A LEVEL PHYSICS

WORKED SOLUTIONS

3.2. Refraction, Diffraction and Interference MCQ

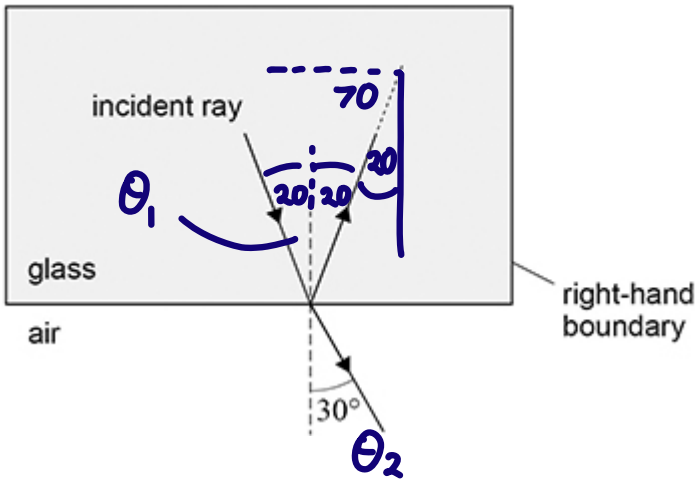
Worked Solutions by Lewis Matheson from
ALevelPhysicsOnline.com in collaboration
with **PhysicsAndMathsTutor**.com

1. A ray of light is incident on the internal boundary of a rectangular glass block in air.

Part of the light refracts out of the block at an angle of 30°.

Some of the remaining light reflects within the block to become incident on the right-hand boundary. refractive index of glass = 1.48

not to scale



What is the angle of incidence of the ray at the right-hand boundary?

A 20° ○

B 42° ○

C 48° ○

D 70° ●

$\sin\theta_1 = \frac{n_2}{n_1}\sin\theta_2$

$\theta_1 = 19.7 \approx 20°$

(Total 1 mark)

2. In a Young's double-slit experiment, monochromatic light is incident on two narrow slits and the resulting interference pattern is observed on a screen.

Which change **decreases** the fringe separation?

$w = \frac{\lambda D}{s}$

A decreasing the separation between the two slits $s\downarrow\ w\uparrow$ ○

B increasing the distance between the slits and the screen $D\uparrow\ w\uparrow$ ○

C using monochromatic light of higher frequency $\therefore \lambda\downarrow\ w\downarrow$ ●

D using monochromatic light of longer wavelength $\lambda\uparrow\ w\uparrow$ ○

(Total 1 mark)

3. A diffraction grating is illuminated normally.

The second-order maximum for light of wavelength 650 nm occurs at the same angle as the third-order maximum for light of wavelength λ.

What is λ?

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

A 217 nm ○

B 325 nm ○

$n_1\lambda_1 = n_2\lambda_2$

C 433 nm ●

D 975 nm ○

$\lambda_2 = \frac{n_1}{n_2}\lambda_1 = \frac{2}{3} \times 650 = 433.3$ nm

(Total 1 mark)

4. Light of wavelength λ is incident normally on two parallel slits of separation s. Fringes of spacing w are seen on a screen at a distance D from the slits.

Which row gives another arrangement that produces a fringe spacing of w?

$w = \frac{\lambda D}{s}$

	Wavelength	Slit separation	Distance between slits and screen	
A	2λ	$2s$	$2D$	○ $= 2w$
B	2λ	$4s$	$2D$	● $= w$
C	2λ	$2s$	$4D$	○ $= 4w$
D	4λ	$2s$	$2D$	○ $= 4w$

(Total 1 mark)

5. A narrow beam of monochromatic light is incident normally to a diffraction grating. The first-order diffracted beam makes an angle of 20° with the normal to the grating.

What is the highest order visible with this grating at this wavelength?

$n\lambda = d\sin\theta$ $\quad \frac{n}{\sin\theta} = \frac{d}{\lambda} = \text{constant}$

A 2 ●

B 3 ○

C 4 ○

D 5 ○

$\therefore \frac{1}{\sin 20} = \frac{n_{max}}{\sin 90}$ $\quad n_{max} = \frac{1}{\sin 20} = 2.92$

n is an integer, less than this

(Total

6. The speed of light decreases by 40% when it travels from air into a transparent medium.

What is the refractive index of the medium?

