How much faster, in meters per second, does light travel in sapphire than in diamond? (01小題)

Ans.=_____ m/s

01: **ANS:=4.55E7**

Problem 1

The wavelength of yellow sodium light in air is 589 nm. (a) What is its frequency? (b) What is its wavelength in glass whose index of refraction is 1.52? (c) From the results of (a) and (b), find its speed in this glass. (03小題)

(a) f=_____ Hz

02: **ANS:=5.09E14**

(b) λ_n=______ nm

03: **ANS:=388**

(c) v=_____ m/s

04: **ANS:=1.97E8**

Some Indexes of Refraction[a]

Medium	Index	Medium	Index
Vacuum	Exactly 1	Typical crown glass	1.52
Air (STP)[b]	1.00029	Sodium chloride	1.54
Water (20°C)	1.33	Polystyrene	1.55
Acetone	1.36	Carbon disulfide	1.63
Ethyl alcohol	1.36	Heavy flint glass	1.65
Sugar solution (30%)	1.38	Sapphire	1.77
Fused quartz	1.46	Heaviest flint glass	1.89
Sugar solution (80%)	1.49	Diamond	2.42

Problem 2

In a double-slit arrangement the slits are separated by a distance equal to 100 times the wavelength of the light passing through the slits. (a) What is the angular separation in radians between the central maximum and an adjacent maximum? (b) What is the distance between these maxima on a screen 50.0 cm from the slits? (02小題)

(a) the angular separation=_____ rad

05: **ANS:=0.01**

(b)the distance between maxima =_________ mm

06: **ANS:=5**

(a) For the maximum adjacent to the central one, we set $m = 1$

$$\theta_1 = \sin^{-1}\left(\frac{m\lambda}{d}\right)\bigg|_{m=1} = \sin^{-1}\left[\frac{(1)(\lambda)}{100\lambda}\right] = 0.010\,\text{rad}.$$

(b) Since $y_1 = D\tan\theta_1$ (see Fig. 35-10(a)), we obtain

$$y_1 = (500\text{ mm})\tan(0.010\text{ rad}) = 5.0\text{ mm}.$$

The separation is $\Delta y = y_1 - y_0 = y_1 - 0 = 5.0$ mm.

Problem 2

A double-slit arrangement produces interference fringes for sodium light ($\lambda = 589$ nm) that have an angular separation of 3.50×10^{3} rad. For what wavelength would the angular separation be 10.0% greater? (01小題)

λ'=______ nm

07: **ANS:=648**

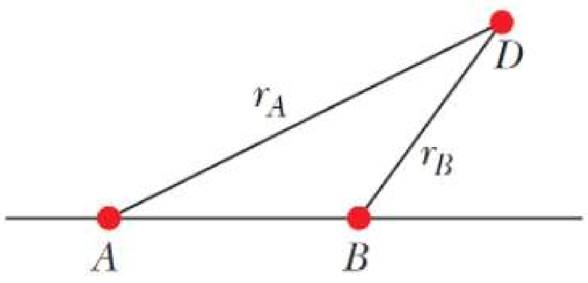
Solution:

The angular positions of the maxima of a two-slit interference pattern are given by $d \sin\theta = m\lambda$, where d is the slit separation, λ is the wavelength, and m is an integer. If θ is small, $\sin\theta$ may be approximated by θ in radians. Then, $\theta = m\lambda/d$ to good approximation. The angular separation of two adjacent maxima is $\Delta\theta = \lambda/d$. Let λ' be the wavelength for which the angular separation is greater by 10.0%. Then, $1.10\lambda/d = \lambda'/d$. or

$$\lambda' = 1.10\lambda = 1.10(589) = 648\,\text{nm}.$$

Problem 3

In the figure, sources A and B emit long-range radio waves of wavelength 400 m, with the phase of the emission from A ahead of that from source B by 90°. The distance r_A from A to detector D is greater than the corresponding distance r_B by 100 m. What is the phase difference of the waves at D? (01小題)



the phase difference=______ rad

08: **ANS:=0**

Solution:

Initially, source A leads source B by 90°, which is equivalent to 1/4 wavelength. However, source A also lags behind source B since r_A is longer than r_B by 100 m, which is 100/400 = 1/4 wavelength. So the net phase difference between A and B at the detector is zero.

