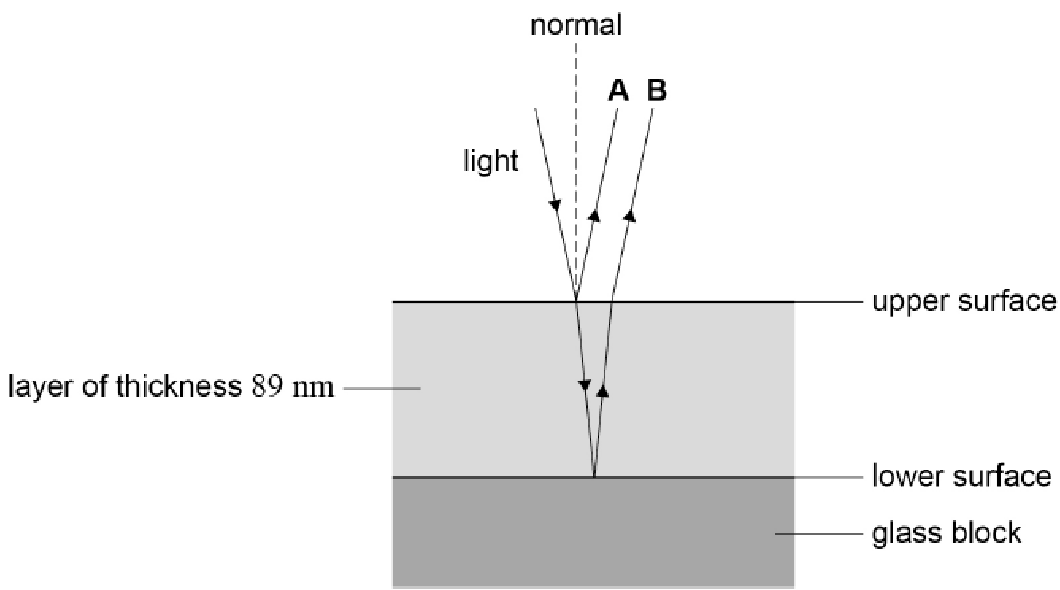
Waves – AS Physics

1. No.2

0 2 A glass block is coated with a layer of transparent material.
Figure 1 shows the incident ray and the reflected rays when monochromatic light is shone onto the upper surface of the transparent layer.

Figure 1



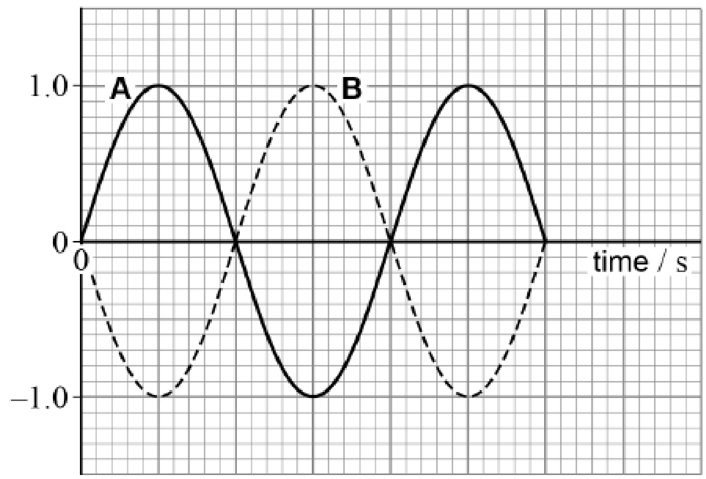
A is light reflecting from the upper surface of the layer.
B is light that leaves the layer after reflection from the lower surface.

When light reflects at the upper and lower surfaces, there is a change of phase.
In this case, the change of phase is the same at each surface and so can be ignored.

When the monochromatic light is incident **normally** on the upper surface of the layer, **A** and **B** meet and interfere.
Assume that the light is incident **normally** on the upper surface throughout this question.

0 2 . 1 **Figure 2** shows how **A** and **B** vary with time at the upper surface.

Figure 2



In the layer, the light has a wavelength of 356 nm.
The thickness of the layer is 89 nm.

Explain why destructive interference occurs at the upper surface for this thickness.

