Mr. Wright's Math Extravaganza

Physical Sciences

(Chemistry, Physics, Physical Science)

Electromagnetic Radiation

Units 10 Waves and Sound, 11 Electromagnetic Rays, 12 Dual Nature of Light

Average Level for All Three Units

Level 2.0: 70% on test, Level 3.0: 80% on test, Level 4.0: level 3.0 and success on particle-wave lab

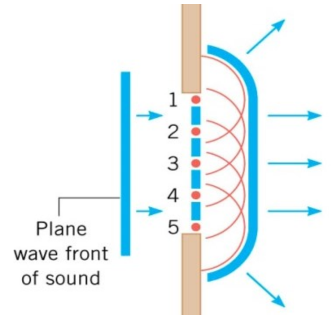
Score	I Can Statements
4.0	**12 Dual Nature of Light** ☐ I can decide whether the effects of different frequencies of electromagnetic radiation are best explained by the particle model or the wave model.
3.5	In addition to score 3.0 performance, partial success at score 4.0 content.
3.0	**11 Electromagnetic Rays** ☐ I can explain the effects of different frequencies of electromagnetic radiation on matter when absorbed. **12 Dual Nature of Light** ☐ I can explain differences between the particle model and the wave model for electromagnetic radiation.
2.5	No major errors or omissions regarding score 2.0 content, and partial success at score 3.0 content.
2.0	**10 Waves and Sound** ☐ I can explain that energy can be transferred from one point to another through a wave or a particle. ☐ I can define characteristics and properties of waves and wave interactions. ☐ I can explain how wave interactions would affect the amplitude of the wave. ☐ I can explain the relationship between the energy carried by a wave, its frequency, its wavelength, and its amplitude. ☐ I can explain the Doppler effect. **11 Electromagnetic Rays** ☐ I can describe the types of waves that compose the electromagnetic spectrum in order from low frequency to high frequency. ☐ I can explain the difference between electromagnetic waves traveling in a vacuum versus those traveling through various media. ☐ I can list characteristics of electromagnetic waves. ☐ I can explain why electromagnetic waves above visible light are considered dangerous to humans after too much exposure. ☐ I can explain how scientists use the emission and absorption spectra to identify the composition of substances. ☐ I can explain the behaviors of waves at a boundary. **12 Dual Nature of Light** ☐ I can relate photons to electromagnetic radiation in terms of waves and particles. ☐ I can explain how photons simultaneously act like particles and waves.

	☐ I can describe the behavior of waves passing through a slit(s). I can identify nodes and antinodes on a resonating wave.
1.5	Partial success at score 2.0 content, and major errors or omissions regarding score 3.0 content.
1.0	With help, partial success at score 2.0 content and score 3.0 content.
0.5	With help, partial success at score 2.0 content but not at score 3.0 content.
0.0	Even with help, no success.

Physics 12-01 The Double Slit Experiment — *Name: _______________*

Wave Character of Light

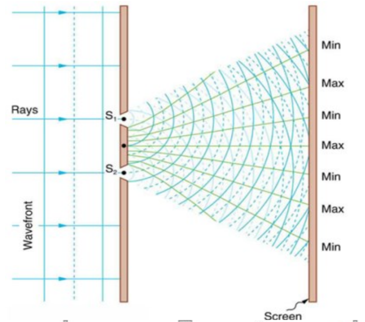
- When __________ interacts with object several __________ it's _______________, it acts like a __________
- When __________ interacts with __________ objects, it acts like a __________

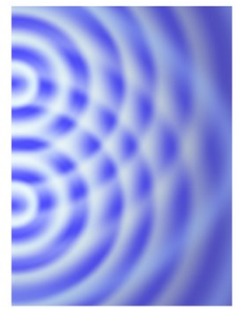


Huygens' Principle

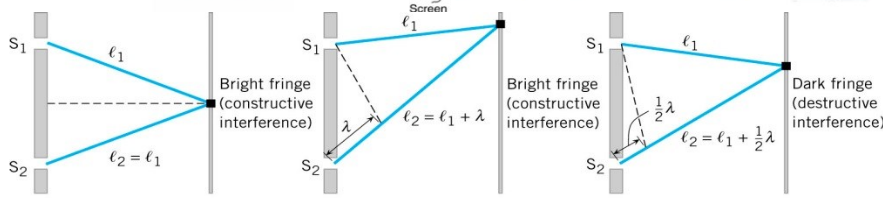
- Every point on a __________ front acts as a __________ of tiny __________ that move forward with the same __________ as the __________; the wave __________ at a later instant is the __________ that is __________ to the wavelets.

Young's Double Slit Experiment

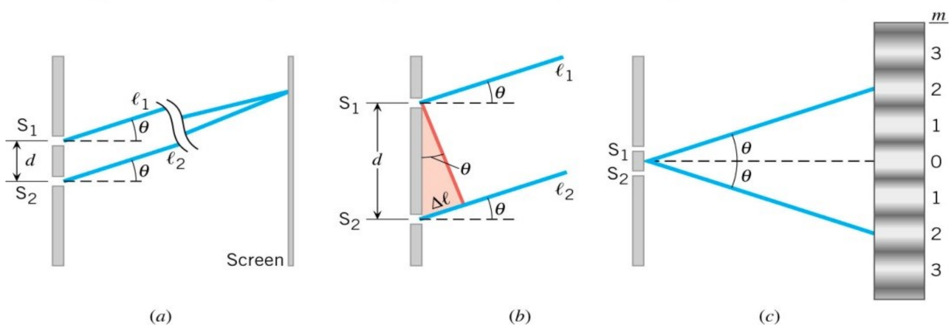




- Thomas Young showed that two overlapping __________ waves ____________ and was able to calculate _____________.
- Bright fringe where $\ell_1 - \ell_2 = m\lambda$
- Dark fringe where $\ell_1 - \ell_2 = \left(m + \frac{1}{2}\right)\lambda$
- Brightness of fringes __________
  - Center fringe the __________ and ____________ on either side