Problem 3

In a double-slit experiment, the distance between slits is 5.0 mm and the slits are 1.0 m from the screen.Two interference patterns can be seen on the screen: one due to light of wavelength 480 nm, and the other due to light of wavelength 600 nm. What is the separation on the screen between the third-order (m = 3) bright fringes of the two interference patterns? (01小題)

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the separation=_______ m

09: **ANS:=7.2E-5**

Solution:

The maxima of a two-slit interference pattern are at angles θ given by $d\sin\theta = m\lambda$, where d is the slit separation, λ is the wavelength, and m is an integer. If θ is small, $\sin\theta$ may be approximated by θ in radians. Then, $\theta = m\lambda/d$ to good approximation. The angular separation of two maxima associated with different wavelengths but the same value of m is

$$\Delta\theta = (m/d)(\lambda_2 - \lambda_1),$$

and their separation on a screen a distance D away is

$$\Delta y = D\tan\Delta\theta \simeq D\Delta\theta = (mD/d)(\lambda_2 - \lambda_1) = 7.2\times10^{-5}\ \mathrm{m}$$

Problem 3

Two waves of the same frequency have amplitudes 1.00 and 2.00. They interfere at a point where their phase difference is 60.0°. What is the resultant amplitude? (01小題)

the resultant amplitude=______

10: **ANS:=2.65**

$$2L = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots \quad \text{(maxima—bright film in air).}$$

$$2L = m\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots \quad \text{(minima—dark film in air).}$$

36. (a) We are dealing with a thin film (material 2) in a situation where $n_1 > n_2 > n_3$, looking for strong *reflections*; the appropriate condition is the one expressed by

Therefore, with lengths in nm and $L = 500$ and $n_2 = 1.7$, we have

$$\lambda = \frac{2n_2L}{m} = \begin{cases} 1700 & \text{for } m = 1 \\ 850 & \text{for } m = 2 \\ 567 & \text{for } m = 3 \\ 425 & \text{for } m = 4 \end{cases}$$

visible light

Problem 4

White light is sent downward onto a horizontal thin film that is sandwiched between two materials. The indexes of refraction are 1.80 for the top material, 1.70 for the thin film, and 1.50 for the bottom material. The film thickness is 5.00×10^{-7} m. Of the visible wavelengths (400 to 700 nm) that result in fully constructive interference at an observer above the film, which is the (a) longer and (b) shorter wavelength? The materials and film are then heated so that the film thickness increases. (02小題)

(a) the longer wavelength=_______ nm

11: **ANS:=567**

(b) shorter wavele

12: **ANS:=425**

$$2L = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots \quad \text{(maxima—bright film in air).}$$

$$2L = m\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots \quad \text{(minima—dark film in air).}$$

(a) We are dealing with a thin film (material 2) in a situation where $n_1 > n_2 > n_3$, looking for strong *reflections*; the appropriate condition is the one expressed by

$$2L = m\frac{\lambda}{n_2}, \quad \text{for } m = 0, 1, 2, \ldots$$

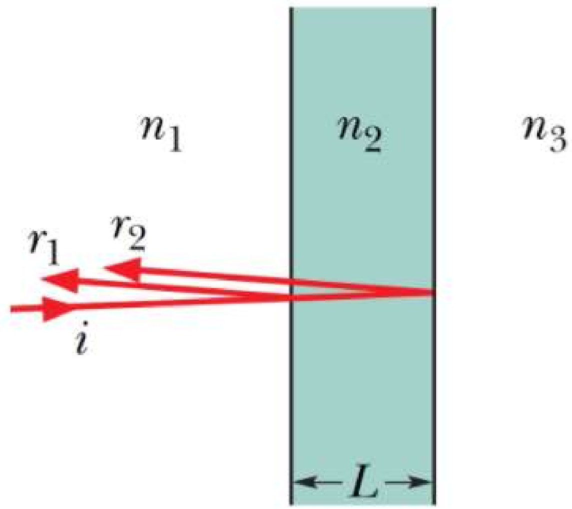
Therefore, with lengths in nm and $L = 500$ and $n_2 = 1.7$, we have