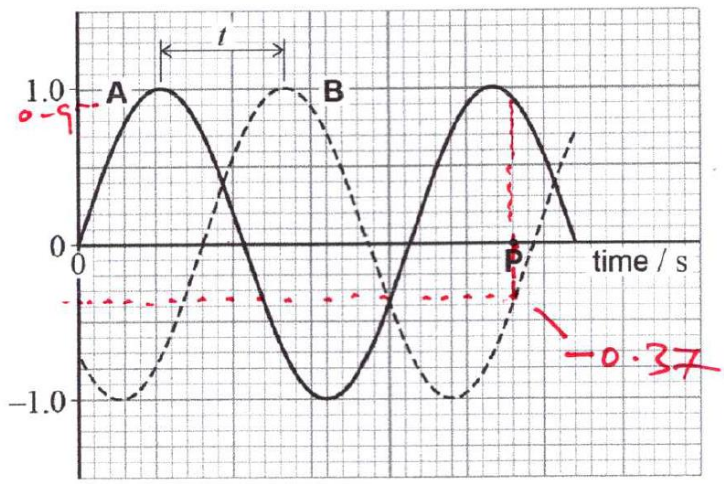
[3 marks]

- A and B are in antiphase (π).
There is also a path difference between A and B.
- The path difference is half of a wavelength of the light in the thin layer.

The frequency of the monochromatic light incident on the layer is changed.

Figure 3 shows how **A** and **B** vary with time at the upper surface for this light.

Figure 3



0 2 . 2 Calculate the resultant of the waves at time **P** in **Figure 3**.

[2 marks]

Resultant = 0.93 + (−0.37)

= 0.56

resultant = 0.56

The frequency of the light in **Figure 3** is 4.72×10^{14} Hz.

0 2 . 3 The phase difference between **A** and **B** shown in **Figure 3** is $137°$.

Show that the time interval labelled t in **Figure 3** is approximately 8×10^{-16} s.

[3 marks]

T = 21.3 squares

t = 8 squares.

$t = \frac{8}{23.1} \times T$

but

$T = \frac{1}{f}$

$= \frac{1}{4.72 \times 10^{14}}$

$= 2.12 \times 10^{-15}$

Then

$t = \frac{8}{23.1} \times 2.12 \times 10^{-15}$

$t = 8.1 \times 10^{-16}$ second

0 2 . 4 89 nm is the minimum thickness that will produce a phase difference of $137°$ between **A** and **B**.

Calculate the refractive index of the material of the layer.

[4 marks]

$S = \frac{D}{T} = \frac{2 \times 89 \times 10^{-9}}{8.06 \times 10^{-16}}$

$= 2.2 \times 10^{8}$ m/s

but

$n_s = \frac{c}{v}$

$= \frac{3 \times 10^8}{2.2 \times 10^8}$

$n_s = 1.36$

refractive index = 1.36

2. No.3

0 3 A student sits near a lake on a sunny day.

Some sunlight is reflected from the surface of the lake. Sunlight is also reflected from objects submerged beneath the surface of the lake. The light reflected from the surface makes it difficult to see the submerged objects.

Sunlight that reflects from the surface of the lake is horizontally polarised. Sunlight that reflects from the submerged objects is unpolarised.

The student puts on a pair of Polaroid sunglasses. The amount of light he sees reflected from the surface is significantly reduced.

Explain why the student can now see the submerged objects more clearly.

In your answer you should:

- describe the nature of an unpolarised wave
- explain what is meant by polarisation
- explain the relative effect of the Polaroid sunglasses on the light reflected from the surface and the light reflected from the submerged objects.