- (a) Rays from slits S_1 and S_2, which make approximately the same __________ θ with the horizontal, strike a distant __________ at the __________ spot.
- (b) The difference in the __________ lengths of the __________ rays is $\Delta\ell = d\sin\theta$.
- (c) The angle θ is the angle at which a __________ fringe (*m* = 2, here) occurs on either side of the __________ bright fringe (*m* = 0)
- __________ fringe: $\sin\theta = m\frac{\lambda}{d}$
- __________ fringe: $\sin\theta = \left(m + \frac{1}{2}\right)\frac{\lambda}{d}$



A laser beam (λ = 630 nm) goes through a double slit with separation of 3 μm. If the interference pattern is projected on a screen 5 m away, what is the distance between the third order bright fringe and the central bright fringe?

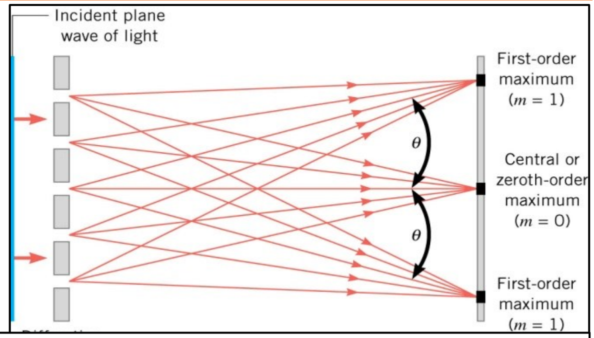
Physics 12-01 The Double Slit Experiment **_Name: _______________**

Practice Work

1. What type of experimental evidence indicates that light is a wave?
2. Does Huygens's principle apply to all types of waves?
3. Young's double slit experiment breaks a single light beam into two sources. Would the same pattern be obtained for two independent sources of light, such as the headlights of a distant car? Explain.
4. At what angle is the first-order maximum for 450-nm wavelength blue light falling on double slits separated by 0.0500 mm? (OpenStax 27.6) $\mathbf{0.516°}$
5. Calculate the angle for the third-order maximum of 580-nm wavelength yellow light falling on double slits separated by 0.100 mm. (OpenStax 27.7) $\mathbf{0.997°}$
6. What is the separation between two slits for which 610-nm orange light has its first maximum at an angle of 30.0°? (OpenStax 27.8) $\mathbf{1.22 \times 10^{-6}\ m}$
7. Find the distance between two slits that produces the first minimum for 410-nm violet light at an angle of 45.0°. (OpenStax 27.9) $\mathbf{0.290\ \mu m}$
8. Calculate the wavelength of light that has its third minimum at an angle of 30.0° when falling on double slits separated by 3.00 μm. (OpenStax 27.10) **600 nm**
9. What is the wavelength of light falling on double slits separated by 2.00 μm if the third-order maximum is at an angle of 60.0°? (OpenStax 27.11) **577 nm**
10. 680 nm light is projected onto two slits separated by 0.0200 mm. What is the distance between the central bright fringe and the second order bright fringe if the screen is 20.0 cm from the slit? (RW) **1.36 cm**
11. How far is the screen from a 10.0 μm double slit if the third-order maximum is 3.0 cm from central bright fringe when illuminated by 540 nm wavelength light? (RW) **18.3 cm**

Physics 12-02 Multiple Slit Diffraction   Name: ______________

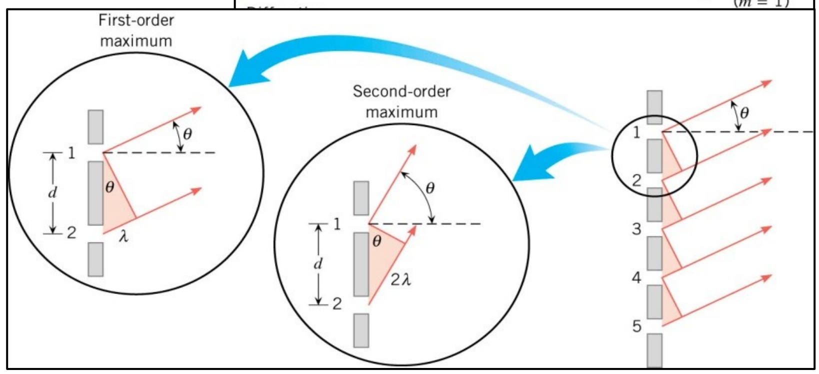
Diffraction Grating



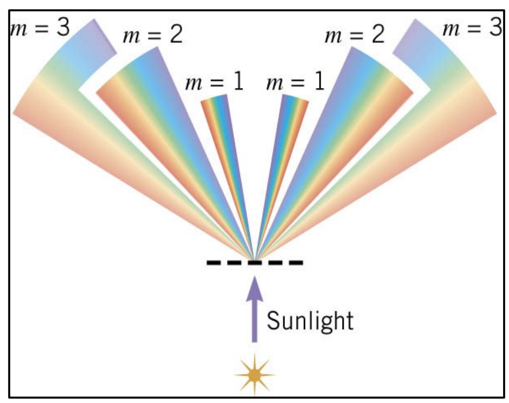
- Arrangement of many __________ spaced __________
- As many as __________ slits per cm
- Produces ________________ patterns