$$\lambda = \frac{2n_2L}{m} = \begin{cases} 1700 & \text{for } m = 1 \\ 850 & \text{for } m = 2 \\ 567 & \text{for } m = 3 \\ 425 & \text{for } m = 4 \end{cases}$$

visible light

Problem 4

In the figure, light is incident perpendicularly on a thin layer of material 2 that lies between (thicker) materials 1 and 3. (The rays are tilted only for clarity.) The waves of rays r_1 and r_2 interfere. For this situation with the indexes of refraction $n_1 = 1.32, n_2 = 1.75$, and$n_3 = 1.33$, the thinlayer thickness $L = 325$ nm, consider the type of interference to be maximum, find and the wavelength λ of the light in the visible range as measured in air. (01小題)



λ=_______ nm

13: **ANS:=455**

In this setup, we have $n_2 > n_1$ and $n_2 > n_3$, and the condition for constructive interference is

$$2L = \left(m + \frac{1}{2}\right)\frac{\lambda}{n_2} \quad \Rightarrow \lambda = \frac{4Ln_2}{2m+1}, \quad m = 0, 1, 2, \ldots$$

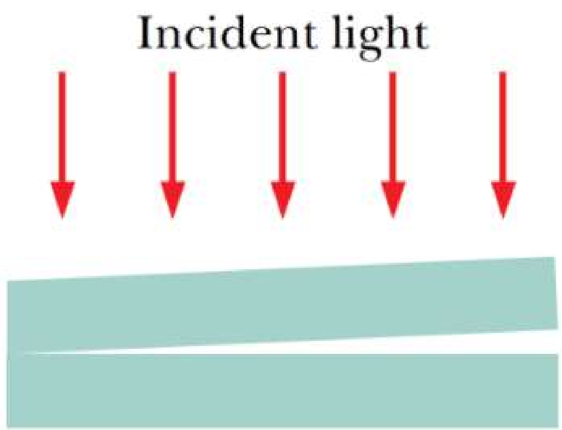
Thus, we have

$$\lambda = \begin{cases} 4Ln_2 = 4(325\text{ nm})(1.75) = 2275\text{ nm} & (m=0) \\ 4Ln_2/3 = 4(325\text{ nm})(1.75)/3 = 758\text{ nm} & (m=1) \\ 4Ln_2/5 = 4(325\text{ nm})(1.75)/5 = 455\text{ nm} & (m=2) \end{cases}.$$

For the wavelength to be in the visible range, we choose m=2 with $\lambda = 455$ nm.

Problem 5

Two rectangular glass plates (n = 1.60) are in contact along one edge and are separated along the opposite edge (see figure). Light with a wavelength of 600 nm is incident perpendicularly onto the top plate. The air between the plates acts as a thin film. 9 dark fringes and 8 bright fringes are observed from above the top plate. If the distance between the two plates along the separated edges is increased by 600 nm, how many dark fringes will there then be across the top plate? (01小題)



The number of dark fringes=_____

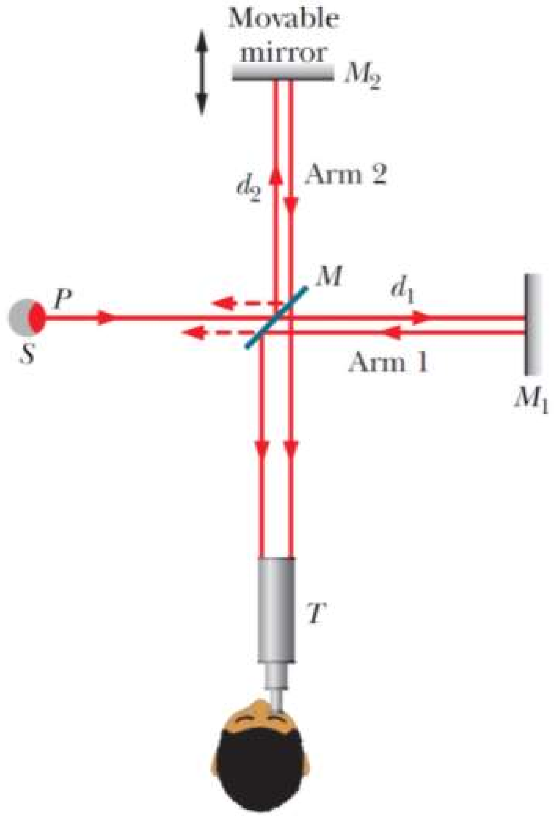
14: **ANS:=11**

Solution:

By the condition $m\lambda = 2y$ where y is the thickness of the air-film between the plates directly underneath the middle of a dark band), the edge of the plates (the edge where they are not touching) are $y = 8\lambda/2 = 2400$ nm apart (where we have assumed that the middle of the ninth dark band is at the edge). Increasing that to $y' = 3000$ nm would correspond to $m' = 2y'/\lambda = 10$ (counted as the eleventh dark band, since the first one corresponds to m = 0). There are thus 11 dark fringes along the top plate.

Problem 6

A thin film with index of refraction $n = 1.40$ is placed in one arm of a Michelson interferometer, perpendicular to the optical path. If this causes a shift of 7 bright fringes of the pattern produced by light of wavelength 589 nm, what is the film thickness? (01小題)



the film thickness=______ nm

15: **ANS:=5200**

Solution:

$$L = \frac{\lambda \Delta N}{2(n-1)} = \frac{589(7.0)}{2(1.40-1)} = 5200 \text{ nm}$$

Problem 6

The element sodium can emit light at two wavelengths, $\lambda_1 = 589.10$ nm and $\lambda_2 = 589.59$ nm. Light from sodium is being used in a Michelson interferometer (see figure above). Through what distance must mirror M_2 be moved if the shift in the fringe pattern for one wavelength is to be 1.00 fringe more than the shift in the fringe pattern for the other wavelength? (01小題)

the distance M_2 moved=______ μm

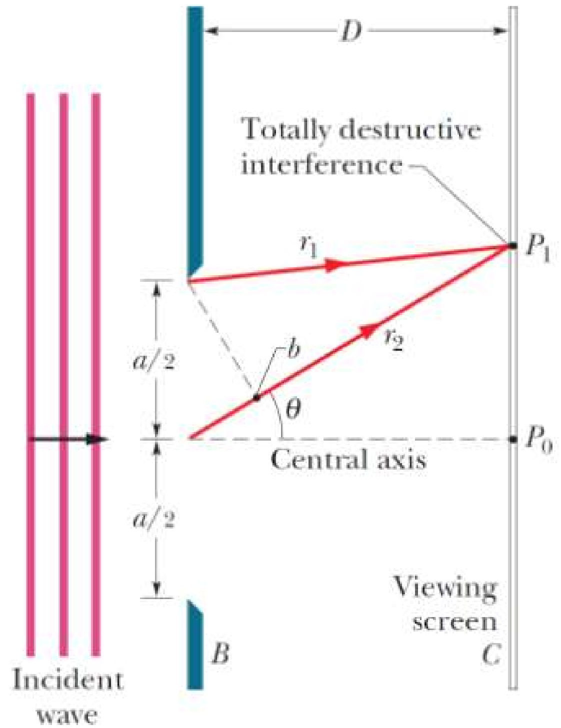
16: **ANS:=354**

$$N' - N = \frac{2L}{\lambda'} - \frac{2L}{\lambda} = 1$$

$$L = \frac{1}{2}\left[\frac{1}{\lambda} - \frac{1}{\lambda'}\right]^{-1} = 3.54 \times 10^5 \text{ nm}$$

Problem 7

Monochromatic light of wavelength 441 nm is incident on a narrow slit. On a screen 2.00 m away, the distance between the second diffraction minimum and the central maximum is 1.50 cm. (a) Calculate the angle of diffraction θ of the second minimum. (b) Find the width of the slit. (02小題)



(a)θ=______ degree

17: **ANS:=0.43**

(b)width of the slite=_______ mm

18: **ANS:=0.118**

Solution:

$$\theta = \sin^{-1}\frac{1.5\,\text{cm}}{2.0\text{m}} = 0.43^\circ$$

$$a = \frac{m\lambda}{a\sin\theta} = \frac{2(441)}{\sin 0.43^\circ} = 6.04 \times 10^{-5}$$

m.