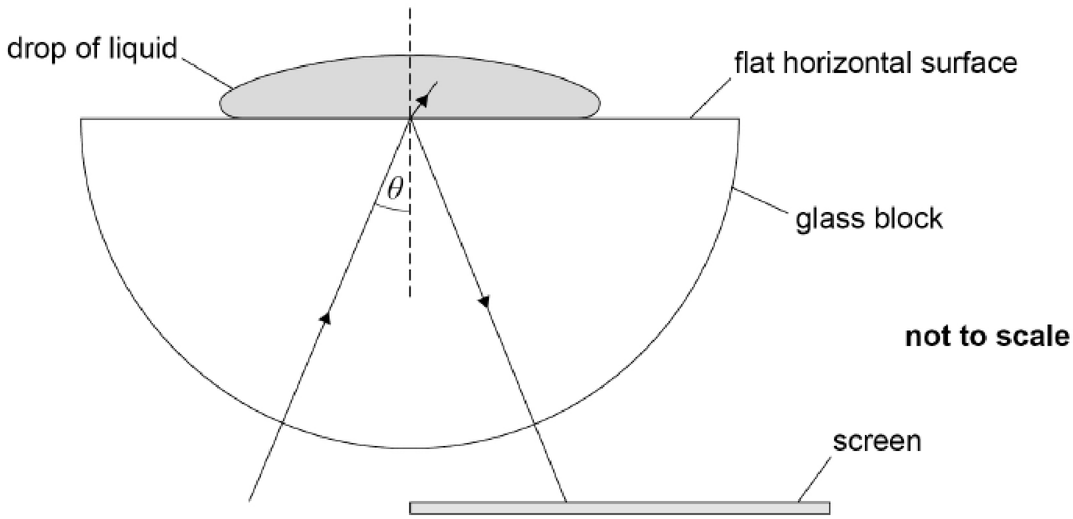
[6 marks]

- Wave oscillations exist in more than a single plane
- Only tranverse waves can be polarized as polarization is restricted to only a single plane.
- The polaroid glasses absorb the horizontal components of the light from the water's surface (Almost all)
- The polaroid transmits the vertical component of the light from The submerged objects

3. No.4

0 4 **Figure 12** shows a type of refractometer.
A semi-circular glass block is arranged so that its semi-circular faces are vertical.
A drop of liquid is placed at the centre of the flat horizontal surface of the block.

Figure 12



Light enters the block through the curved surface and is incident on the midpoint of the horizontal surface at angle of incidence θ.
Light that reflects at the glass–liquid boundary is detected on a screen that lies parallel to the horizontal surface.

0 4 . 1 Explain why the light ray in **Figure 12** does not change direction as it enters the block.
[1 mark]

Due to semicircular block, angle of incidence always 0°, travels along the Normal.

0 4 . 2 The refractometer is calibrated using a drop of liquid.
When $\theta = 15°$, light is partially refracted at the glass–liquid boundary.

Calculate the angle of refraction at this boundary.

refractive index of glass block = 1.84
refractive index of liquid = 1.33

[2 marks]

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

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

$= \dfrac{1.84 \times \sin 15}{1.33}$

$\sin\theta_2 = 0.358$

$\theta_2 = \sin^{-1}(0.358)$

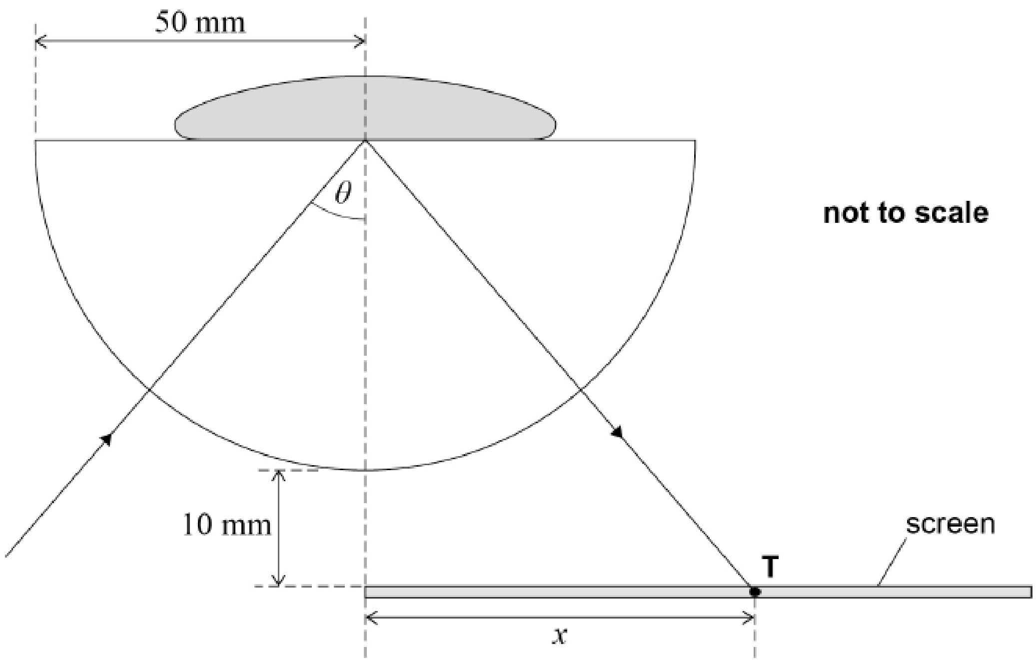
$\theta_2 = 21°$

angle of refraction = 21 °

The refractometer is used to determine the critical angle θ_c at the glass–liquid boundary.

