 7

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{f} = \frac{1}{15} + \frac{1}{20}$$

$$f = 8.57 \text{ cm}$$

Q9: Which best describes the image formed?

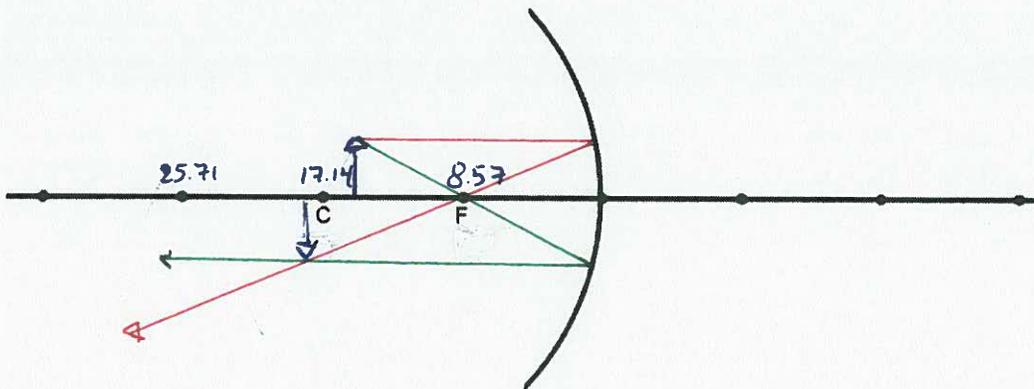
- a. 1.5 cm tall and erect
- b. 1.5 cm tall and inverted
- c. 2.7 cm tall and erect
- d. 2.7 cm tall and inverted

$$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$\frac{h_i}{2} = -\frac{(20)}{15}$$

$$h_i = -2.6 \text{ cm}$$

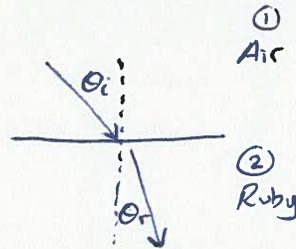
Q10: Sketch a ray diagram for this question.



L05 - Refraction

Q11: When light passes from air into a ruby ( $n = 1.54$ ), the wavelength of the light i and the frequency of the light ii.

	i	ii
A	increases	<del>decreases</del>
B	increases	stays the same
C	decreases	<del>decreases</del>
D	decreases	stays the same



- a) A
- b) B
- c) C
- d) D**

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$$

$$n_1 \lambda_1 = n_2 \lambda_2$$

Q12: Visible light that has a wavelength of  $6.00 \times 10^{-7}$  m in air is directed into fused quartz. The index of refraction of fused quartz is 1.46. The wavelength of this light inside the fused quartz, expressed in scientific notation, is       $\times 10^{-7}$  m.

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

4	.	1	1
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Air (1)

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$n_1 = 1.00$   
 $\lambda_1 = 6.00 \times 10^{-7} \text{ m}$

Ruby (2)

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$n_2 = 1.46$   
 $\lambda_2 = ?$

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$$

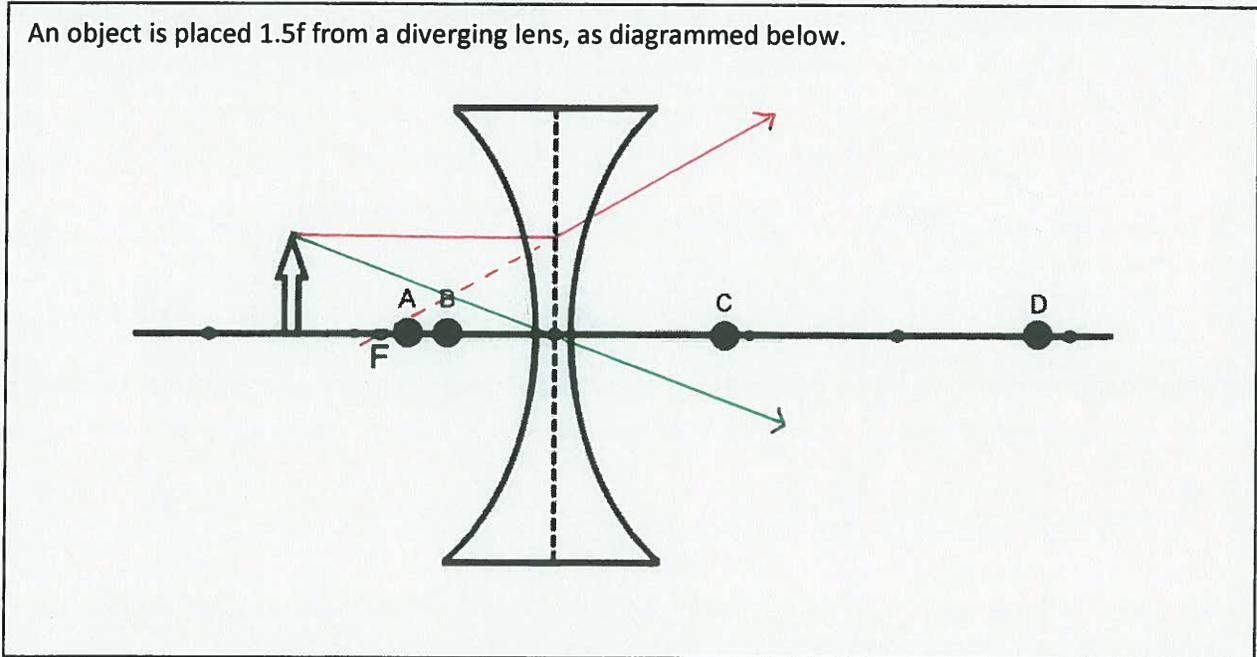
$$\frac{1.46}{1.00} = \frac{6.00 \times 10^{-7}}{\lambda_2}$$