Problem 7

A plane wave of wavelength 590 nm is incident on a slit with a width of $a = 0.40$ mm. A thin converging lens of focal length +70 cm is placed between the slit and a viewing screen and focuses the light on the screen. (a) How far is the screen from the lens? (b) What is the distance on the screen from the center of the diffraction pattern to the first minimum? (02小題)

(a)the distance of screen from the lens=______ m

19: **ANS:=0.7**

(b)the distance of the center of the diffraction pattern to the first mininmum=_____ m

20: **ANS:=1E-3**

(a) A plane wave is incident on the lens so it is brought to focus in the focal plane of the lens, a distance of 70 cm from the lens.

(b) Waves leaving the lens at an angle θ to the forward direction interfere to produce an intensity minimum if $a \sin \theta = m\lambda$, where a is the slit width, λ is the wavelength, and m is an integer. The distance on the screen from the center of the pattern to the minimum is given by $y = D \tan \theta$, where D is the distance from the lens to the screen. For the conditions of this problem,

$$\sin \theta = \frac{m\lambda}{a} = \frac{(1)(590 \times 10^{-9}\ \text{m})}{0.40 \times 10^{-3}\ \text{m}} = 1.475 \times 10^{-3} .$$

This means $\theta = 1.475 \times 10^{-3}$ rad and

$$y = (0.70\ \text{m}) \tan(1.475 \times 10^{-3}\ \text{rad}) = 1.0 \times 10^{-3}\ \text{m}.$$

Problem 8

Millimeter-wave radar generates a narrower beam than conventional microwave radar, making it less vulnerable to antiradar missiles than conventional radar. (a) Calculate the angular width 2θ of the central maximum, from first minimum to first minimum, produced by a 220 GHz radar beam emitted by a 55.0-cm-diameter circular antenna. (The frequency is chosen to coincide with a low-absorption atmospheric "window.") (01小題)

(a)θ=______ rad

21: **ANS:=3.02E-3**

(a) The first minimum in the diffraction pattern is at an angular position θ, measured from the center of the pattern, such that $\sin\theta = 1.22\lambda/d$, where λ is the wavelength and d is the diameter of the antenna. If f is the frequency, then the wavelength is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}\ \text{m/s}}{220\times10^{9}\ \text{Hz}} = 1.36\times10^{-3}\ \text{m}\ .$$

Thus,

$$\theta = \sin^{-1}\left(\frac{1.22\lambda}{d}\right) = \sin^{-1}\left(\frac{1.22(1.36\times10^{-3}\ \text{m})}{55.0\times10^{-2}\ \text{m}}\right) = 3.02\times10^{-3}\ \text{rad}\ .$$

The angular width of the central maximum is twice this, or 6.04×10^{-3} rad (0.346°).

(b) Now $\lambda = 1.6$ cm and $d = 2.3$ m, so

$$\theta = \sin^{-1}\left(\frac{1.22(1.6\times10^{-2}\ \text{m})}{2.3\ \text{m}}\right) = 8.5\times10^{-3}\ \text{rad}\ .$$

The angular width of the central maximum is 1.7×10^{-2} rad (or 0.97°).

Problem 8

The two headlights of an approaching automobile are 1.4 m apart. At what (a) angular separation and (b) maximum distance will the eye resolve them? Assume that the pupil diameter is 5.0 mm, and use a wavelength of 550 nm for the light. Also assume that diffraction effects alone limit the resolution so that Rayleigh's criterion can be applied. (02小題)

(a)the angular separation=______ rad

22: **ANS:=1.34E-4**

(b)maximum distance :=______ m

23: **ANS:=10000**

(a) We use the Rayleigh criteria. Thus, the angular separation (in radians) of the sources must be at least $\theta_R = 1.22\lambda/d$, where λ is the wavelength and d is the diameter of the aperture. For the headlights of this problem,

$$\theta_R = \frac{1.22\left(550\times10^{-9}\text{ m}\right)}{5.0\times10^{-3}\text{ m}} = 1.34\times10^{-4}\text{ rad},$$

or 1.3×10^{-4} rad, in two significant figures.

(b) If L is the distance from the headlights to the eye when the headlights are just resolvable and D is the separation of the headlights, then $D = L\theta_R$, where the small angle approximation is made. This is valid for θ_R in radians. Thus,

$$L = \frac{D}{\theta_R} = \frac{1.4\text{ m}}{1.34\times10^{-4}\text{ rad}} = 1.0\times10^{4}\text{ m} = 10\text{ km}.$$