Figure 13 shows dimensions of the arrangement.

Figure 13



The intensity of the light ray on the screen is observed as θ is increased from $15°$.
When $\theta = \theta_c$ the intensity of the light ray is seen to increase sharply at a point **T** on the screen.

The distance between the left-hand edge of the screen and **T** is x.

0 4 . 3 Explain why the intensity of the light ray on the screen increases at **T**.

[2 marks]

The total internal reflection has occured. So all light is reflected

0 4 . 4 The liquid is replaced with a drop of sugar solution.
The refractive index of the sugar solution is greater than 1.33

Deduce how this change affects the position at which the sharp increase in intensity is observed on the screen.

[2 marks]

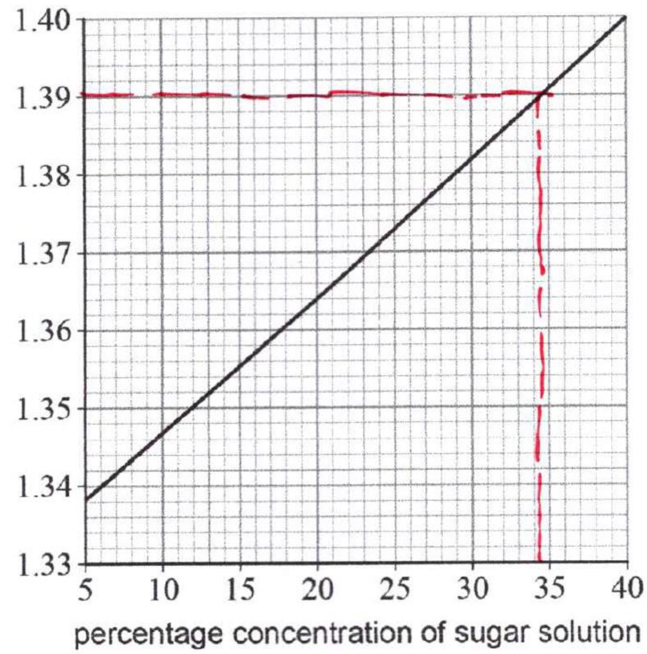
$n_1 \sin\theta_1 = n_2 \sin\theta_2$, $\sin\theta_c = \frac{n_2}{n_1}$ as $\theta_2 = 90°$.

So θ_c increases so does x

0 4 . 5 The refractometer in **Figure 13** is used to determine the concentration of a sugar solution.

Figure 14 shows the variation of refractive index with concentration of sugar solution.

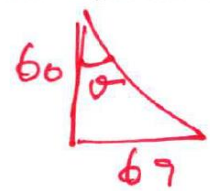
Figure 14



For a drop of a particular sugar solution, $x = 69$ mm.

Determine the percentage concentration of the sugar solution.

refractive index of glass block = 1.84



[3 marks]

when $x = 69$ mm, angle;

$\tan\theta = \frac{69}{60}$

$\theta = \tan^{-1}\left(\frac{69}{60}\right) = 49°$

So

$\sin\theta_c = \frac{n_2}{n_1}$

$n_2 = n_1 \sin\theta_2$

$n_2 = 1.84 \sin 49°$

$n_2 = 1.39$

From graph, $n_2 = 1.39$,
% Concentration = 34.5%

percentage concentration = 34.5%

4. No.5

Light of wavelength λ is incident normally on a diffraction grating.
The separation between adjacent slits is equal to 5λ.

What is the smallest angle between the third-order maximum and fourth-order maximum diffracted beams?

[1 mark]

$n\lambda = 5\lambda \sin\theta$

A 13.3°

B 16.2° ☒

C 36.9°

D 53.1°

$\theta_3 = \sin^{-1}\left(\frac{3}{5}\right) = 36.9$

$\theta_4 = \sin^{-1}\left(\frac{4}{5}\right) = 53.1$

$= 53.1^\circ - 36.9^\circ$

$= 16.2^\circ$

5. No.6

$\mathbf{S_1}$ and $\mathbf{S_2}$ are coherent sources of microwaves that produce waves of the same amplitude.
A microwave detector gives a zero reading when placed at a point that is the same distance from $\mathbf{S_1}$ and $\mathbf{S_2}$.