A 0.6 ○

B 1.4 ○

C 1.7 ●

D 2.5 ○

$n = \frac{c}{c_s} = \frac{1}{0.60} = 1.67$

(Total 1 mark)

7. A monochromatic light wave travels from glass into air.

Which row shows what happens to the wavelength, speed and photon energy?

	Wavelength	Speed	Photon energy
A	increases	increases	increases
B	does not change	decreases	does not change
C	does not change	decreases	increases
D	increases	increases	does not change

A ○ **B** ○ **C** ○ **D** ●

$\lambda \uparrow \quad v \uparrow$

f stays the same

$E = hf$

E stays the same

(Total 1 mark)

8. Monochromatic light is incident normally on a diffraction grating that has 4.50×10^5 lines m^{-1}. The angle between the second-order diffraction maxima is 44°.

What is the wavelength of the light?

$\theta = \frac{44}{2} = 22$

$d \sin\theta = n\lambda$

A 208 nm ○

B 416 nm ●

C 772 nm ○

D 832 nm ○

$\lambda = \frac{d \sin\theta}{n} = \frac{\frac{1}{4.50 \times 10^5} \times \sin 22}{2}$

$\lambda = 4.162 \times 10^{-7}\,m = 416\,nm$

(Total 1 mark)

9. In a Young's double-slit experiment, the spacing of the double slits is s and the distance between the slits and the screen on which fringes are formed is D. When monochromatic light of wavelength λ is incident on the slits the distance between adjacent fringes on the screen is w.

Which row shows another arrangement that produces a fringe spacing of w?

$w = \frac{\lambda D}{s}$

	Spacing of double slits	Distance between the slits and the screen	Wavelength of the light	
A	$4s$	$2D$	2λ	● $= w$
B	$2s$	$4D$	2λ	○ $= 4w$
C	$2s$	$2D$	4λ	○ $= 4w$
D	$2s$	$2D$	2λ	○ $= 2w$

(Total 1 mark)

10. Monochromatic electromagnetic radiation of wavelength 5.8×10^{-7} m is incident normally on a diffraction grating with 3.0×10^{5} lines per metre.

What is the highest order maximum produced?

A 5 ●

B 6 ○

C 10 ○

D 13 ○

$d \sin\theta = n\lambda$

n_{max} when $\theta = 90°$

$n_{max} = \frac{d \sin\theta}{\lambda} = \frac{\frac{1}{3.0\times10^{5}} \times \sin 90}{5.8\times10^{-7}} = 5.7$

$\therefore n_{max} = 5$

(Total 1 mark)

11. Which characteristics of monochromatic light change when the light passes from air into glass?

A Speed, wavelength and frequency. ○

B Speed and frequency only. ○

C Speed and wavelength only. ● (f stays the same)

D Wavelength and frequency only. ○

(Total 1 mark)

12. Which is a description of the pattern produced when monochromatic light passes through a very narrow slit?

A A series of equally-spaced light and dark fringes. ⬭

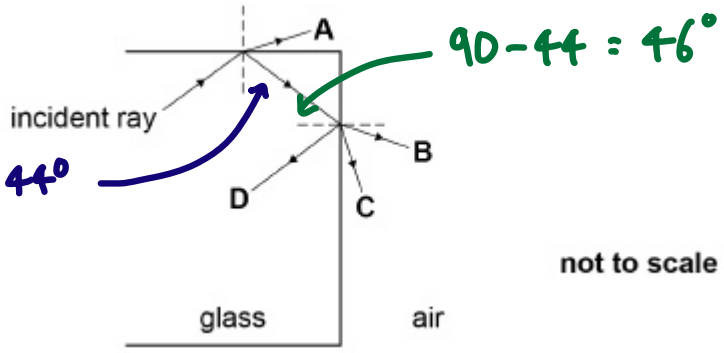
B A narrow central maximum with wider side fringes. ⬭

C A few bright fringes that are widely spaced. ⬭

D A wide central maximum with narrower side fringes. ⬬

(Total 1 mark)

13. A ray of light is incident on a glass–air boundary of a rectangular block as shown.



The refractive index of this glass is 1.5
The refractive index of air is 1.0
The angle of incidence of the light at the first glass–air boundary is 44°

What is the path of the ray of light?