- The light __________ are essentially __________.
- The principal __________ occur when light from one slit travels __________ more to meet light from a __________slit producing ________________ interference.
- Principal __________

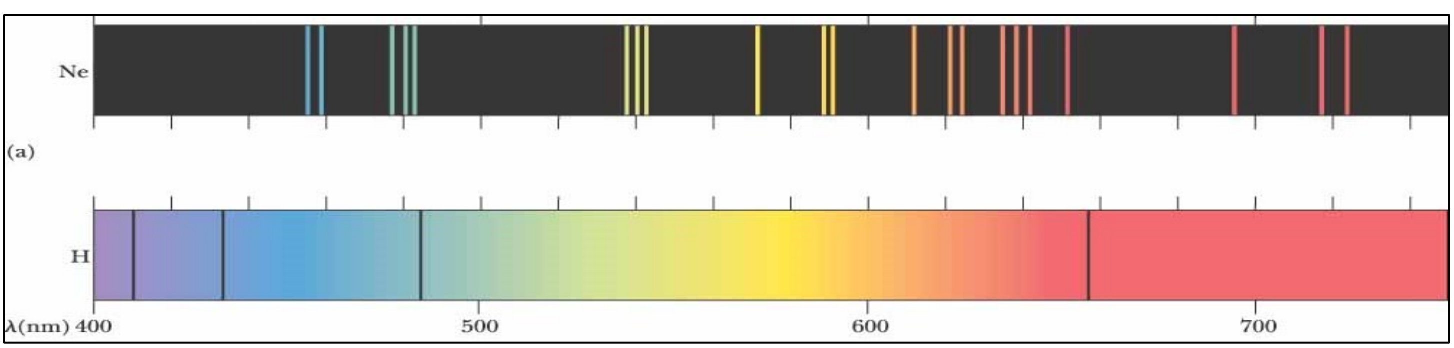
$$\sin\theta = m\frac{\lambda}{d}$$



A laser which produces 650 nm light shines through a diffraction grating. An interference pattern is produced on a screen 50 cm away. The distance on the screen between the second order maxima and the center is 13.5 cm. What is the slit separation in the grating?



- Diffraction gratings produce ____________, more __________ maxima, but have small _____________ maxima in __________.
- Splitting colors
  - Each __________ of light is a different ______________, so each color bends a different __________.
  - Which color bends the most? __________
  - Which color bends the least? __________
- Application - Determining Elements in Stars
  - Each __________ in a hot gas __________ or __________ certain ________________ of light.
  - By using a diffraction __________ the light can be __________ and the wavelengths ______________.



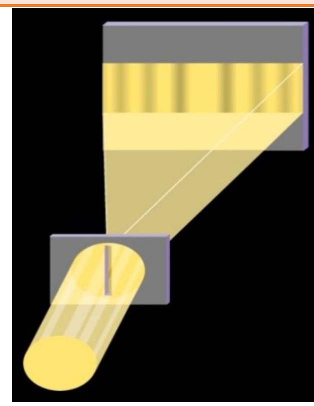
Physics 12-02 Multiple Slit Diffraction **Name: _______________**

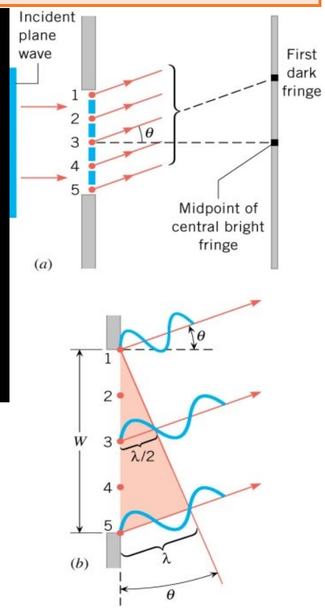
Practice Work

1. What is the advantage of a diffraction grating over a double slit in dispersing light into a spectrum?
2. What are the advantages of a diffraction grating over a prism in dispersing light for spectral analysis?
3. A diffraction grating has 2000 lines per centimeter. At what angle will the first-order maximum be for 520-nm wavelength green light? (OpenStax 27.21) $\mathbf{5.97°}$
4. Find the angle for the third-order maximum for 580-nm wavelength yellow light falling on a diffraction grating having 1500 lines per centimeter. (OpenStax 27.22) $\mathbf{15.1°}$
5. How many lines per centimeter are there on a diffraction grating that gives a first-order maximum for 470-nm blue light at an angle of 25.0°? (OpenStax 27.23) $\mathbf{8.99 \times 10^3\ lines/cm}$
6. What is the distance between lines on a diffraction grating that produces a second-order maximum for 760-nm red light at an angle of 60.0°? (OpenStax 27.24) $\mathbf{1.76 \times 10^{-6}\ m}$
7. Calculate the wavelength of light that has its second-order maximum at 45.0° when falling on a diffraction grating that has 5000 lines per centimeter. (OpenStax 27.25) $\mathbf{707\ nm}$
8. What is the maximum number of lines per centimeter a diffraction grating can have and produce a complete first order spectrum for visible light? (OpenStax 27.28) $\mathbf{13300\ lines/cm}$
9. What is the spacing between structures in a feather that acts as a reflection grating, given that they produce a first order maximum for 525-nm light at a 30.0° angle? (OpenStax 27.30) $\mathbf{1.05 \times 10^{-6}\ m}$
10. A He–Ne laser beam is reflected from the surface of a CD onto a wall. The brightest spot is the reflected beam at an angle equal to the angle of incidence. However, fringes are also observed. If the wall is 1.50 m from the CD, and the first fringe is 0.600 m from the central maximum, what is the spacing of grooves on the CD? (OpenStax 27.38) $\mathbf{1.70 \times 10^{-6}\ m}$

