Suggested Solutions

Tutorial 10B Young's Double Slits and Diffraction Grating

Self-Practice Questions on Young's Double Slits

S1

This question involves **direct substitution** of given quantities into the **fringe separation equation** for Young's double slits.

For Young's double slits experiment, fringe separation $\Delta y = \frac{\lambda L}{d}$

$$\Delta y = \frac{(0.59\times10^{-6})(0.30)}{0.36\times10^{-3}} = 4.92\times10^{-4}\text{ m}$$

S2

This question involves the use of the **fringe separation equation**, similar to S1.

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Method 1

$\Delta y = \frac{\lambda L}{d}$

$\Rightarrow$ Distance of slits from screen, L = 0.34 m

a. $\Delta y = \frac{\lambda L}{d} = \frac{(0.60\times10^{-6})(0.34)}{0.60\times10^{-3}} = 0.51mm$

b. $\Delta y = \frac{\lambda L}{d} = \frac{(0.70\times10^{-6})(0.34)}{0.30\times10^{-3}} = 0.80mm$

c. $\Delta y = \frac{\lambda L}{d} = \frac{(0.70\times10^{-6})(2\times0.34)}{0.30\times10^{-3}} = 1.60mm$

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Method 2

a. $\Delta y \propto \lambda \Rightarrow$

$\Delta y_{new} = \Delta y_{old}(\frac{\lambda_{new}}{\lambda_{old}})$

$= 0.60(\frac{0.60}{0.70})$

$= 0.51mm$

b. $\Delta y \propto \frac{1}{d} \Rightarrow$

$\Delta y_{new} = \Delta y_{old}(\frac{d_{old}}{d_{new}})$

$= 0.60(\frac{0.40}{0.30})$

$= 0.80mm$

c. $\Delta y \propto \frac{L}{d} \Rightarrow$

$\Delta y_{new} = \Delta y_{old}(\frac{d_{old}}{d_{new}})(\frac{L_{new}}{L_{old}})$

$= 0.60(\frac{0.40}{0.30})(2)$

$= 1.60mm$

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Note: There are two ways to solve this question.
In this question, since you are given explicit values for fringe separation, slit separation and wavelength, you can calculate explicitly the slit-screen distance *L.*

A more general approach would be to consider the proportionalities of the quantities involved in the equation. This would be useful if explicit values were not given in the question.

S3

This question is on **fringe separation** for Young's Double Slits.

> Note:
>
> $$\Delta y = \frac{\lambda L}{d}$$
>
> Question wants bright fringes to be farthest apart → they are asking what combination of λ, L, d would maximize the value of fringe separation Δy

By inspection, Δy is maximized when

- λ is maximized
- *L* is maximized
- *d* is minimized

Ans: (C)

Self-Practice Questions on Diffraction Grating

S4

This question involves direct use of the **diffraction grating equation**.

For diffraction grating, $d \sin \theta = n\lambda$

$$\Rightarrow \left(\frac{1 \text{ x } 10^{-3}}{600}\right)\sin(22.50°) = (1)(\lambda)$$

$\Rightarrow \lambda = 638$ nm

> Reminder!
>
> Pay close attention to the **units** of *N.*
> In most cases, *N* is not given in SI units, which you need to account for when taking the reciprocal to find the slit separation *d.*

S5

This question involves direct use of the **diffraction grating equation**.

For diffraction grating, $d \sin \theta = n\lambda$

$$\Rightarrow d \sin\left(\frac{\alpha}{2}\right) = 2\lambda$$

$$\Rightarrow d = \frac{2\lambda}{\sin\left(\frac{\alpha}{2}\right)}$$

> Common Error:
>
> Remember that θ in the diffraction grating equation refers to the angle **with respect to the principle axis.**

Ans: (C)

S6

This question involves taking **proportionalities** of quantities in the **diffraction grating equation**.

For diffraction grating, $d \sin \theta = n\lambda \Rightarrow \lambda \propto \sin\theta$ for same *d*, *n*

$$\lambda_{red} = \lambda_{blue}\left(\frac{\sin\theta_{red}}{\sin\theta_{blue}}\right)$$
$$= (435\times10^{-9})\left(\frac{\sin(23.7°)}{\sin(15.8°)}\right)$$
$$= 643.3nm$$

Note: Similar to S1, you can also calculate the slit separation explicitly for blue light, and subsequently use it to calculate the wavelength of the red light.

Comparing to the data table, the impurity is cadmium.

Ans: (B)

S7

This question involves use of the **diffraction grating equation,** and subsequently calculating the **maximum order** of fringes observed.

For diffraction grating, $d \sin \theta = n\lambda \Rightarrow \theta = \sin^{-1}\left(\frac{n\lambda}{d}\right)$

Angular separation between the first order diffracted wavelengths,

$$\Delta\theta = \theta_2 - \theta_1 = \sin^{-1}\left(\frac{(1)(615 \text{ x } 10^{-9})}{(10^{-3})/600}\right) - \sin^{-1}\left(\frac{(1)(589 \text{ x } 10^{-9})}{(10^{-3})/600}\right) = 0.959^{o}$$

Max observable order for λ = 589 nm

$$n_{\max,519nm} = \frac{d\sin(90°)}{\lambda}$$
$$= \frac{(10^{-3}/600)(1)}{589\times10^{-9}}$$
$$= 2.8$$
$$= 2$$

This part is similar to Lecture Example 10.6.2. Conceptually, it makes use of the fact that $\theta_{\max} = 90°$ for a diffraction grating experiment.

Max observable order for λ = 615 nm

$$n_{\max,615nm} = \frac{d\sin(90°)}{\lambda}$$
$$= \frac{(10^{-3}/600)(1)}{615\times10^{-9}}$$
$$= 2.7$$
$$= 2$$

Note: Since *n* must be a whole number, the calculated values of *n* were rounded down.

S8

This question involves **qualitative** analysis of the **diffraction grating equation**.

(i)

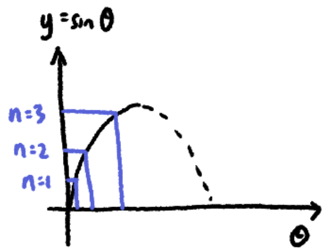
$d \sin \theta = n\lambda \quad \Rightarrow \sin\theta = \frac{n\lambda}{d} = (\frac{\lambda}{d})n$

$\sin(\theta_2) = 2\sin(\theta)$

$\Rightarrow \theta_2 > 2\theta$

Ans: (C)

Note: If you plot the graph of $\sin\theta$ against θ, you can observe that the angular displacement θ between neighbouring orders increases with order *n.*)



(ii)

$d \sin \theta = n\lambda \quad \Rightarrow \sin\theta \propto \lambda$

In other words, θ increases with λ, hence $\theta' > \theta$

Ans: (C)