A ⬭

B ⬭

C ⬭

D ⬬

$\sin\theta_c = \frac{n_2}{n_1}$ $\theta_c = \sin\left(\frac{1.0}{1.5}\right) = 41.8°$

$44 > \theta_c$ ∴ TIR → Not A

$46 > \theta_c$ ∴ TIR → Not B or C

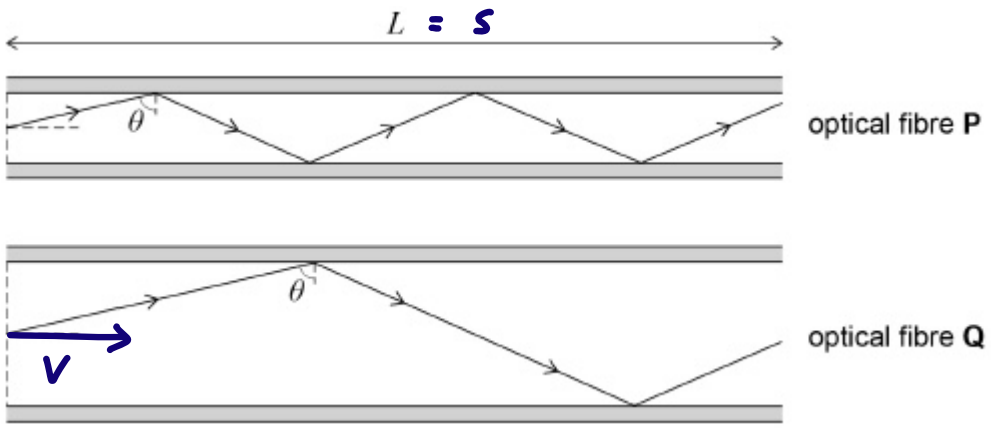
(Total 1 mark)

14. Rays of light are incident at the same angle θ on the core–cladding boundary of optical fibres **P** and **Q**.

The cores of **P** and **Q** have the same refractive index n.

P and **Q** are the same length L.

The core diameter of **P** is half that of **Q**.



The time for the ray to travel along optical fibre **P** is

$$\frac{nL}{c\sin\theta}$$

where c is the speed of light in a vacuum.

What is the time for the ray to travel along optical fibre **Q**?

$v = \frac{s}{t}$ $t = \frac{s}{v}$

$s = L$

$n = \frac{c}{c_s}$ $c_s = \frac{c}{n}$

$v = c_s \sin\theta = \frac{c\sin\theta}{n}$

A $\frac{nL}{c\sin\theta}$ ●

B $\frac{nL}{2c\sin\theta}$ ○

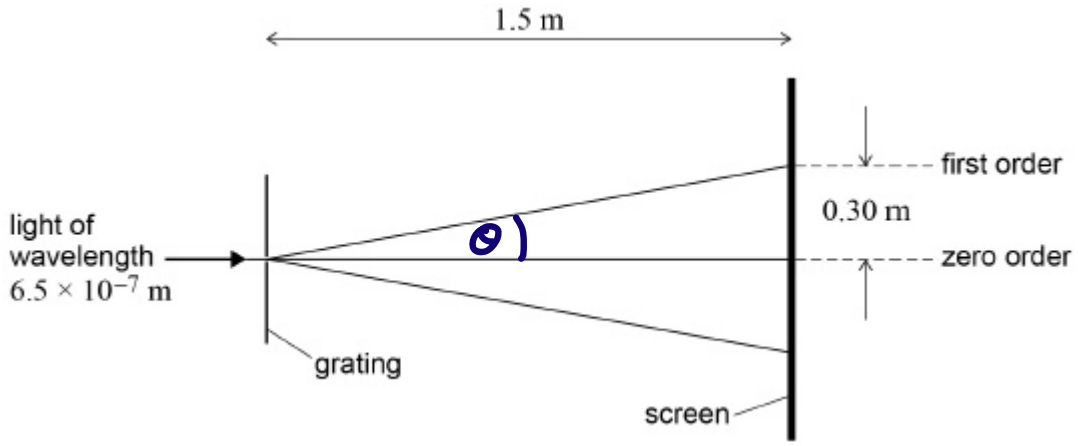
C $\frac{2nL}{c\sin\theta}$ ○

D $\frac{4nL}{c\sin\theta}$ ○

(Total 1 mark)

$t = \frac{L}{c\sin\theta/n} = \frac{Ln}{c\sin\theta}$

15. A diffraction grating is illuminated normally with light of wavelength 6.5×10^{-7} m
When a screen is 1.5 m from the grating, the distance between the zero and first-order maxima on the screen is 0.30 m



What is the number of lines per mm of the diffraction grating?