Physics 12-03 Single Slit Diffraction — *Name: _______________*

Single Slit Diffraction





- Large opening → ___________ bend
- Small opening → ___________ bend
- ___________ slit produces a _________________ pattern
- The ___________ wavelets _____________ with each ___________
- The center ___________ band is ________ width of the other _________.
- First order ___________ band occurs when ___________ edge and ___________ edge ___________ lengths differ by 1 wavelength.
- The ___________ wave path length ___________ by ___________ wavelength leading to the __________________ interference.
- The wavelet slightly ___________#1 will cancel with wavelet slightly below ___________ and so on.

For multiple dark fringes

$$\sin\theta = m\frac{\lambda}{W}$$

- Where θ = angle between wave and normal to slit, m = dark band order, λ = wavelength, W = width of slit

A laser shines through a single slit of width 3.25×10^{-6} m. The first order dark fringe is 10.2 cm from the center and the slit is 50 cm from the screen. What is the wavelength of the laser?

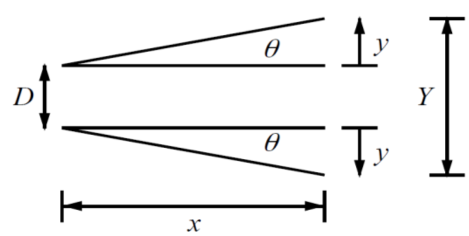
Limits of Resolution

- Light going through a ___________ aperture has ________________
  - Also true for light from ___________ and ___________
- 1st minimum at

$$\theta = 1.22\frac{\lambda}{D}$$

- Where θ is in ___________, λ = wavelength, D = diameter of aperture, lens, mirror, etc.
- Two light sources are "___________" when one's ___________ is at the 1st ______________ of the other

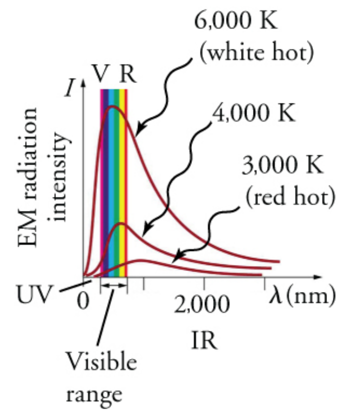
(a) What is the minimum angular spread of a 633-nm wavelength He-Ne laser beam that is originally 1.00 mm in diameter? (b) If this laser is aimed at a mountain cliff 15.0 km away, how big will the illuminated spot be?



Physics 12-03 Single Slit Diffraction *Name: _______________*

Practice Work

1. As the width of the slit producing a single-slit diffraction pattern is reduced, how will the diffraction pattern produced change?
2. A beam of light always spreads out. Why can a beam not be created with parallel rays to prevent spreading? Why can lenses, mirrors, or apertures not be used to correct the spreading?
3. (a) At what angle is the first minimum for 550-nm light falling on a single slit of width 1.00 μm? (b) Will there be a second minimum? (OpenStax 27.43) $\mathbf{33.4°}$**, No**
4. (a) Calculate the angle at which a 2.00-μm-wide slit produces its first minimum for 410-nm violet light. (b) Where is the first minimum for 700-nm red light? (OpenStax 27.44) $\mathbf{11.8°}$**,** $\mathbf{20.5°}$
5. (a) How wide is a single slit that produces its first minimum for 633-nm light at an angle of 28.0°? (b) At what angle will the second minimum be? (OpenStax 27.45) $\mathbf{1.35 \times 10^{-6}}$ **m,** $\mathbf{69.9°}$
6. (a) What is the width of a single slit that produces its first minimum at 60.0° for 600-nm light? (b) Find the wavelength of light that has its first minimum at 62.0°. (OpenStax 27.46) **693 nm, 612 nm**
7. Find the wavelength of light that has its third minimum at an angle of 48.6° when it falls on a single slit of width 3.00 μm. (OpenStax 27.47) **750 nm**
8. Calculate the wavelength of light that produces its first minimum at an angle of 36.9° when falling on a single slit of width 1.00 μm. (OpenStax 27.48) **600 nm**
9. The 300-m-diameter Arecibo radio telescope detects radio waves with a 4.00 cm average wavelength. (a) What is the angle between two just-resolvable point sources for this telescope? (b) How close together could these point sources be at the 2 million light year distance of the Andromeda galaxy? (OpenStax 27.57) $\mathbf{1.63 \times 10^{-4}}$ **rad, 325 ly**
10. Diffraction spreading for a flashlight is insignificant compared with other limitations in its optics, such as spherical aberrations in its mirror. To show this, calculate the minimum angular spreading of a flashlight beam that is originally 5.00 cm in diameter with an average wavelength of 600 nm. (OpenStax 27.59) $\mathbf{1.46 \times 10^{-5}}$ **rad**
11. A telescope can be used to enlarge the diameter of a laser beam and limit diffraction spreading. The laser beam is sent through the telescope in opposite the normal direction and can then be projected onto a satellite or the Moon. (a) If this is done with the Mount Wilson telescope, producing a 2.54-m-diameter beam of 633-nm light, what is the minimum angular spread of the beam? (b) Neglecting atmospheric effects, what is the size of the spot this beam would make on the Moon, assuming a lunar distance of 3.84×10^8 m? (OpenStax 27.61) $\mathbf{3.04 \times 10^{-7}}$ **rad, 236 m**



- Black absorbs _________ light
  - It also _________ that light
- Blackbody
  - Absorbs _________light
  - Re-emits _________that light
- The color that a hot object (___________) emits depends on its __________________.