$$\lambda_2 = 4.1095 \dots \times 10^{-7}$$

$$\approx 4.11 \times 10^{-7} \text{ m}$$

L06 – Refraction Lenses

Use the following information to answer Q13:



Q13: Which of the following best described the image that is formed?

- a) Position A, Virtual, Inverted, and Enlarged
- b) Position B, Virtual, Erect, and Diminished
- c) Position C, Real, Erect, and Diminished
- d) Position D, Real, Inverted, and Enlarged

Q14: At what distance above this page would a convex magnifying lens that has a focal length of 10.0 cm have to be held for the image of the letters to appear upright and 3 times as tall?

- a. 3.33 cm
- b. 6.67 cm
- c. 13.3 cm
- d. 15.0 cm

$$m = \frac{-d_i}{d_o}$$

$$+3 = \frac{-d_i}{d_o}$$

$$3d_o = -d_i$$

$$d_i = -3d_o$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{10} = \frac{1}{d_o} + \frac{1}{-3d_o}$$

Make a common denominator of  $30d_o$ .

$$\frac{3d_o}{30d_o} = \frac{30}{30d_o} - \frac{10}{30d_o}$$

$$3d_o = 30 - 10$$

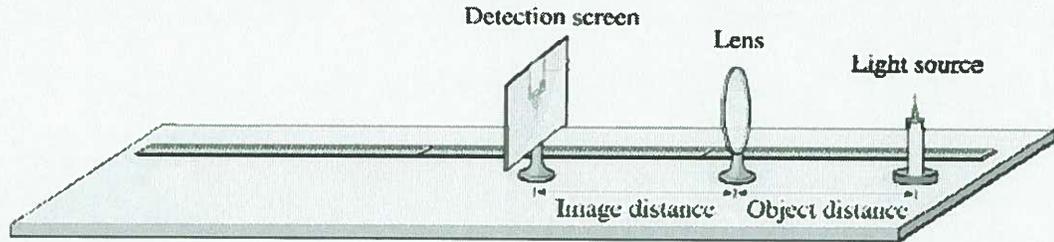
$$3d_o = 20$$

$$d_o = \frac{20}{3} = 6.6\bar{7} \text{ cm}$$

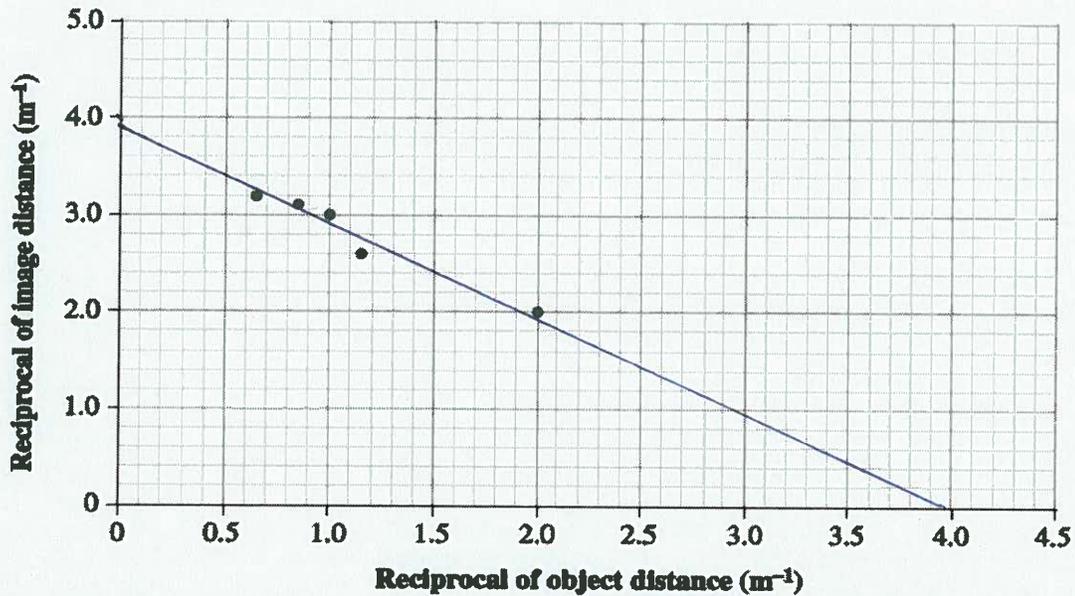
L07 – Refraction Lenses Graphing and Optics Rails

