Wallace Hall Academy

CfE Higher Physics

Particles and Waves

Exam Questions Part 2: Solutions

SECTION 5 : INTERFERENCE AND DIFFRACTION

1. (a) First minimum ⇒ $L_2Y - L_1Y = \frac{1}{2}\lambda$

$2.14 - 1.80 = \frac{1}{2}\lambda$

$\frac{1}{2}\lambda = 0.34$

$\lambda = 0.68\ m$

(b) Amplitude increases.
Destructive interference no longer occurs.

2. (a) (i) Maxima and minima are caused due to the interference of the two sets of waves from X and Y.

When the two waves are exactly in phase constructive interference occurs and there is a maximum.

When the two waves are exactly out of phase destructive interference occurs and there is a minimum.

(ii) $1\frac{1}{2}\lambda = YQ - XQ$

$= 5.2 - 4.0$

$= 1.2$

$\lambda = 0.8\text{ m}$

(b) (i) As the frequency is increased the wavelength of the sound decreases.

(ii) As the frequency is increased the phase relationship between the two waves changes. When the waves are exactly in phase there is a maximum. When the waves are exactly out of phase there is a minimum.

3. $v = f\lambda$

$340 = 1000\lambda$

$\lambda = 0.34$ m

path difference $= 1.37 - 1.20$

$= 0.17$ m

path difference $= \frac{\lambda}{2}$ ⇒ out of phase

⇒ destructive interference

When loudspeaker 2 is switched on the amplitude of the signal decreases due to destructive interference occuring at the microphone.

4. (a) Maxima are produced when waves are in phase and constructive interference occurs. Minima are produced when waves are exactly out of phase and destructive interference occurs.

(b) Blue light has a shorter wavelength than red light.

(c) $n\lambda = d \sin\theta$

$2 \times 4.73 \times 10^{-7} = 2.00 \times 10^{-6} \sin\theta$

$\sin\theta = 0.473$

$\theta = 28.2^{\circ}$

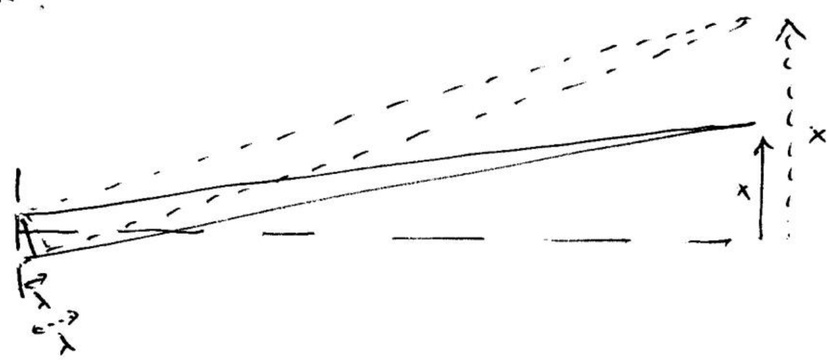
5. (a) $n\lambda = d \sin\theta$

$633 \times 10^{-9} = d \sin 18.5°$

$d = \dfrac{633 \times 10^{-9}}{\sin 18.5°}$

$= 1.9 \times 10^{-6}$ m

(b) Wavelength of the new laser is shorter than the original.
A shorter wavelength results in a shorter path difference to give a maximum and this then occurs at a smaller angle and produce spots that are close together.



6. (a) (i)

$$n\lambda = d\sin\theta$$
$$2\lambda = 5.0 \times 10^{-6} \sin 14°$$
$$\lambda = 6.0 \times 10^{-7}\ \text{m}$$

(ii) With a grating with slits that are closer together the points of maxima are further apart. This allows the distance between the maxima and hence the angle to be determined more accurately.

(b) (i) All wavelengths are in phase at the central maximum. All wavelengths of light mix to give white light.

(ii) Different wavelengths interfere at different angles. The range of different colours in a spectrum therefore interfere at different angles from short wavelength violet to longer wavelength red.

PARTICLES AND WAVES - EXAM QUESTIONS PART 2

SECTION 6 : REFRACTION OF LIGHT

1. (a) $\sin \theta_c = \frac{1}{n}$

$\sin \theta_c = \frac{1}{1 \cdot 33}$

$\theta_c = 48 \cdot 8^\circ$

Angle of incidence in water is greater than the critical angle so total internal reflection occurs.