- As the temperature _________, the total amount of _________increases
- While _________the wavelengths are emitted, there is one _________wavelength
- As the temperature _________, the peak wavelength gets _________
  - The increased temperature atoms move _________and the ___________of the light increases.
  - By $v = f\lambda$, the wavelength _________
- This graph does not match _________physics which is based on ___________energy
- Planck invented the idea that the frequencies emitted are based on __________________
- Energy is _________
  - Only exists in _________amounts
  - Like the number of electrons in something must be a _________number
  - $E = nhf = n\frac{hc}{\lambda}$
    - n = 0, 1, 2, 3, … (# of _________)
    - $h = 6.626\times10^{-34}$ J·s
    - f = frequency of light
  - Low frequency (long λ) light is _________energy
  - High frequency (short λ) light is _________energy
- Low temperature has low _________so more low ___________light
- High temperature has higher _________so more higher ___________light

- Other things that are quantized
  - _________and _________
  - _________
  - _________

How many photons per second does a typical 10W LED lightbulb produce if 80% of the electrical energy is turned into useable light with an average wavelength of 520 nm?

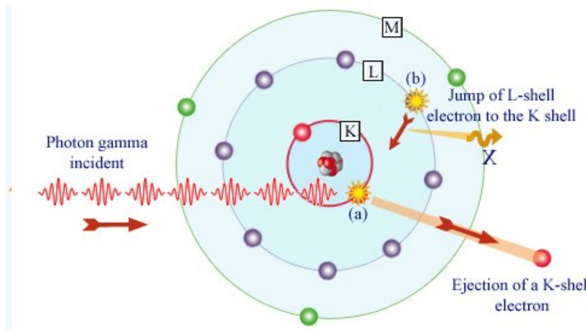
Physics 12-04 Quantum Nature of Light **Name:** ______________

Compare the energy of one photon of UV light (λ = 250 nm) with IR light (λ = 890 nm).

Practice Work

1. Give an example of a physical entity that is quantized. State specifically what the entity is and what the limits are on its values.
2. Give an example of a physical entity that is not quantized, in that it is continuous and may have a continuous range of values.
3. An AM radio station broadcasts at a frequency of 1,530 kHz . What is the energy in Joules of a photon emitted from this station? (HSP PP21.1) $\mathbf{1.01 \times 10^{-27}\ J}$
4. A photon travels with energy of 1.0 eV. What type of EM radiation is this photon? (HSP PP21.2) **Infrared**
5. Why do we not notice quantization of photons in everyday experience? (HSP PP21.6)
6. Two flames are observed on a stove. One is red while the other is blue. Which flame is hotter? How do you know? (HSP PP21.7) **Blue**
7. Your pupils dilate when visible light intensity is reduced. Does wearing sunglasses that lack UV blockers increase or decrease the UV hazard to your eyes? Explain. (HSP PP21.8) **Increase**
8. The temperature of a blackbody radiator is increased. What will happen to the most intense wavelength of light emitted as this increase occurs? (HSP PP21.9)
9. How many X-ray photons per second are created by an X-ray tube that produces a flux of X-rays having a power of 1.00 W? Assume the average energy per photon is 75.0 keV. (HSP 21.22) $\mathbf{8.33 \times 10^{13}\ photons}$
10. What is the frequency of a photon produced in a CRT using a 25.0-kV accelerating potential? This is similar to the layout as in older color television sets. (HSP 21.23) $\mathbf{6.04 \times 10^{18}\ Hz}$
11. Find the energy in joules of photons of radio waves that leave an FM station that has a 90.0-MHz broadcast frequency. (HSP 21.31) $\mathbf{5.96 \times 10^{-26}\ J}$
12. Which region of the electromagnetic spectrum will provide photons of the least energy? Explain. (HSP 21.32)
13. What is the efficiency of a 100-W, 550-nm lightbulb if a photometer finds that 1×10^{20} photons are emitted each second? (HSP 21.51) $\mathbf{36.1}\%$

Physics 12-05 Photoelectric Effect **Name:** ______________



- When a photon of light hits an ___________, the electron absorbs the energy and jumps to a higher ___________
- If the photon has enough ___________, the electron can completely leave the atom
- If there is a wire for the electrons to move through, then there will be a ___________
- This the is ______________________effect
- Energy of photon from photoelectric effect is ___________