Use the following information to answer the next question.

Some physics students do an experiment to find the focal length of a converging lens. They set up an optical bench and measure the image distance as a function of the object distance.



Their data are plotted below.



Q15: The slope of the line is  $-a.b$ . You will need to record the values of  $a$  and  $b$ .

Using the y-intercept, the experimental value of the focal length of the lens, expressed in units of centimeters, is  $ef$  cm. You will need to record the values of  $e$  and  $f$ .

The values of  $a$ ,  $b$ ,  $e$ , and  $f$  are 1, 0, 2, and 6.

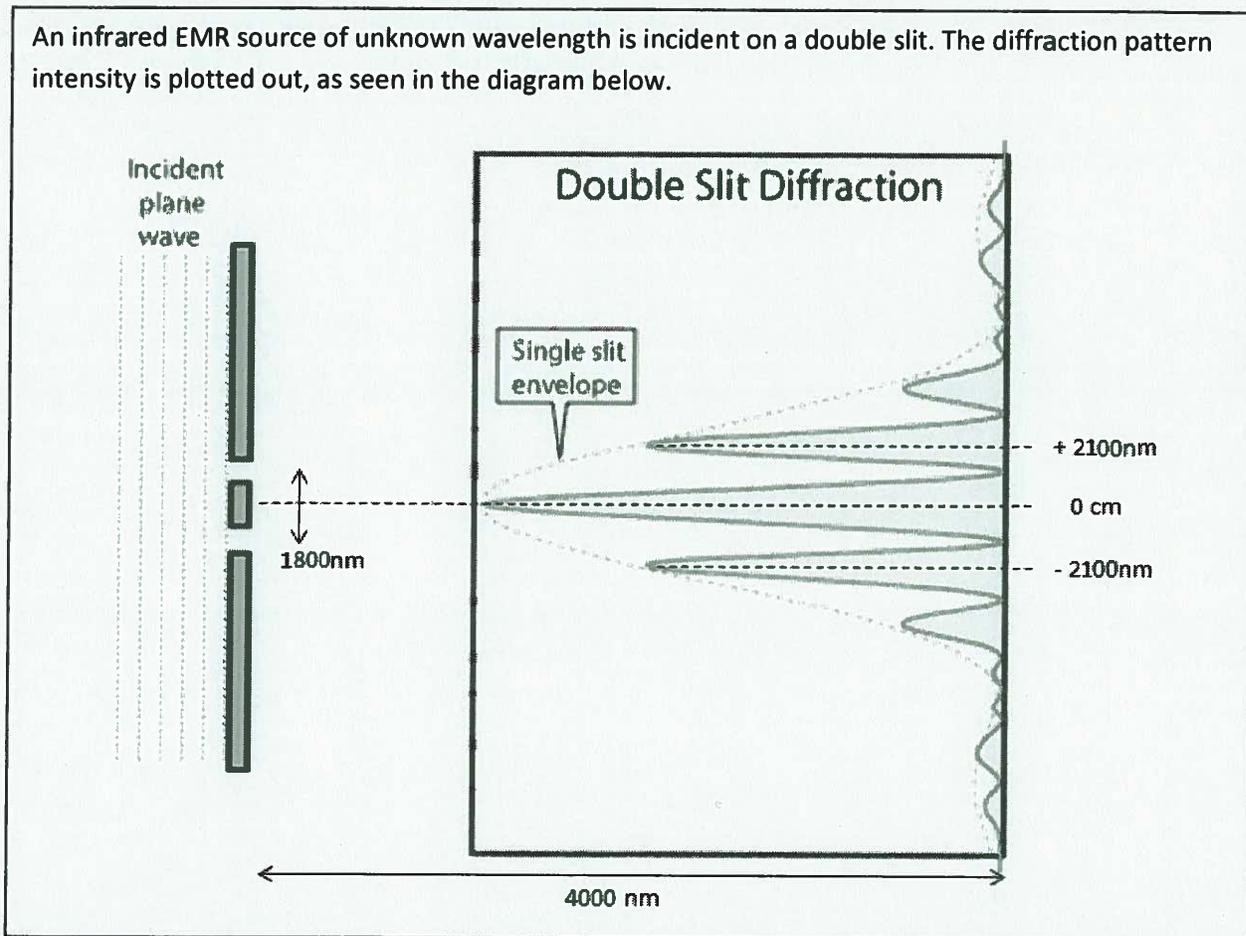
(Record your four digit answer in the Numerical Response boxes below)