What is the phase difference between microwaves from $\mathbf{S_1}$ and $\mathbf{S_2}$ at the detector?

Destructive Interference **[1 mark]**

A zero

B 1.6 rad

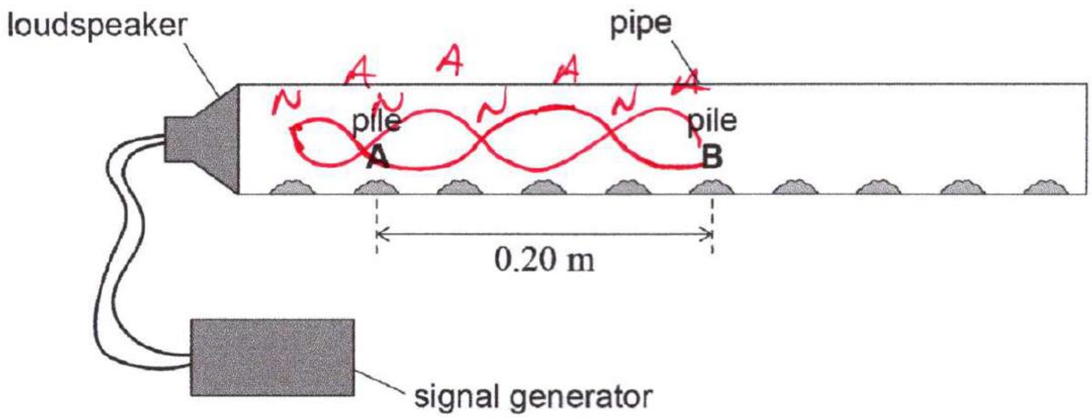
C 3.1 rad ☒

D 6.3 rad

π rad = 3.14

6. No.7

Powder is spread along the inside of an air-filled pipe that is closed at one end.
A loudspeaker is placed at the other end.
At certain sound frequencies a stationary wave is produced so that powder collects in evenly spaced piles. These piles correspond to positions of minimum amplitude.



The distance between pile **A** and pile **B** is 0.20 m.

What is the wavelength of the stationary sound wave?

[1 mark]

$\frac{0.2}{2} = \frac{2\lambda}{2}$

$\lambda = 0.1\,m$

A 0.04 m ☐

B 0.05 m ☐

C 0.10 m ☒

D 0.20 m ☐

7. No.17

Two aerials A_1 and A_2 receive radio waves from the same distant transmitter **T**.

The waves have a frequency of 88 MHz.

The phase difference between the waves received by A_1 and A_2 is 6.6 rad.

What is the distance $A_1T - A_2T$?

[1 mark]

$f = 85\text{ MHz}$

$\text{phase diff} = \frac{\Delta d}{\lambda} \times 2\pi$ | $c = \lambda f$, $\lambda = \frac{c}{f}$

$6.6 = \frac{\Delta d \times f}{c} \times 2\pi$

$\Delta d = \frac{6.6\,c}{2\pi f} = \frac{6.6 \times 3 \times 10^8}{2\pi \times 85 \times 10^6}$

A 1.6 m ☐

B 3.2 m ☐

C 3.6 m ☒

D 7.2 m ☐

8. No.24

A stationary wave of wavelength λ is produced on a string.

What are the phase difference and the distance between adjacent antinodes?

[1 mark]

$\frac{1}{2}$ wave $= \pi$ rad $= \frac{\lambda}{2}$

	Phase difference	Distance	
A	$\frac{\pi}{2}$	$\frac{\lambda}{4}$	☐
B	$\frac{\pi}{2}$	$\frac{\lambda}{2}$	☐
C	π	$\frac{\lambda}{4}$	☐
D	π	$\frac{\lambda}{2}$	☒

9. No.25

A central diffraction maximum is observed when monochromatic light of wavelength λ passes through a single slit of width s.

Which combination of changes to λ and s will always produce a wider central diffraction maximum?

[1 mark

	Change to λ	Change to s	
A	decrease	decrease	☐
B	decrease	increase	☐
C	increase	decrease	☒
D	increase	increase	☐

$w\uparrow$?

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

S_0

$w \propto \frac{\lambda \uparrow}{s \downarrow}$