1. For a given material, there is a threshold frequency f_0 for the EM radiation below which ___________electrons are ejected, regardless of intensity. Using the photon model, the explanation for this is clear. Individual ___________interact with individual ___________. Thus if the energy of an individual photon is too low to break an electron away, no electrons will be ejected. However, if EM radiation were a simple wave, sufficient energy could be obtained simply by increasing the ___________.
2. Once EM radiation falls on a material, electrons are ejected ___________delay. As soon as an individual photon of sufficiently high frequency is ___________by an individual electron, the electron is ejected. If the EM radiation were a simple wave, several ___________would be required for sufficient energy to be deposited at the metal surface in order to eject an electron.
3. The number of electrons ejected per unit time is proportional to the ___________of the EM radiation and to no other characteristic. High-intensity EM radiation consists of large numbers of photons per unit area, with all photons having the same characteristic energy, *hf*. The increased number of photons per unit area results in an increased number of electrons per unit area ejected.
4. The maximum ___________energy of ejected electrons is independent of the ___________of the EM radiation. Instead, as noted in point 3 above, increased intensity results in more electrons of the same energy being ejected. If EM radiation were a simple wave, a higher intensity could transfer more energy, and ___________-energy electrons would be ejected.
5. The kinetic energy *KE* of an ejected electron equals the ___________energy minus the ___________energy *BE* of the electron in the specific material. An individual photon can give all of its energy to an electron. The photon's energy is partly used to break the electron away from the material. The remainder goes into the ejected electron's kinetic energy. In equation form, this is given by
$$KE_e = hf - BE$$
where KE_e is the maximum kinetic energy of the ejected electron, hf is the photon's energy, and *BE* is the binding energy of the electron to the particular material.

What is the energy in joules and electron volts of a photon of 250 nm ultraviolet light?

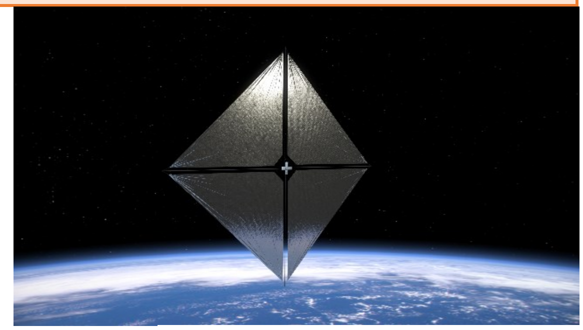
What is the maximum kinetic energy of electrons ejected from cesium by 250 nm UV light, given that the binding energy of electrons from silver is 3.894 eV?

- Uses of the photoelectric effect
  - Photovoltaic solar cells
- Electric eye
  - Lights turn on in the dark
  - Automatic faucets, paper towels, toilets, etc.

Physics 12-05 Photoelectric Effect	*Name:* _______________
Practice Work	

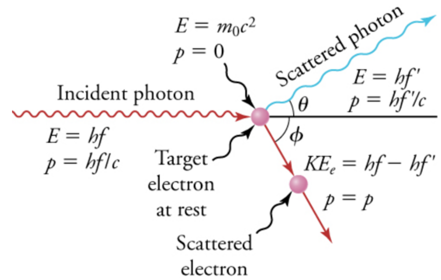
1. Is visible light the only type of EM radiation that can cause the photoelectric effect? (OpenStax C29.2)
2. Is the photoelectric effect a direct consequence of the wave character of EM radiation or of the particle character of EM radiation? Explain briefly. (OpenStax C29.8)
3. What is the longest-wavelength EM radiation that can eject a photoelectron from silver, given that the binding energy is 4.73 eV? Is this in the visible range? (OpenStax 29.4)
4. Find the longest-wavelength photon that can eject an electron from potassium, given that the binding energy is 2.24 eV. Is this visible EM radiation? (OpenStax 29.5) **555 nm**
5. What is the binding energy in eV of electrons in magnesium, if the longest-wavelength photon that can eject electrons is 337 nm? (OpenStax 29.6) **3.69 eV**
6. Calculate the binding energy in eV of electrons in aluminum, if the longest-wavelength photon that can eject them is 304 nm. (OpenStax 29.7) **4.09 eV**
7. What is the maximum kinetic energy in eV of electrons ejected from sodium metal by 450-nm EM radiation, given that the binding energy is 2.28 eV? (OpenStax 29.8) **0.48 eV**
8. UV radiation having a wavelength of 120 nm falls on gold metal, to which electrons are bound by 4.82 eV. What is the maximum kinetic energy of the ejected photoelectrons? (OpenStax 29.9) **5.53 eV**
9. What is the wavelength of EM radiation that ejects 2.00-eV electrons from calcium metal, given that the binding energy is 2.71 eV? What type of EM radiation is this? (OpenStax 29.12) **264 nm, UV**
10. Find the wavelength of photons that eject 0.100-eV electrons from potassium, given that the binding energy is 2.24 eV. Are these photons visible? (OpenStax 29.13) **531 nm, Yes**
11. What is the maximum velocity of electrons ejected from a material by 80-nm photons, if they are bound to the material by 4.73 eV? (OpenStax 29.14) $\mathbf{1.95 \times 10^{6}\ m/s}$
12. Photoelectrons from a material with a binding energy of 2.71 eV are ejected by 420-nm photons. Once ejected, how long does it take these electrons to travel 2.50 cm to a detection device? (OpenStax 29.15) $\mathbf{8.47 \times 10^{-8}\ s}$

Physics 12-06 The Dual Nature of Light **Name: ______________**



- Light behaves as a wave
    - __________
    - __________
    - __________
- Light behaves as a particle
    - __________energy – Blackbody radiation
    - ____________________effect
    - __________

Momentum of light



- Light from the sun pushes a __________tail away
- NASA is developing a __________spaceship that is pushed away from the sun using a sail that is hit by the __________
- When __________ are shot through atoms, then they __________from hitting electrons
    - The scattered photons have __________energy than before because they gave some energy to the electron like a ______________collision

$$p = \frac{h}{\lambda} = \frac{hf}{c}$$

Calculate the momentum of a visible photon that has a wavelength of red light 680 nm.