1	0	2	6
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$m = -1.0$   
 y-intercept is 3.9  
 $f = \frac{1}{3a} = 0.2564$   
 $\approx 26\text{cm}$

L09 – Diffraction, Interference, and Polarization

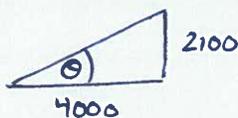
Use the following information to answer Q16:



Q16: In the above experiment, the wavelength of the infrared EMR wave is  $a.bc \times 10^{-d}$  m, where the values of  $a$ ,  $b$ ,  $c$ , and  $d$  are \_\_, \_\_, \_\_, and \_\_. (2 marks)

(Write your four-digit numerical response answer in the boxes below)

8	3	7	7
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$$\tan \theta = \frac{2100}{4000}$$

$$\theta = \tan^{-1} \left( \frac{2100}{4000} \right)$$

$$\theta = 27.6994728081^\circ$$

$$\lambda = \frac{d \sin \theta}{n}$$

$$\lambda = \frac{(1800 \times 10^{-9}) \sin (27.6994 \dots)}{1}$$

$$\lambda = 0.367 \dots \times 10^{-7} \text{ m}$$

$$\lambda = 0.37 \times 10^{-7} \text{ m}$$

L13 - Photons

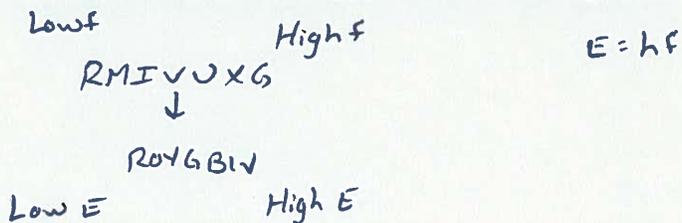
Use the following information to answer Q17:

The different colors seen in exploding fireworks are produced using different elements.

Element	Predominant Color
Strontium	Red ←
Barium	Green
Copper	Blue-Green
Sodium	Yellow-Orange

Q17: Given the information above, the element that emits the lowest energy photon of visible light is

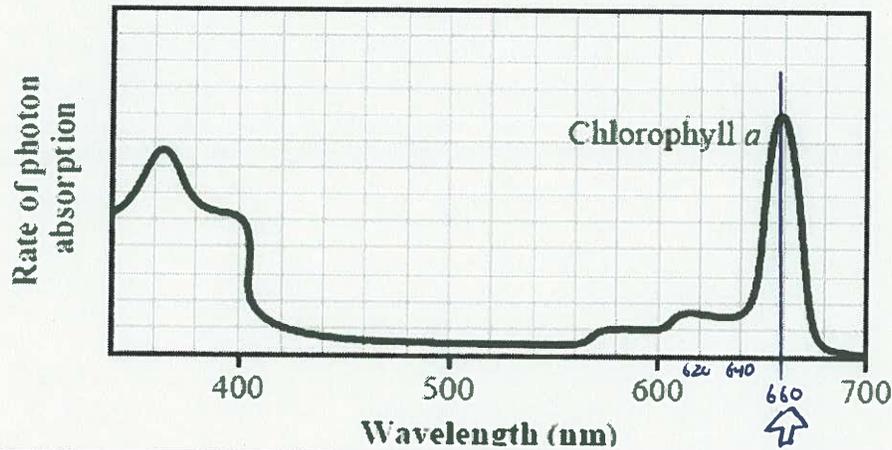
- a. Strontium
- b. Barium
- c. Copper
- d. Sodium



Use the following information to answer Q18:

Chlorophyll in plants absorbs photon energy of electromagnetic radiation and converts them into chemical potential energy. Chlorophyll *a* is one of the main types of chlorophyll. The graph below shows the relationship between the absorption of photons by chlorophyll *a* and the wavelength of the photons striking the plants.

