Version A: 1E, 2B, 3A, 4E, 5D, 6C, 7A, 8B, 9E, 10C, 11A, 12E, 13B, 14D, 15B, 16D, 17D, 18B, 19A, 20C
Version B: 1E, 2B, 3C, 4B, 5E, 6A, 7D, 8B, 9D, 10C, 11A, 12E, 13B, 14C, 15B, 16C, 17C, 18C, 19B, 20C

Some example calculation below (data for version A)

1. The image created in a concave mirror of focal length $|f| = 80$ mm is reversed, real and magnified ($m > 1$). The object may be located

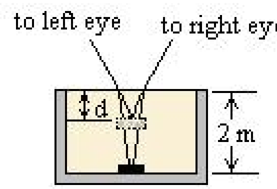
A) 20 mm before the mirror
B) 45 mm before the mirror
C) 70 mm before the mirror
D) 95 mm before the mirror
E) none from the above

$f := 0.080$ $\quad p := 0.095$ $\quad i := \left(\frac{1}{f} - \frac{1}{p}\right)^{-1}$ $\quad i = 0.507$ $\quad m := \frac{-i}{p}$ $\quad m = -5.333$

3. A convex spherical mirror has a focal length of 12 cm. If an object is placed 6 cm in front of mirror the image position is:

$f := -0.12$ $\quad p := 0.06$ $\quad i := \left(\frac{1}{f} - \frac{1}{p}\right)^{-1}$ $\quad i = -0.04$

5. A coin lies at the bottom of the 2 m deep tank filled with pure water. At what depth below the top water surface do you perceive the coin? Refracting index of a water is 1.33. You can assume $\sin\Theta = \Theta$ for small angles.



$n := 1.33$ $\quad H := 2$ $\quad \frac{x}{d} = \tan(\Theta)$ $\quad \frac{x}{H} = \tan(\Theta_1)$ $\quad d \cdot \tan(\Theta) = H \cdot \tan(\Theta_1)$ $\quad \frac{d}{H} = \frac{\tan(\Theta_1)}{\tan(\Theta)} = \frac{\sin(\Theta_1)}{\sin(\Theta)} = \frac{n \cdot \sin(\Theta_1)}{n \cdot \sin(\Theta)} = \frac{1}{n}$

$d := \frac{H}{n}$ $\quad d = 1.504$

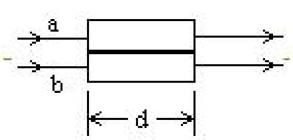
6. An object is 24 cm to the left of thin diverging lens having a 40 cm focal length. What is the image distance i?

$p := 0.24$ $\quad f := -0.40$ $\quad i := \left(\frac{1}{f} - \frac{1}{p}\right)^{-1}$ $\quad i = -0.15$

7. A camera with a single lens of focal length 35 mm takes a picture of a 180 - cm -high person standing 10 m away. What is the height of the image of the person on the film? (Film is at focal length from lens)

$p := 10$ $\quad f := 0.035$ $\quad i := 0.035$ $\quad H := 1.8$ $\quad m := \frac{i}{p}$ $\quad m = 3.5 \cdot 10^{-3}$ $\quad h := H \cdot m$ $\quad h = 6.3 \cdot 10^{-3}$

9. Two pulses of light a and b of the same wavelength $\lambda = 550$ nm (in air) and initially in phase are sent through two layers of plastic whose indexes of refraction are 1.5 and 1.6 respectively. The thickness d of the two layers is the same d = 2 μm. The phase difference between the both pulses when they emerge from plastics is:



$\lambda := 550 \cdot 10^{-9}$ $\quad n_a := 1.5$ $\quad n_b := 1.6$ $\quad d := 2 \cdot 10^{-6}$ $\quad \lambda_a := \frac{\lambda}{n_a}$ $\quad \lambda_b := \frac{\lambda}{n_b}$

$\frac{d}{\lambda_a} = 5.455$ $\quad \frac{d}{\lambda_b} = 5.818$ $\quad \left(\frac{d}{\lambda_b} - \frac{d}{\lambda_a}\right) \cdot 360 = 130.909$

11. A thin layer of Si_2O_3 (n = 1.50) of thickness 2 μm is deposited on a plastic (n = 1.25). The He-Ne laser light (λ = 633 nm) is incident normal to the glass. The phase difference between the light reflected from Si_2O_3 and plastic is:

$n_g := 1.5$ $n_p := 1.25$ $d := 2\cdot 10^{-6}$ $\lambda := 633\cdot 10^{-9}$ $\lambda := \frac{\lambda}{n_g}$

$x := \frac{2\cdot d}{\lambda}$ $x = 9.479$ only reminder counts so $(\mathrm{mod}(x+0.5,1))\cdot 360 = 352.322$ or $(1-(\mathrm{mod}(x+0.5,1)))\cdot 360 = 7.678$

13. In a Young's double-slit experiment, light of wavelength 450 nm illuminates two slits which are separated by 0.5 mm. The separation between adjacent bright fringes on a screen 2.5 m from the slits is:

$d := 0.5\cdot 10^{-3}$ $\lambda := 450\cdot 10^{-9}$ $D := 2.5$ assuming small Θ (sin = tan): $d\cdot\sin(\Theta) = d\cdot\frac{x}{D} = m\cdot\lambda = 1\cdot\lambda$

$x := \frac{D\cdot\lambda}{d}$ $x = 2.25\cdot 10^{-3}$

14. A camera with a 50 mm lens (the film is 50 mm from the lens) has an opening 5 mm in diameter. For light with wavelength 500 nm the resolution of the lens (the distance from the middle of the central bright band to the first - order dark band) is:

$d := 0.005$ $f := 0.050$ $\lambda := 500\cdot 10^{-9}$

$d\cdot\sin(\Theta) = 1.22\cdot\lambda$ assuming small Θ (tan = sin): $\frac{x}{f} = \tan(\Theta) = \sin(\Theta)$ so $d\cdot\frac{x}{f} = 1.22\cdot\lambda$

$x := \frac{1.22\cdot\lambda\cdot f}{d}$ $x = 6.1\cdot 10^{-6}$

15. Light of wavelength 550 nm falls on a diffraction grating ruled with 1100 lines/cm. The angular separation between the second order images on either side of the central maximum is

$d := \frac{0.010}{1100}$ $d = 9.091\cdot 10^{-6}$ $\lambda := 550\cdot 10^{-9}$ $d\cdot\sin(\Theta) = 2\cdot\lambda$ $\Theta := 2\cdot\mathrm{asin}\left(\frac{2\cdot\lambda}{d}\right)\cdot\frac{180}{\pi}$

$\Theta = 13.9$

16. The spacing between planes of nickel atoms in a nickel crystal is 0.174 nm. The 24 pm x-rays penetrate the crystal. The second - order Bragg reflection occur at an angle:

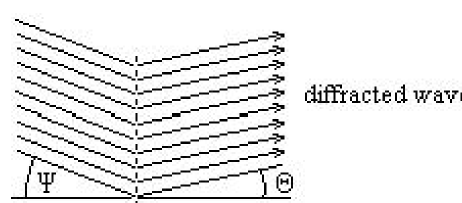
Bragg's law $2\cdot d\cdot\sin(\Theta) = m\cdot\lambda$

$d := 0.174\cdot 10^{-9}$ $\lambda := 24\cdot 10^{-12}$

$\Theta := \mathrm{asin}\left(\frac{2\cdot\lambda}{2\cdot d}\right)\cdot\frac{180}{\pi}$ $\Theta = 7.928$

17. Light (λ = 600 nm) is incident on a grating at an angle Ψ = 10 deg. The second order bright fringe is seen at an angle Φ = 7 deg. (see fig.). The separation between the slits of diffraction grating is:

$\Psi := 10\cdot deg$ $\Phi := 7\cdot deg$ $\lambda := 600\cdot 10^{-9}$



path difference is: $d\cdot\sin(\Psi) + d\cdot\sin(\Phi)$ and the fringe is second so: $d\cdot\sin(\Psi) + d\cdot\sin(\Phi) = m\cdot\lambda$

$d := \frac{2\cdot\lambda}{\sin(\Psi) + \sin(\Phi)}$ $d = 4.061\cdot 10^{-6}$

18. In a double slit experiment, the slit separation d is 2 times the slit width w. How many bright interference fringes are in the central diffraction envelope

subscripts: **i** for interference **d** for diffraction

$d \cdot \sin(\Theta) = m_i \cdot \lambda$ $a \cdot \sin(\Theta) = m_d \cdot \lambda$

diffraction envelope has first minimum (zero) for $m_d := 1$, , $d := 2 \cdot a$ Θ is the same for diffraction and interference pattern. $2 \cdot a \cdot \sin(\Theta) = 2 \cdot a \cdot \left(\frac{m_d \cdot \lambda}{a}\right) = m_i \cdot \lambda$ so: $m_i := 2$

19. The Hubble Space Telescope in orbit above the Earth has a 2.4 m circular aperture. The telescope has equipment for detecting ultraviolet light. What is the minimum angular separation between two objects that the Hubble Space Telescope can resolve in ultraviolet light of wavelength 95 nm?

$\lambda := 95 \cdot 10^{-9}$ $d := 2.4$ $d \cdot \sin(\Theta) = 1.22 \cdot \lambda$

$\Theta := \operatorname{asin}\left(\frac{1.22 \cdot \lambda}{d}\right)$ $\Theta = 4.829 \cdot 10^{-8}$

20. Light of wavelength 625 nm shines through a single slit of width 0.32 mm and forms a diffraction pattern on a flat screen located 8.0 m away. Determine the distance between the middle of the central bright fringe and the first dark fringe.

$a := 0.32 \cdot 10^{-3}$ $\lambda := 625 \cdot 10^{-9}$ $L := 8$

assuming small angle sin(Θ) = tan(Θ): $a \cdot \sin(\Theta) = a \cdot \tan(\Theta) = a \cdot \frac{x}{L} = 1 \cdot \lambda$

$x := \frac{L \cdot \lambda}{a}$ $x = 0.016$