Find the velocity of an electron with the same momentum.

What is the energy of the electron, and how does it compare with the energy of the photon?

Particle-Wave Duality

- Light waves can act as __________
- Particles can act as __________
    - Electrons can __________with each other
    - Electron currents can __________out
- __________matter is both __________and __________

Physics 12-06 The Dual Nature of Light	***Name:*** ______________
Practice Work	

1. Why don't we feel the momentum of sunlight when we are on the beach? (HSP 21.8)
2. Describe one type of evidence for the wave nature of matter. (OpenStax C29.23)
3. Describe one type of evidence for the particle nature of EM radiation. (OpenStax C29.24)
4. In what region of the electromagnetic spectrum will photons be most effective in accelerating a solar sail? (HSP 21.19)
5. Terms like frequency, amplitude, and period are tied to what component of wave-particle duality? (HSP 21.44)
6. Upon collision, what happens to the frequency of a photon? (HSP 21.59)
7. How does the momentum of a photon compare to the momentum of an electron of identical energy? (HSP 21.60)
8. Large objects can move with great momentum. Why then is it difficult to see their wave-like nature? (HSP 21.66)
9. What is the momentum of a 0.0100-nm-wavelength photon that could detect details of an atom? (HSP 21.26) $\mathbf{6.63 \times 10^{-23}\ \boldsymbol{kg\ m/s}}$
10. What is the momentum of a 500-nm photon? (HSP 21.42) $\mathbf{1.33 \times 10^{-27}\ \boldsymbol{kg\ m/s}}$
11. A 500-nm photon strikes an electron and loses 20 percent of its energy. What is the new momentum of the photon? (HSP 21.61) $\mathbf{1.06 \times 10^{-27}\ \boldsymbol{kg\ m/s}}$
12. A 500-nm photon strikes an electron and loses 20 percent of its energy. What is the speed of the recoiling electron? (HSP 21.62) $\mathbf{4.18 \times 10^{5}\ \boldsymbol{m/s}}$
13. The wavelength of a particle is called the de Broglie wavelength, and it can be found with the equation, $p = \frac{h}{\lambda}$.
Can the wavelength of an electron match that of a proton? Explain. (HSP 21.65) **Yes**

Physics Unit 12: The Dual Nature of Light Review

1. Know about double-slit experiment, diffraction, diffraction grating, dispersing light into a spectrum, single-slit diffraction, limits of resolution, blackbody radiation and the relationship between temperature and frequency of light emitted, photoelectric effect, quantization, evidence that light is a wave, evidence that light is a particle, particle-wave duality of nature
2. Why is it difficult to observe everyday sized objects' wave nature?
3. At what angle is the first-order maximum for 800.0-nm wavelength light falling on double slits separated by 0.00100 mm?
4. Calculate the wavelength of light that has its third minimum at an angle of 10.0° when falling on double slits separated by 8.000 μm.
5. Light with a 700nm wavelength is shown through a double slit. If the $m = 0$ and $m = 1$ bright fringes are separated by 10°, what is the separation of the slits?
6. A diffraction grating has 2000 lines/cm and has monochromatic light shown on it. If the 3rd-order maximum is at 20°, what is the wavelength of the light?
7. What is the distance between lines on a diffraction grating that produces a second-order maximum for 200.0-nm light at an angle of 20.0°?
8. Light with a wavelength of 250 nm uniformly illuminates a single slit. What is the width of the slit if the first-order dark fringe is located at $\theta = 1.50°$?
9. Light with a 700nm wavelength is shown through a single slit onto a screen 3 m away. What is the width of the slit if the 2nd-order dark fringe is located 50 cm from the center of the central bright region?
10. Calculate the minimum angular spreading of a laser beam that is originally 1.00 mm in diameter with an average wavelength of 680.0 nm.
11. A spy satellite is in orbit at a distance of 5.0×10^6 m above the ground. It carries a telescope that can resolve the two rails of a railroad track that are 1.0 m apart using light of wavelength 400 nm. What is the diameter of the lens in the telescope?
12. A radio antenna emits photons at a frequency of 101.5 MHz. What is the energy of this photon in Joules?
13. A photon strikes a detector with 2.00 eV of energy. What is the wavelength of the photon?
14. What is the maximum kinetic energy in eV of electrons ejected from a metal by 800-nm EM radiation, given that the binding energy is 0.70 eV?
15. Find the longest-wavelength photon that can eject an electron from a metal, given that the binding energy is 2.00 eV.
16. Find the momentum of a photon with a wavelength of 1200 nm.

Physics Unit 12: The Dual Nature of Light Review
Answers

2. The wavelength is too small to observe.

3. $\sin\theta = m\frac{\lambda}{d} \rightarrow \sin\theta = 1\left(\frac{800.0\times10^{-9}\ m}{0.00100\times10^{-3}\ m}\right) \rightarrow \sin\theta = 0.800° \rightarrow \theta = \mathbf{53.1°}$

4. $\sin\theta = \left(m+\frac{1}{2}\right)\frac{\lambda}{d} \rightarrow \sin 10.0° = \left(2+\frac{1}{2}\right)\left(\frac{\lambda}{8.000\times10^{-6}\ m}\right) \rightarrow \sin 10.0° = 312500\lambda \rightarrow \lambda = 5.56\times10^{-7}\ m = \mathbf{556\ nm}$