**Absorption Rate as a Function of Incident Wavelength**



**Q18:** To produce the maximum rate of photon absorption by chlorophyll *a*, photons should have an energy of

- a. 1.77 eV
- b. 1.88 eV
- c. 2.48 eV
- d. 3.40 eV

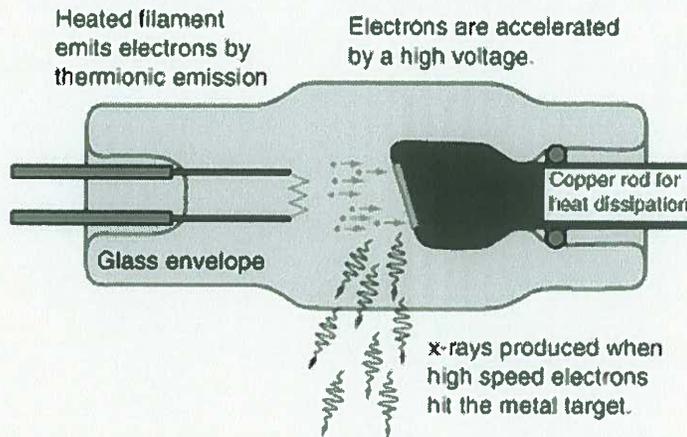
$$E = \frac{hc}{\lambda} = \frac{(4.14 \times 10^{-15})(3.0 \times 10^8)}{(660 \times 10^{-9})}$$

$$E = 1.8818... \text{ eV}$$

**L13 – X-Ray Production**

Use the following information to answer Q19-Q20:

X-Rays for medical diagnostic procedures or for research purposes are produced in a standard way: by accelerating electrons with a high voltage and allowing them to collide with a metal target. X-Rays are produced when the electrons are suddenly decelerated upon collision with the metal target.



**Q19:** Which *Physics Principle(s)* is/are needed to describe the above phenomena?

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

5	9		
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5- Conservation of Energy  
9- Wave-particle duality

**Q20:** If the emitted X-Rays have a frequency of  $3.2 \times 10^{16}$  Hz, how fast did the electrons strike the metal target?

- a)  $1.33 \times 10^2$  m/s
- b)  $3.41 \times 10^6$  m/s
- c)  $6.82 \times 10^6$  m/s**
- d)  $1.71 \times 10^{16}$  m/s

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

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

$$\frac{1}{2}(9.11 \times 10^{-31})v^2 = (6.63 \times 10^{-34})(3.2 \times 10^{16})$$

$$v = 6.82 \times 10^6 \text{ m/s}$$

Use the following information to answer Q21:

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.

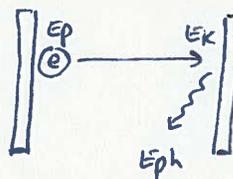
**Three Types of Energy**

- 1 electrical potential energy
- 2 electromagnetic energy
- 3 kinetic energy

**Q21:** In the production of X-rays, the three types of energy listed above occur in order from \_\_\_ to \_\_\_ to \_\_\_.

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

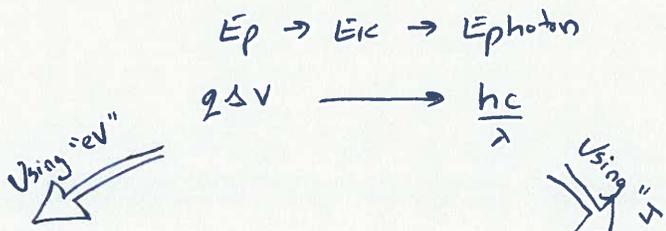
1	3	2	
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**Q22:** The minimum accelerating voltage necessary to produce an X-ray with a wavelength of  $6.25 \times 10^{-11}$  m, expressed in scientific notation, is  $a.bc \times 10^d$  V. The values of  $a$ ,  $b$ ,  $c$ , and  $d$  are \_\_, \_\_, \_\_, and \_\_.

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

1	9	9	4
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$$(1e)(\Delta V) = \frac{(4.14 \times 10^{-15})(3.0 \times 10^8)}{(6.25 \times 10^{-11})}$$

$$\Delta V = 19872 \text{ V}$$

$$\approx 1.99 \times 10^4 \text{ V}$$

$$(1.60 \times 10^{-19})(\Delta V) = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(6.25 \times 10^{-11})}$$