(b) $n = \frac{\sin \theta_2}{\sin \theta_1}$

$= \frac{0 \cdot 40}{0 \cdot 28}$

$= 1 \cdot 43$

(c) $n = \frac{\lambda_{air}}{\lambda_{liquid}}$

$1 \cdot 47 = \frac{670 \times 10^{-9}}{\lambda_{liquid}}$

$\lambda_{liquid} = \frac{670 \times 10^{-9}}{1 \cdot 47}$

$= 456 \times 10^{-9}$ m.

2. (a) $n = \frac{\sin\theta_a}{\sin\theta_g}$

$1.50 = \frac{\sin 50}{\sin\theta_g}$

$\sin\theta_g = \frac{\sin 50}{1.50}$

$\theta_g = 30.7°$

(b) $n = \frac{\lambda_a}{\lambda_g}$

$1.50 = \frac{\lambda_a}{420 \times 10^{-9}}$

$\lambda_a = 1.50 \times 420 \times 10^{-9}$

$= 630 \times 10^{-9}$ m

(c) The refractive index of a material is slightly different for different frequencies of light.

Refractive index is slightly greater for blue light than red light so blue light is refracted closer to the normal than red, so $\theta_{blue} < \theta_{red}$.

3. (a) (i) $n = \frac{\sin \theta_a}{\sin \theta_g}$

$1.61 = \frac{\sin 28.0°}{\sin \theta_g}$

$\sin \theta_g = \frac{\sin 28.0°}{1.61}$

$\theta_g = 17.0°$

(ii) $v = f\lambda$

$3.00 \times 10^8 = 4.80 \times 10^{14} \lambda_a$

$\lambda_a = \frac{3.00 \times 10^8}{4.80 \times 10^{14}}$

$\lambda_a = 6.25 \times 10^{-7}$ m

$n = \frac{\lambda_a}{\lambda_g}$

$1.61 = \frac{6.25 \times 10^{-7}}{\lambda_g}$

$\lambda_g = \frac{6.25 \times 10^{-7}}{1.61}$

$\lambda_g = 3.88 \times 10^{-7}$ m

(b) X

Blue light is refracted more than red light as the refractive index of the glass is slightly greater for blue light than for red light.

4. (a) (i) $n = \frac{\sin\theta_a}{\sin\theta_g}$

$= \frac{\sin 82}{\sin 45}$

$= 1{\cdot}40$

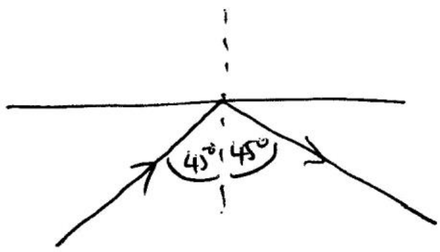
(ii) Angle of refraction for blue light is greater than 82°.

A greater refractive index causes a greater change of direction as light travels from the liquid into the air.

(b) $\sin\theta_c = \frac{1}{n}$

$\sin\theta_c = \frac{1}{1{\cdot}44}$

$\theta_c = 44°$



Angle of incidence > critical angle so total internal reflection occurs.

5. (a) $n = \frac{\sin\theta_a}{\sin\theta_g}$

$n = \frac{\sin 20}{\sin 13}$

$n = 1.52$

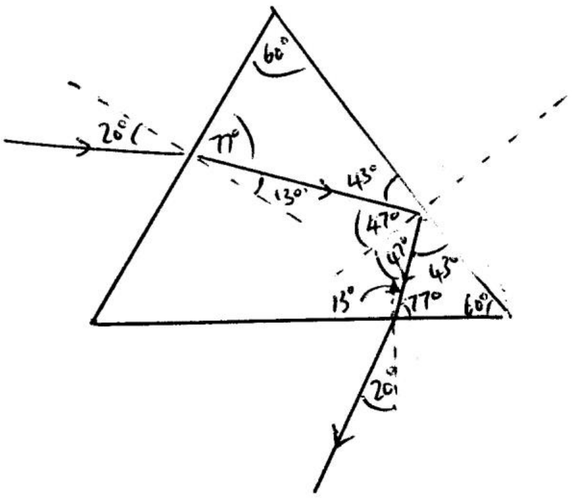
(b) The angle of incidence in a medium beyond which only total internal reflection occurs.