5. $\sin\theta = m\frac{\lambda}{d} \rightarrow \sin 10° = \frac{1(700\times10^{-9}\ m)}{d} \rightarrow d = 4.03\ \mu m = \mathbf{4.03\times10^{-6} m}$

6. $\sin\theta = m\frac{\lambda}{d}$

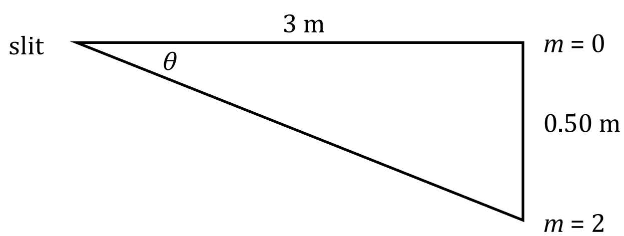
$d = \frac{1}{2000\frac{lines}{cm}} = 0.0005\ cm = 0.000005\ m$

$\sin 20° = 3\left(\frac{\lambda}{0.000005\ m}\right) \rightarrow \lambda = 5.7\times10^{-7}\ m = \mathbf{570\ nm}$

7. $\sin\theta = m\frac{\lambda}{d} \rightarrow \sin 20.0° = 2\left(\frac{200.0\times10^{-9}\ m}{d}\right) \rightarrow d\sin 20.0° = 4.00\times10^{-7}\ m \rightarrow d = \mathbf{1.17\times10^{-6}\ m}$

8. $\sin\theta = m\frac{\lambda}{W} \rightarrow \sin 1.50° = 1\left(\frac{250\times10^{-9}\ m}{W}\right) \rightarrow W\sin 1.50° = 2.50\times10^{-7}\ m \rightarrow W = \mathbf{9.55\times10^{-6}\ m}$

9. $\sin\theta = m\frac{\lambda}{W}$

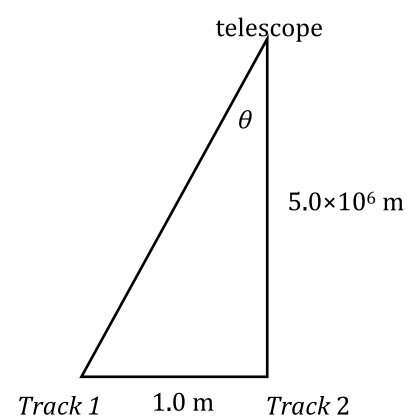


$\tan\theta = \frac{0.5}{3} \rightarrow \theta = 9.46°$

$\sin 9.46° = \frac{2(700\times10^{-9}\ m)}{W} \rightarrow \mathbf{W = 8.52\times10^{-6}\ m}$

10. $\theta = 1.22\frac{\lambda}{D} \rightarrow \theta = 1.22\left(\frac{680.0\times10^{-9}\ m}{1.00\times10^{-3}\ m}\right) \rightarrow \theta = \mathbf{8.30\times10^{-4}\ rad}$

11. Use a right triangle to find the angle in radians:



$\tan\theta = \frac{1.0\ m}{5.0\times10^6\ m} \rightarrow \theta = 2\times10^{-7}\ rad$

$\theta = 1.22\frac{\lambda}{D} \rightarrow 2\times10^{-7}\ rad = 1.22\left(\frac{400\times10^{-9}\ m}{D}\right) \rightarrow$

$D(2\times10^{-7}\ rad) = 4.88\times10^{-7}\ m \rightarrow D = \mathbf{2.44\ m}$

12. $E = nhf \rightarrow E = (1)(6.626\times10^{-34}\ Js)(101.5\times10^6\ Hz) \rightarrow E = \mathbf{6.72\times10^{-26}\ J}$

13. $2.00\ eV\left(\frac{1.60\times10^{-19}\ J}{1\ eV}\right) = 3.20\times10^{-19}\ J$

$E = nhf \rightarrow 3.20\times10^{-19}\ J = (1)(6.626\times10^{-34}\ Js)f \rightarrow f = 4.83\times10^{14}\ Hz$

$c = f\lambda \rightarrow 3.00\times10^8\frac{m}{s} = (4.83\times10^{14}\ Hz)\lambda \rightarrow \lambda = 6.21\times10^{-7}\ m = \mathbf{621\ nm}$

14. $KE = \frac{hc}{\lambda} - BE \rightarrow KE = \frac{(6.626\times10^{-34}\ Js)\left(3.00\times10^8\frac{m}{s}\right)}{800\times10^{-9}\ m}\left(\frac{1\ eV}{1.60\times10^{-19}\ J}\right) - 0.70\ eV \rightarrow KE = 1.55\ eV - 0.70\ eV \rightarrow KE = \mathbf{0.85\ eV}$

15. $KE = \frac{hc}{\lambda} - BE \rightarrow 0 = \frac{(6.626\times10^{-34}\ Js)\left(3.00\times10^8\frac{m}{s}\right)}{\lambda} - 2.00\ eV\left(\frac{1.60\times10^{-19}\ J}{1\ eV}\right) \rightarrow 3.20\times10^{-19}\ J = \frac{1.99\times10^{-25}\ Jm}{\lambda}$

$\lambda(3.20\times10^{-19}\ J) = 1.99\times10^{-25}\ Jm \rightarrow \lambda = 6.21\times10^{-7}\ m = \mathbf{621\ nm}$

16. $p = \frac{h}{\lambda} \rightarrow p = \frac{6.626\times10^{-34}\ Js}{1200\times10^{-9}\ m} \rightarrow p = \mathbf{5.52\times10^{-28}\ kg\ m/s}$