$$\Delta V = 19890 \text{ V}$$

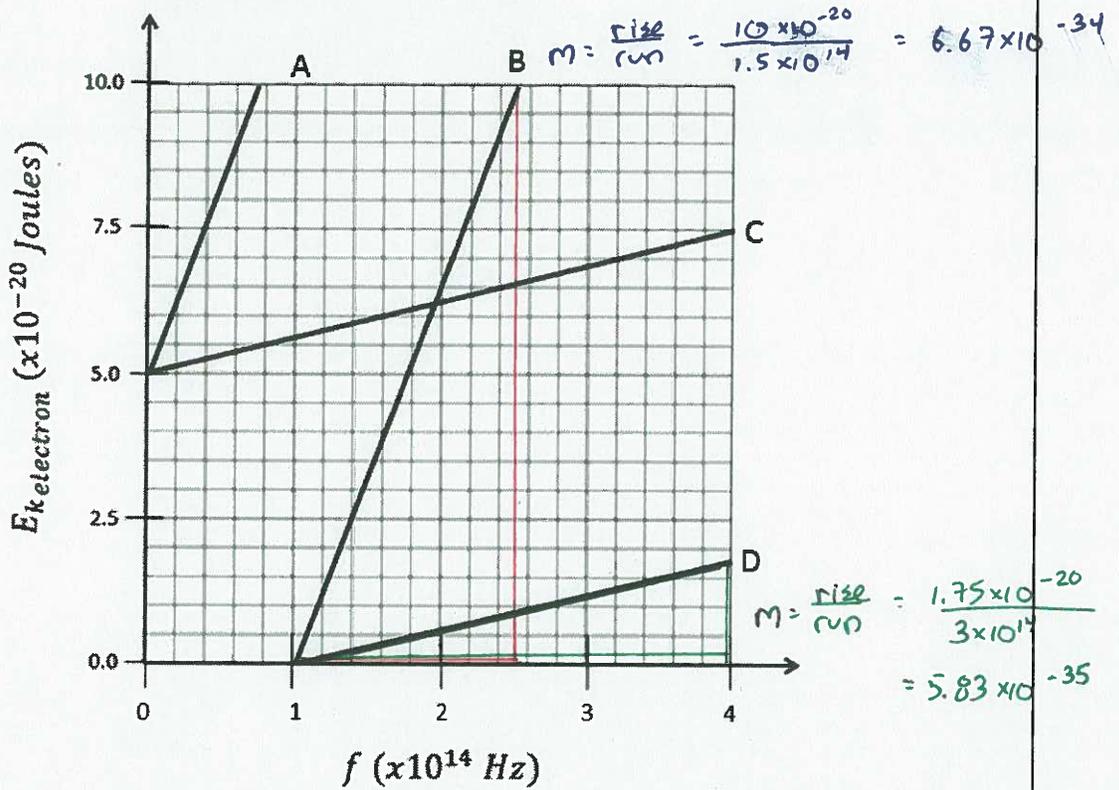
$$\approx 1.99 \times 10^4 \text{ V}$$

L14&15 – Photoelectric Effect 1&2

Use the following information to answer Q23:

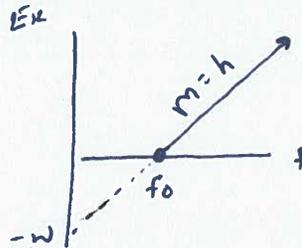
Light of varying frequency is incident on a photoelectron emitting surface. Maverick Wilford has attempted to plot out the relationship between the two, but Mr. Bayer is still upset about Maverick trying to feed him cookies with the consistency of particle board, so Mr. Bayer vindictively draws additional lines on Maverick's graph to confuse him.

Calculating Plank's Constant



Q23: In the above graph, which of the following lines best shows the relationship between the incident light frequency and the kinetic energy of the emitted photoelectrons?

- a) Line A
- b) Line B
- c) Line C
- d) Line D



Slope should be  $6.63 \times 10^{-34} \text{ Js}$

Check slopes of B and D.

**Q24:** The energy that is required to remove the electron from the photoelectric surface in the phototube is called the

- a. Work function
- b. Threshold frequency
- c. Electric potential energy
- d. Maximum kinetic energy

**Q25:** In one second,  $1.45 \times 10^{16}$  photons are incident on the phototube. If each of the photons has a frequency greater than the threshold frequency, then the maximum current to the amplifier, expressed in scientific notation, is  $a.bc \times 10^d$  A. The values of  $a$ ,  $b$ ,  $c$ , and  $d$  are \_\_, \_\_, \_\_, and \_\_.