(c) $\sin\theta_c = \frac{1}{n}$

$\sin\theta_c = \frac{1}{1.52}$

$\theta_c = 41.1°$

(d)



6. (a) (i)

$$n = \frac{\sin\theta_a}{\sin\theta_g}$$

$$n = \frac{\sin 50}{\sin 28}$$

$$n = 1.63$$

(ii)

$$\sin\theta_c = \frac{1}{n}$$

$$\sin\theta_c = \frac{1}{1.63}$$

$$\theta_c = 37.8°$$

(b) (i) $n = 1.55$ from graph

$$n = \frac{\lambda_a}{\lambda_g}$$

$$1.55 = \frac{510 \times 10^{-9}}{\lambda_g}$$

$$\lambda_g = \frac{510 \times 10^{-9}}{1.55}$$

$$\lambda_g = 329 \times 10^{-9} \text{ m}$$

(ii) $\sin\theta_c \propto \frac{1}{n}$

as wavelength increases n decreases

$\Rightarrow$ as wavelength increases, θ_c increases.

(iii) Flint glass has a higher refractive index than crown glass so spectrum is refracted further down screen for flint glass.
The refractive index of flint glass has a greater range of values for the wavelengths of visible light than crown glass so the spectrum is more dispersed for flint glass.

7. (a) $n = \frac{\sin\theta_a}{\sin\theta_g}$ or $n = \frac{\sin 70}{\sin 39}$

$= \frac{\sin 15}{\sin 10}$ $= 1.49$

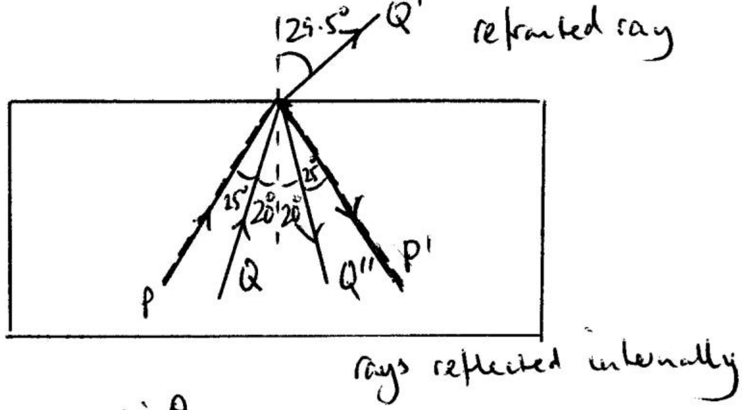
$= 1.49$

(b) (i) $\sin\theta_c = \frac{1}{n}$

$\sin\theta_c = \frac{1}{1.44}$

$\theta_c = 44.0°$

(ii)



$n = \frac{\sin\theta_a}{\sin\theta_g}$

$1.44 = \frac{\sin\theta_a}{\sin 20}$

$\sin\theta_a = 1.44 \sin 20$

$\theta_a = 29.5°$

8. (a)