$\theta = \tan^{-1}\left(\frac{0.30}{1.5}\right) = 11.3°$

A 3.3×10^{-6} ○

B 3.3×10^{-3} ○

C 3.0×10^{2} ●

D 3.0×10^{5} ○

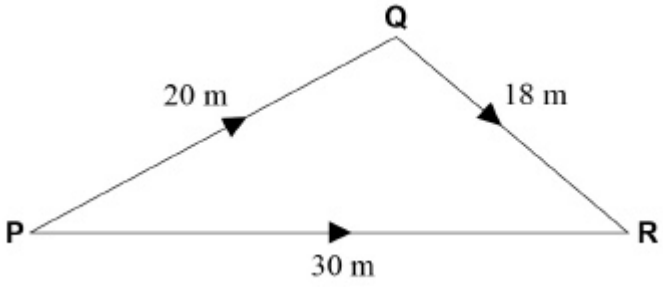
$d\sin\theta = n\lambda$

$d = \frac{1 \times 6.5 \times 10^{-7}}{\sin 11.3} = 3.31 \times 10^{-6}$

$n\ mm^{-1} = \frac{1}{3.31 \times 10^{-6}} \div 1000 = 302$

(Total 1 mark)

16. In the diagram, **P** is the source of a wave of frequency 50 Hz



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The wave travels to **R** by two routes, **P** → **Q** → **R** and **P** → **R**. The speed of the wave is 30 m s−1

Path difference = 38 − 30 = 8.0 m

$\lambda = \frac{v}{f} = \frac{30}{50} = 0.60$ m

$\frac{8.0}{0.60} = 13.3$

What is the path difference between the two waves at **R** in terms of the wavelength λ of the waves?

A 4.8λ ○

B 8.0λ ○

C 13.3λ ●

D 20.0λ ○

(Total 1 mark)

17. An electromagnetic wave enters a fibre-optic cable from air. On entering the cable, the wave slows down to three-fifths of its original speed.

What is the refractive index of the core of the fibre-optic cable?

A 0.67 ○

B 1.33 ○

C 1.50 ○

D 1.67 ●

$$n = \frac{c}{c_s} = \frac{1}{3/5} = \frac{5}{3} = 1.67$$

(Total 1 mark)

18. A diffraction grating has 500 lines per mm. When monochromatic light is incident normally on the grating the third-order spectral line is formed at an angle of 60° from the normal to the grating.

What is the wavelength of the monochromatic light?

A 220 nm ○

B 580 nm ●

C 960 nm ○

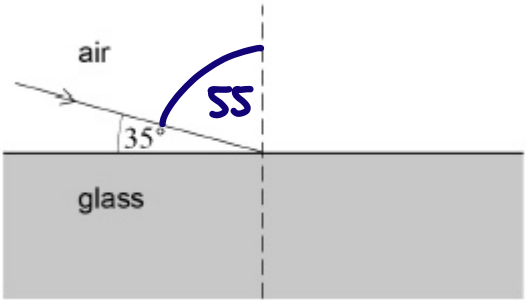
D 1700 nm ○

$$\lambda = \frac{d \sin\theta}{n} = \frac{\frac{1}{500 \times 10^3} \times \sin 60}{3}$$

$$\lambda = 5.77 \times 10^{-7}\ m$$

(Total 1 mark)

19. The diagram shows a ray of light travelling in air and incident on a glass block of refractive index 1.5



What is the angle of refraction in the glass?

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\theta_2 = \sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right) = \sin^{-1}\left(\frac{1}{1.5} \times \sin 55\right)$

$= 33.099959$

A 22.5° ○

B 23.3° ○

C 33.1° ●

D 59.4° ○

(Total 1 mark)

20. When light of wavelength 5.0×10^{-7} m is incident normally on a diffraction grating the fourth-order maximum is observed at an angle of 30°.

What is the number of lines per mm on the diffraction grating?

$d = \frac{n\lambda}{\sin\theta} = \frac{4 \times 5.0 \times 10^{-7}}{\sin 30}$

$d = 4.0 \times 10^{-6}$

A 2.5×10^2 ●

B 2.5×10^5 ○

C 1.0×10^3 ○

D 1.0×10^6 ○

(Total 1 mark)

$n\ mm^{-1} = \frac{1}{4.0 \times 10^{-6}} \div 1000 = 250$