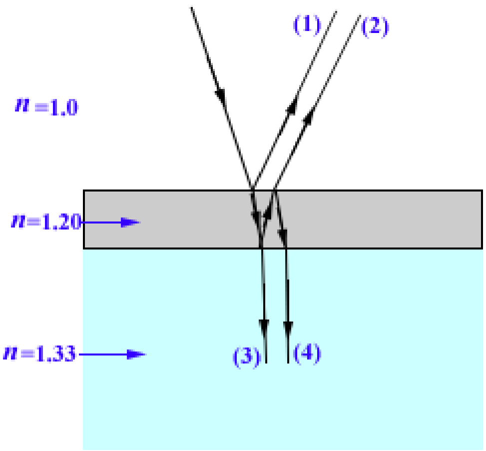
637.

Problem 45.29 (RHK)

A disabled tanker leaks kerosene $(n = 1.20)$ *into the Persian gulf, creating a large slick on top of the water* $(n = 1.33)$. (a) *If we are looking straight down from an airplane onto a region of the slick where the thickness is* 460 nm, *we have to find the wavelength*(*s*) *of the visible light for which the reflection is the greatest*. (b) *If we are scuba-diving directly under the same region of the slick, we have to find the wavelength*(*s*) *of the transmitted visible light for which the intensity is strongest*.



Solution:

(a)

It is given that the thickness of the kerosene slick $(n = 1.20)$ is 460 nm. We recall that a wave that undergoes reflection from a medium whose refractive index is greater than the refractive index of the medium from which it is incident will undergo a phase change of π. From the figure we note that both waves (1) and (2) undergo one reflection each from media having greater index of refraction than the refractive index of the incident media, therefore each acquires a phase change of π. Wave (2) undergoes addition phase difference of amount

$$2\pi \times \frac{2x}{\lambda_{\text{kerosene}}},$$

where x is the thickness of the kerosene slick, 460 nm.

We know that

$$\lambda_{\text{kerosene}} = \frac{\lambda}{n_{\text{kerosene}}} = \frac{\lambda}{1.20},$$

where λ is the wavelength in air.

Waves (1) and (2) will interfere constructively, if their phase difference is $2m\pi,\ m = 1, 2, 3...$

Therefore, the waves with the following wavelengths will appear brightest to an observer who is sighting the slick from vertically above it:

$$\frac{4\pi x n_{\text{kerosene}}}{\lambda} = 2m\pi,$$

or

$$\lambda = \frac{2\times 460\times 1.20}{m} \text{ nm, where } m = 1,2,3,..$$

We thus find that the waves of the following wavelengths will appear with greatest intensity when viewed from above the slick:

$$\lambda = 1{,}104 \text{ nm},\ 552 \text{ nm}, 368 \text{ nm},$$

Out of these we note that the wavelength in the visible region is 552 nm.

(b)

For answering the second part of the problem we will consider interference of waves (3) and (4), see the figure. Wave (3) is transmitted from air to kerosene and then to water. But wave (4) undergoes two reflections; one from kerosene-water interface and another from kerosene-air interface. As the refractive index of sea water is greater than that of kerosene there is an additional phase change of π in wave (4). Therefore, the condition for constructive interference of waves (3) and (4) is that phase change because of additional path length in kerosene of wave (4) has to be $(2m+1)\pi,\ m=0,1,2,..$

The wavelengths for which the transmitted waves in water will appear brightest will be determined by the following condition:

$$\frac{2\pi}{\lambda_{\text{kerosene}}}\times 2\times 460\text{ nm}=(2m+1)\pi,$$

as

$$\lambda_{\text{kerosene}}=\frac{\lambda}{n_{\text{kerosene}}}=\frac{\lambda}{1.20},$$

we find

$$\lambda=\frac{4\times 1.20\times 460}{(2m+1)}\text{ nm, m=0,1,2,3,..}$$

$$=2208\text{ nm, }736\text{ nm, }441.6\text{ nm.}$$

Out of these the wavelength in the visible part of the spectrum is 442 nm.