$$\sin\theta_c = \frac{1}{n}$$

$$\sin\theta_c = \frac{1}{1.33}$$

$$\theta_c = 49^\circ$$

$$n = \frac{\sin\theta_a}{\sin\theta_g}$$

$$1.33 = \frac{\sin\theta_a}{\sin 30}$$

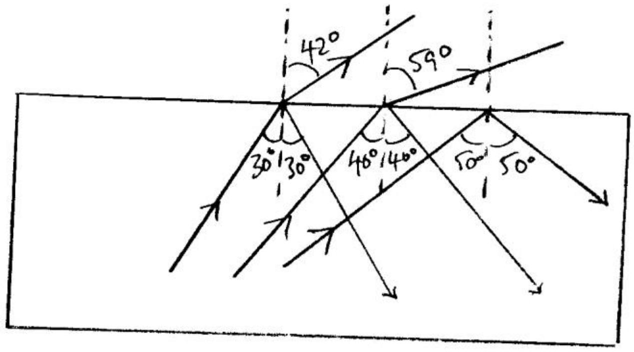
$$\sin\theta_a = 1.33 \sin 30$$

$$\theta_a = 42^\circ$$

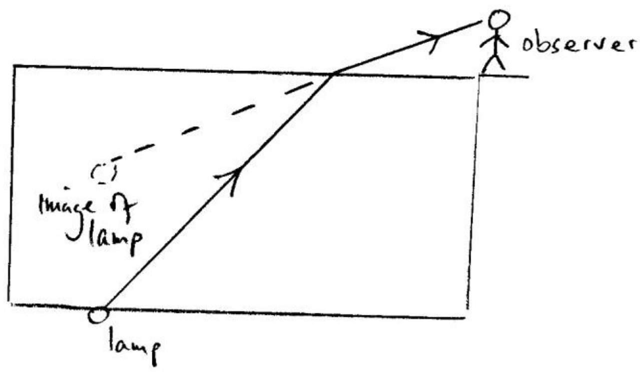
$$1.33 = \frac{\sin\theta_a}{\sin 40}$$

$$\sin\theta_a = 1.33 \sin 40$$

$$\theta_a = 59^\circ$$



(b)



The light refracts at the surface of the water so that the light appears to come from a shallower depth.

PARTICLES AND WAVES - EXAM QUESTIONS PART 2

SECTION 7 : SPECTRA

1. (a) $I = \frac{P}{A}$

$= \frac{2 \times 1.0 \times 10^{-3}}{8.0 \times 10^{-5}}$

$= 25 \text{ W m}^{-2}$

(b) for point light source $I \propto \frac{1}{d^2}$

$\Rightarrow Id^2 = \text{constant}$

$1.1 \times 0.5^2 = 0.275$

$0.8 \times 0.7^2 = 0.392$

$0.6 \times 0.9^2 = 0.486$

$Id^2 \neq \text{constant}$

$\Rightarrow$ source is not a point light source.

2. (a) Power of light incident on a unit area.

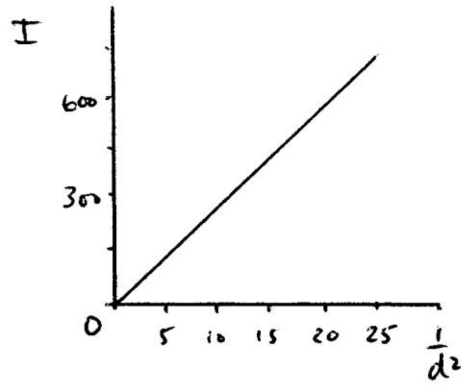
(b) $Id^2 \Rightarrow$

$$\left.\begin{array}{lcl} 675 \times 0{\cdot}20^2 & = & 27 \\ 302 \times 0{\cdot}30^2 & = & 27{\cdot}18 \\ 170 \times 0{\cdot}40^2 & = & 27{\cdot}2 \\ 108 \times 0{\cdot}50^2 & = & 27 \end{array}\right\} \text{constant}$$

$\Rightarrow Id^2 = \text{constant}$

$\Rightarrow I \propto \frac{1}{d^2}$

<u>OR</u>



$I \propto \frac{1}{d^2}$

(c) To reduce reflections from the bench surface so that light meter measures only light from small lamp.

(d) Light meter measures same reading since the laser beam is a parallel beam and irradiance remains constant.

<u>OR</u>

Light meter measures only very slightly less as laser beam only diverges very slightly.

3. (a) 6

(b) $E_3 \rightarrow E_2$ (smallest energy gap)

(c) If more electrons jump down between two particular energy levels more photons of that energy will be emitted than for other energy jumps. Therefore that line will be brighter than the others.

4. (a) $E_3 \rightarrow E_2$ smallest energy jump

$\Rightarrow$ lowest energy

$\Rightarrow$ longest wavelength

$\Rightarrow$ line Z

(b) More electrons jump down these transitions (ie $E_3 \rightarrow E_2$, $E_4 \rightarrow E_2$) so they are brighter.

(c) (i) $E = hf$

$E = 6.63 \times 10^{-34} \times 7.48 \times 10^{13}$

$E = 4.96 \times 10^{-20}$ J

(ii) 4.96×10^{-20} J $= 0.496 \times 10^{-19}$ J

$-0.864 \times 10^{-19} - 0.496 \times 10^{-19} = -1.360 \times 10^{-19}$

$\Rightarrow E_5 \rightarrow E_4$.

