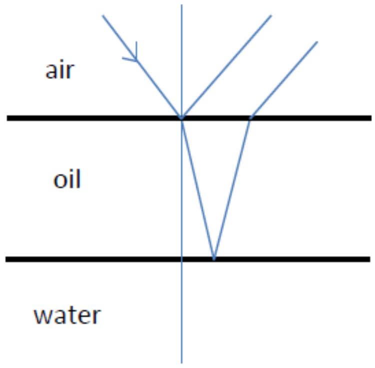
Answer on Question #50694, Physics, Optics

2.

a) An oil (μ_0 = 1.45) film of thickness 280 nm floats on water (μ_w = 1.33). It is illuminated by white light at normal incidence. Which colour in the visible spectrum will be most strongly (i) reflected, and (ii) transmitted?

b) Obtain the expression for shift in fringes when a thin transparent sheet is introduced in the path of one of the waves in a double slit interference experiment.

Solution:



Since 1<1.45, the light reflected from the top of the oil film undergoes phase reversal. The light reflected from the bottom undergoes no reversal because 1.45>1.33.

(i) For constructive interference, we require

$$2\mu_0 d = (m + \frac{1}{2})\lambda$$

Substituting for m gives, m=0, λ_0=1624 nm (infrared)

m=1, λ_1=541 nm (green)

m=2, λ_2=325 nm (ultraviolet)

Both infrared and ultraviolet light are invisible to human eye, so the dominant color in reflected light is **green**.

(ii) transmitted

For destructive interference – Transmission

$$2\mu_0 d = m\lambda$$

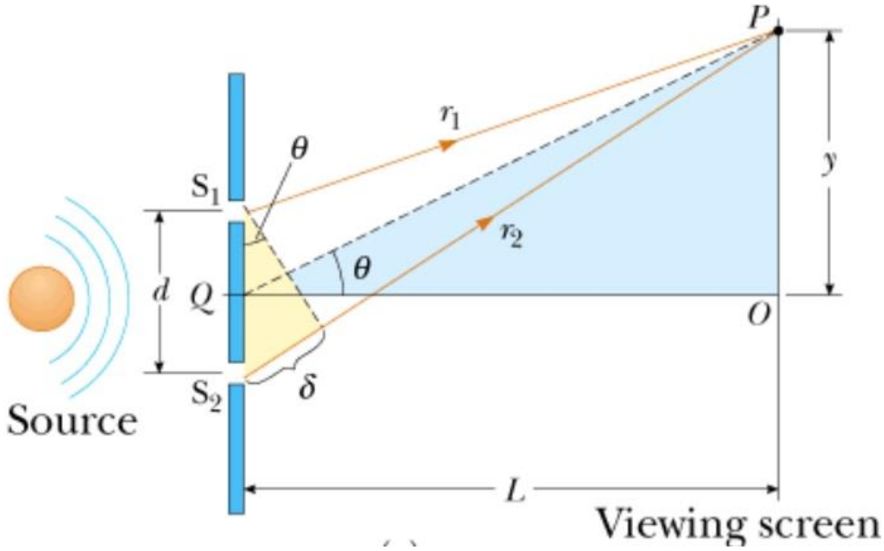
Substituting for m gives, m=1, λ_1=812 nm (near infrared)

m=2, λ_2=406 nm (violet)

m=3, λ_3=271 nm (ultraviolet)

The dominant color visible to human eye is **violet**.

b) Consider the light rays from the two coherent point sources made from *infinitesimal* slits a distance d apart. We assume that the sources are emitting monochromatic light of wavelength λ. The rays are emitted in all forward directions, but let us concentrate on only the rays that are emitted in a direction θ toward a distant screen (θ measured from the normal to the screen, diagram below) . One of these rays has further to travel to reach the screen, and the *path difference* is given by $d\sin\theta$. If this path difference is exactly one wavelength λ or an integer number of wavelengths, then the two waves arrive at the screen in phase and there is constructive interference, resulting in a bright area on the screen. If the path difference is $\frac{1}{2}\lambda$, or $\frac{3}{2}\lambda$, etc., then there is destructive interference, resulting in a dark area on the screen.



$$\delta = r_2 - r_1 = d\sin\theta,$$

$$\left.\begin{aligned} &Bright: d\sin\theta = m\lambda \\ &Dark: \quad d\sin\theta = (m+\tfrac{1}{2})\lambda. \end{aligned}\right\} m=0,\pm1,\pm2..$$

$$d \gg \lambda, \qquad \sin\theta \approx \tan\theta$$
$$y = L\tan\theta \approx L\sin\theta \approx \tan\theta$$

$$y_{bright} = \frac{\lambda L}{d} m$$
$$y_{dark} = \frac{\lambda L}{d}\left(m + \frac{1}{2}\right)$$

When a transparent glass plate of thickness *t* and refractive index *n* is placed in one of the incoming wave path, due to the increase of the path by *(n-1)t*, the interference pattern undergoes a shift ***s***.

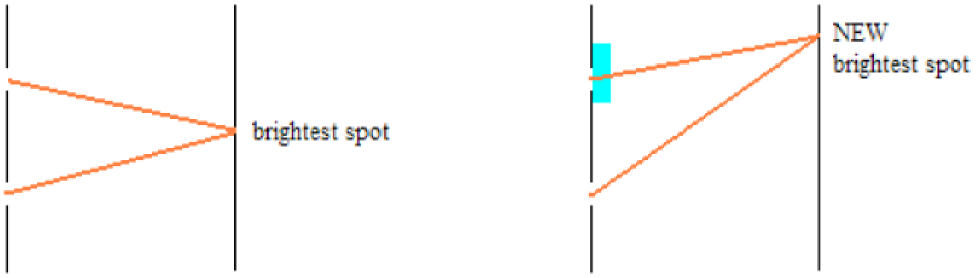


Fig. Equal effective path lengths without (left) and with (right) glass slide.

Once the glass slide is in place, the central point moves. This is due to there being more wavelengths inside the glass slide than in the air in front of the second slit.

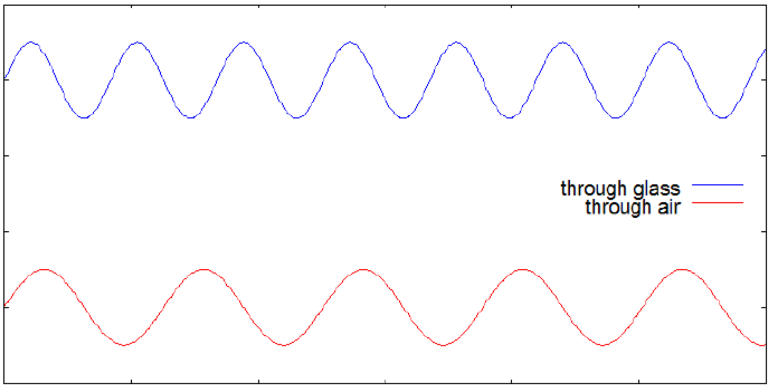


Fig. Difference in wavelengths traveling through air and glass

If the glass has a thickness t, then there are $\frac{t}{\lambda/n}$ complete wavelengths that travel through it, while there are $\frac{t}{\lambda/1}$ wavelengths that travel through the same thickness of air.

The number of fringes shifted is

$$m = \left|\frac{t}{\lambda/n} - \frac{t}{\lambda}\right| = \frac{t}{\lambda}(n-1)$$

Shift of pattern is

$$s = y_{bright} = \frac{\lambda L}{d} m = \frac{\lambda L}{d}\frac{t}{\lambda}(n-1) = \frac{L}{d}(n-1)t.$$