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

2	3	2	3
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$1.45 \times 10^{16}$  photons eject  $1.45 \times 10^{16}$  electrons.

$$I = \frac{q}{t} = \frac{(1.45 \times 10^{16})(1.60 \times 10^{-19})}{(1)} = 0.00232 \text{ A}$$

$$= 2.32 \times 10^{-3} \text{ A}$$

**Q26:** If the stopping potential of a photocell is 5.60 V, then the maximum kinetic energy of the photoelectrons emitted is

- a.  $3.50 \times 10^{19}$  J
- b. 5.60 J
- c.  $8.96 \times 10^{-19}$  J
- d.  $2.90 \times 10^{-20}$  J

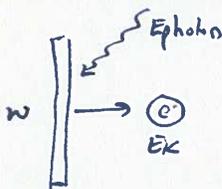
$$E_{K \max} = qV_{\text{stop}} \quad (\text{or } E_K \rightarrow E_p)$$

$$E_{K \max} = (1.60 \times 10^{-19})(5.60)$$

$$= 8.96 \times 10^{-19} \text{ J}$$

**Q27:** If a metal with a threshold frequency of  $1.1 \times 10^{15}$  Hz is illuminated by light with a wavelength of  $1.70 \times 10^{-7}$  m, then the maximum kinetic energy of the emitted photoelectrons will be

- a.  $4.4 \times 10^{-19}$  J
- b.  $7.3 \times 10^{-19}$  J
- c.  $1.2 \times 10^{-18}$  J
- d.  $1.5 \times 10^{-18}$  J



$$E_{\text{photon}} \rightarrow W + E_K$$

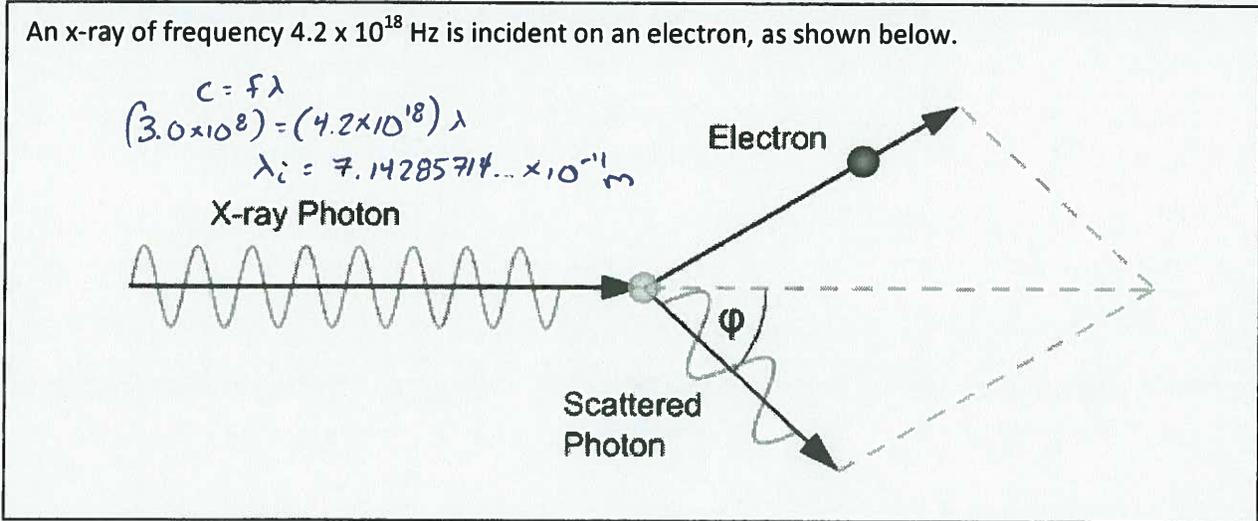
$$\frac{hc}{\lambda} \rightarrow hf_0 + E_K$$

$$\frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(1.70 \times 10^{-7})} = (6.63 \times 10^{-34})(1.1 \times 10^{15}) + E_K$$

$$E_K = 4.407 \times 10^{-19} \text{ J}$$

L16 – Compton Effect

Use the following information to answer Q28 and Q29:



Q28: If the wavelength of the scattered photon is  $7.18 \times 10^{-11}$  m, what angle was it scattered at? (2 marks)

(Write your 3-digit numerical response answer in the boxes below)

3	2	.	1
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$$\Delta\lambda = \lambda_f - \lambda_i$$

$$= 7.18 \times 10^{-11} - 7.142857 \times 10^{-11}$$

$$= 3.714285... \times 10^{-13} \text{ m}$$

$$\Delta\lambda = \frac{h}{mc} (1 - \cos\theta)$$

$$3.714285 \times 10^{-13} = \frac{(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(3 \times 10^8)} (1 - \cos\theta)$$

$$(1 - \cos\theta) = 0.1531092...$$

$$-\cos\theta = -0.84689$$

$$\cos\theta = +0.84689$$

$$\theta = 32.12^\circ$$

Q29: The momentum of the incident photon is:

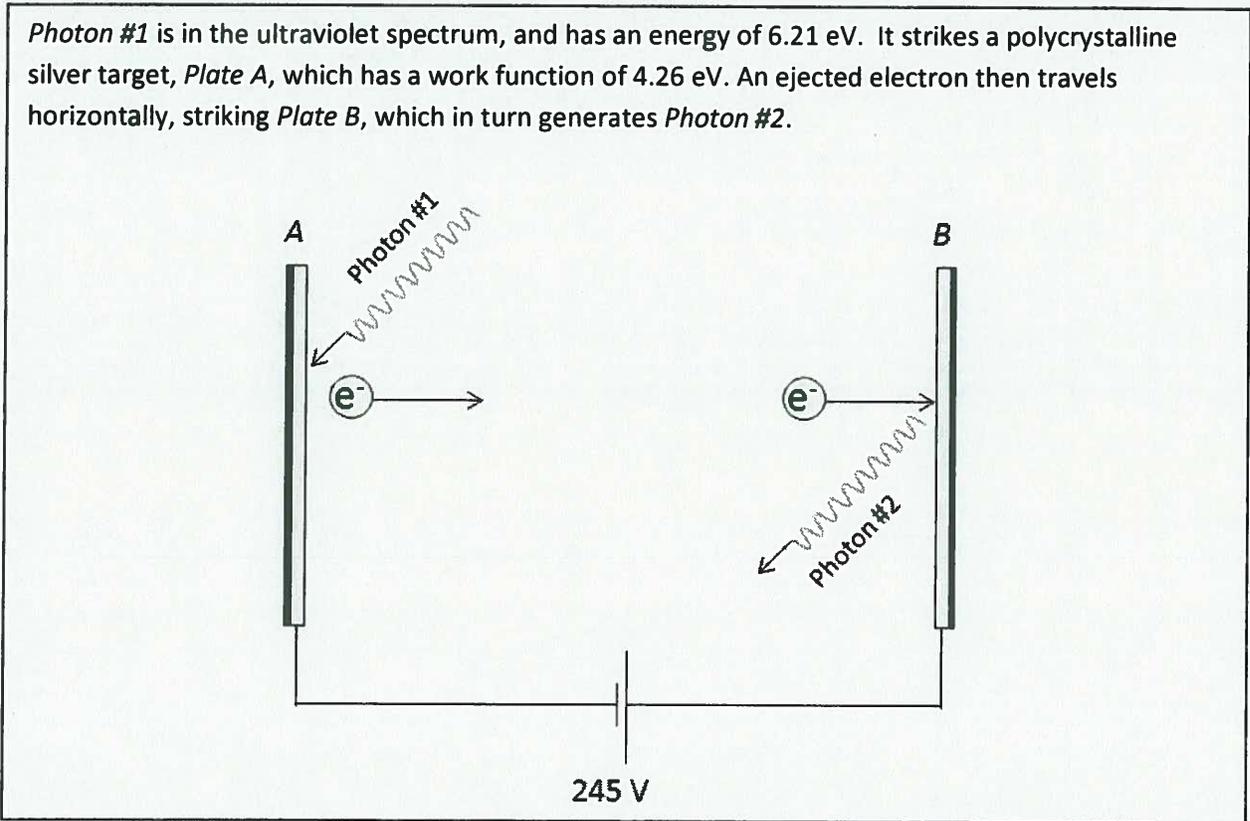
- a)  $9.234 \times 10^{-24}$  Newton Seconds (Ns)
- b)  $9.234 \times 10^{-24}$  Joule Seconds (Js)
- c)  $9.282 \times 10^{-24}$  Newton Seconds (Ns)
- d)  $9.282 \times 10^{-24}$  Joule Seconds (Js)

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{7.14285714... \times 10^{-11}}$$

$$= 9.282 \times 10^{-24} \text{ Ns}$$

Challenge Question

Use the following information to answer Q30:



Q30: The energy of Photon #2 is \_\_\_\_ eV.

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

2	4	7	
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Photoelectric Effect

$$E_{ph} \rightarrow W + E_K$$

$$6.21 \text{ eV} \rightarrow 4.26 \text{ eV} + E_K$$

$$E_K = 1.95 \text{ eV}$$

X-Ray Production (Cons. of E)

$$E_i \rightarrow E_f$$

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

$$1.95 \text{ eV} + q \Delta V \rightarrow E_{\text{photon}}$$

$$1.95 \text{ eV} + (1e)(245 \text{ V}) \rightarrow E_{\text{photon}}$$

$$1.95 \text{ eV} + 245 \text{ eV} \rightarrow E_{\text{photon}}$$

$$246.95 \text{ eV} \rightarrow E_{\text{photon}}$$

$$E_{\text{photon}} \approx 247 \text{ eV}$$