5\. (a) (i) Lower

(ii) $\Delta E = hf$

$= \frac{hv}{\lambda}$

$= \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{589 \times 10^{-9}}$

$= 3.38 \times 10^{-19}\ J$

(b) (i) Light emitted by the sodium vapour lamp is absorbed by the vaporised sodium in the flame so it does not strike the screen. This forms a shadow of the flame.

(ii) The frequencies / wavelengths / energies of the light emitted by the cadmium vapour lamp do not match the energy level gaps in the sodium atoms in the flame so no light is absorbed and no shadow cast.

PARTICLES AND WAVES - EXAM QUESTIONS PART 2

SECTION 8 : UNCERTAINTIES AND EXPERIMENTS IN WAVES

1. (a) The power of radiation per unit area.

(b) With a diverging light beam the irradiance of the light decreases with distance. In order for it to be a fair experiment the distance must be kept constant as the angle is changed.

(c) (i) 42°

(ii) $n = \frac{1}{\sin c}$

$= \frac{1}{\sin 42}$

$= 1.49$

(iii) As θ is increased the irradiance of ray T decreases.

2. (a) When two waves meet exactly in phase constructive interference occurs and a maximum is obtained.

(b) (I) (A) $\bar{d}_{AB} = \dfrac{1.11 + 1.08 + 1.10 + 1.13 + 1.11 + 1.07}{6}$

$= 1.10 \text{ m}$

(B) $\Delta d_{AB} = \dfrac{1.13 - 1.07}{6}$

$= 0.01 \text{ m}$

(II) $\Delta d_{AB} = \dfrac{0.01}{1.10} \times 100 = 0.9\%$

$\Delta d_{BC} = \dfrac{10}{270} \times 100 = 3.7\%$

d_{BC} has the largest percentage uncertainty.

(III) $n\lambda = d \sin\theta = d\left(\dfrac{d_{BC}}{d_{AB}}\right)$

$2\lambda = 4.00 \times 10^{-6} \left(\dfrac{0.270}{1.10}\right)$

$\lambda = \dfrac{4.00 \times 10^{-6} \times 0.2454}{2}$

$= 4.91 \times 10^{-7} \text{ m}$

Largest uncertainty $= 3.7\%$

$\dfrac{3.7}{100} \times 4.91 \times 10^{-7} = 0.18 \times 10^{-7}$
$= 0.2 \times 10^{-7}$

$\Rightarrow \lambda = (4.9 \pm 0.2) \times 10^{-7} \text{ m}.$

3. (a) $\bar{L} = \dfrac{2.402 + 2.399 + 2.412 + 2.408 + 2.388 + 2.383 + 2.415}{7}$

$= 2.401 \text{ m}$

$\Delta L = \dfrac{2.415 - 2.383}{7}$

$= 0.0046$

$= 0.005 \text{ m}$

$L = (2.401 \pm 0.005) \text{ m}$

(b) $\% \Delta L = \dfrac{\Delta L}{\bar{L}} \times 100 = \dfrac{0.005}{2.401} \times 100 = 0.2\%$

$\% \Delta x = \dfrac{\Delta x}{\bar{x}} \times 100 = \dfrac{1}{91} \times 100 = 1.1\%$

x has the largest percentage uncertainty.

(c) $n\lambda = d \sin\theta = d\left(\dfrac{x}{L}\right)$

$\lambda = 1.693 \times 10^{-5} \times \left(\dfrac{0.091}{2.401}\right)$

$\lambda = 6.4166 \times 10^{-7} \text{ m}$

largest percentage uncertainty = 1.1%

$\Delta\lambda = \dfrac{1.1}{100} \times 6.4166 \times 10^{-7}$

$= 0.07 \times 10^{-7} \text{ m}$

$\lambda = (6.42 \pm 0.07) \times 10^{-7} \text{ m}$

(d) Distance x has the greatest uncertainty. To improve overall uncertainty its measurement should be improved.
Measure x to second order maximum and use $2\lambda = \dfrac{dx}{L}$.
By measuring between both second order maxima and halving the distance gives a further improvement.