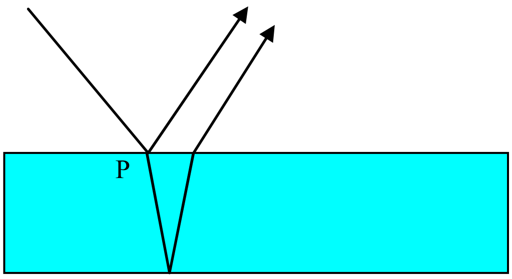
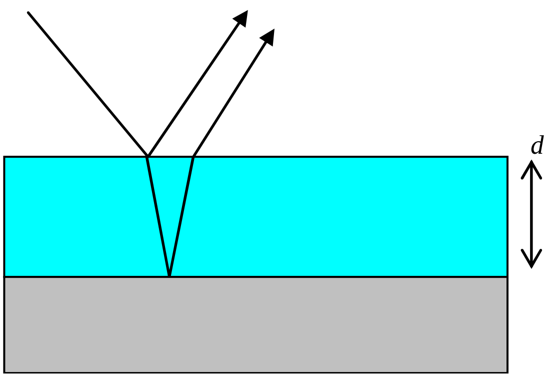
Answers to Coursebook questions – Chapter G5

1 Assuming the film to be suspended in air we see that light reflected off the top and bottom faces of the film will interfere.



There will be a phase change of π at point P and so the condition for destructive interference (for rays incident normally on the film) is $2d = \frac{\lambda}{n}$, where n is the refractive index of the film.
The wavelength (in air) that destructively interferes is therefore $\lambda = 2dn$.
Now, purple is the combination of red and violet (blue), which suggests that the wavelengths in the middle of the spectrum (yellow/green) destructively interfere. These wavelengths are approximately $\lambda = 550\text{ nm}$ and $n = 1.33$, so we get a thickness of $550\text{ nm} = 2d \times 1.33 \Rightarrow d \approx 208\text{ nm}$. So it could be that film thicknesses of this order of magnitude are the most common thickness for soap films, which is why most of them appear purple.

2 There will be a phase change of π at both reflection points and so the condition for destructive interference (for normal incidence) is $2d = (k + \frac{1}{2})\frac{\lambda}{n}$, where n is the refractive index of the coating.



This gives $d = (k + \frac{1}{2})\frac{\lambda}{2n} = (k + \frac{1}{2})\frac{680}{2 \times 1.38}\text{ nm}$.
The least thickness d is obtained for $k = 0$ and is $d = 123\text{ nm}$.

3 The reflected light must show constructive interference. There is a phase change only at the top reflection, so the condition for constructive interference is

$2d = (k + \frac{1}{2})\frac{\lambda}{n}$ where n is the refractive index of the film.

Then $d = (k + \frac{1}{2})\frac{\lambda}{2n} = (k + \frac{1}{2})\frac{550}{2 \times 1.33} = (k + \frac{1}{2}) \times 206.8 \text{ nm}$.

Possible values of d are then $d = 103 \text{ nm}$, $d = 310 \text{ nm}$ etc.

4 Consider a soap film surrounded by air. The condition for destructive interference is

$2d = k\frac{\lambda}{n}$ where k is an integer and n is the refractive index of the film.

This gives $\frac{k}{2n} = \frac{d}{\lambda}$. If the thickness of the film is **much less** than a wavelength ($d < \lambda$)

then $\frac{d}{\lambda} \approx 0$ and so $\frac{k}{2n} \approx 0$.

This condition is always satisfied for all wavelengths for $k = 0$. Thus all wavelengths will undergo destructive interference in this case and the film appears dark.

On the other hand, if the film is placed upon a surface of higher refractive index than that of the soap film (for example on glass) then because of the phase difference at both reflection points the condition $2d = k\frac{\lambda}{n}$ is now the condition for **constructive** interference. This means that for very thin films, this is satisfied for $k = 0$ for almost all wavelengths and the film appears bright.

Consider now the case of a thick film surrounded, say, by air. The condition for destructive interference is again $2d = k\frac{\lambda}{n}$ and for constructive interference it is

$2d = (k + \frac{1}{2})\frac{\lambda}{n}$, where this time, $d > \lambda$. In this case very many different values of k can satisfy this condition. This means that what the eye sees is a **combination** of the various interference patterns for different values of k, and as a result no actual interference pattern is observable – the result appears just like ordinary reflection.

5 If the angle θ of the wedge is made smaller, the separation Δx of the fringes will increase since $\tan\theta = \frac{\lambda}{2\Delta x}$.

6 The separation of the bright fringes is $\frac{5 \times 10^{-2}}{12} = 4.17 \times 10^{-3}$ m (strictly $\frac{5 \times 10^{-2}}{11}$)

and so $\tan\theta = \frac{\lambda}{2\Delta x} = \frac{500 \times 10^{-9}}{2 \times 4.17 \times 10^{-3}} = 6.0 \times 10^{-5}$,

giving $\theta \approx 3 \times 10^{-3}$ degrees or $\theta \approx 6 \times 10^{-6}$ rad.

