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.

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Answers

2. The wavelength is too small to observe.

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

4. $\sin\theta = m\frac{\lambda}{d} \rightarrow \sin 10.0° = 3\left(\frac{\lambda}{8.000\times10^{-6}\ m}\right) \rightarrow \sin 10.0° = 375000\lambda \rightarrow \lambda = 4.63\times10^{-7}\ m = \mathbf{463\ nm}$

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

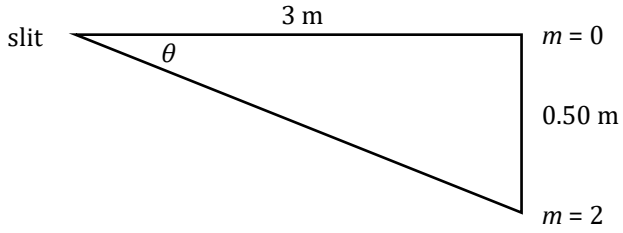
   $d = \dfrac{1}{2000\frac{lines}{cm}} = 0.0005\ cm = 0.000005\ m$

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

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

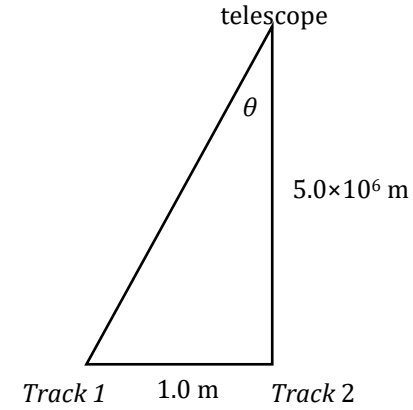


   $\tan\theta = \dfrac{0.5}{3} \rightarrow \theta = 9.46°$

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

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:



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

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

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

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

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

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

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