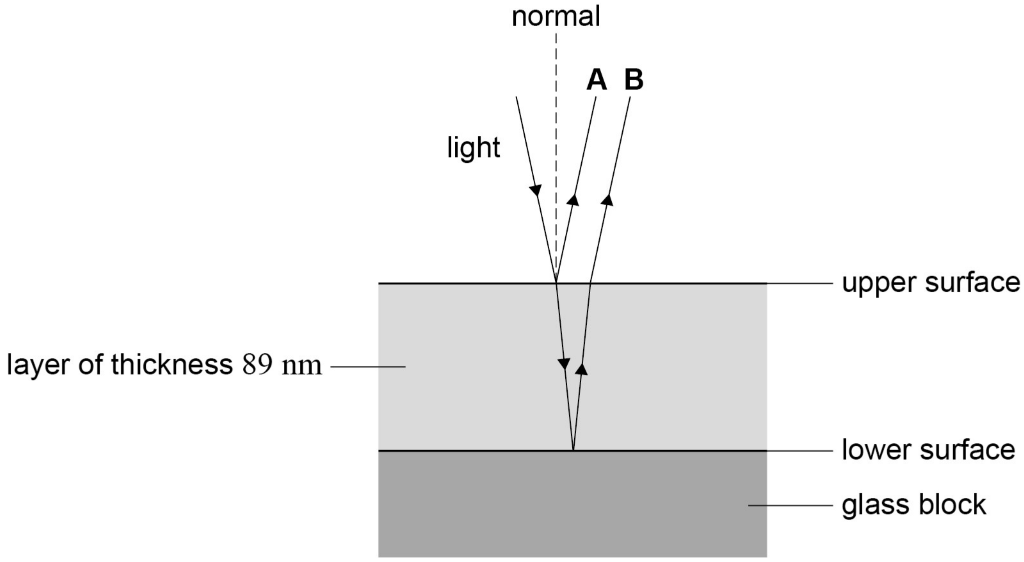
Do not write outside the box

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.

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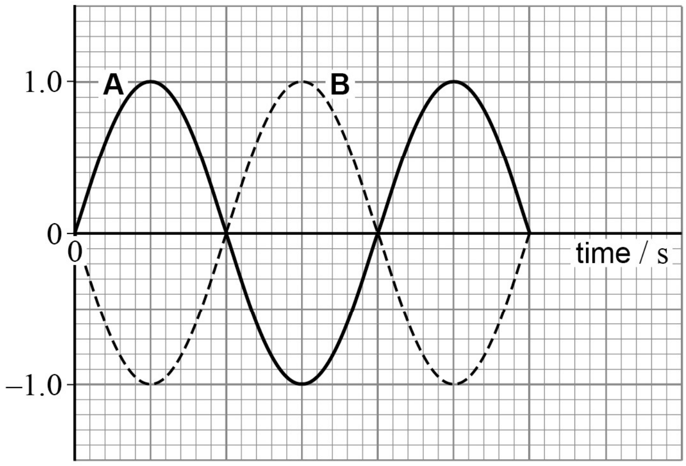
0 2 . 1 **Figure 2** shows how **A** and **B** vary with time at the upper surface.

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]

since we assume the light enters normally the path difference between A and is twice the thickness of the layer which is 178nm

This is exactly half of the wavelength of the light, meaning that a phase difference of exactly π radians is introduced

This in turn means that the waves will destructively interfere leading to a minimum

Question 2 continues on the next page

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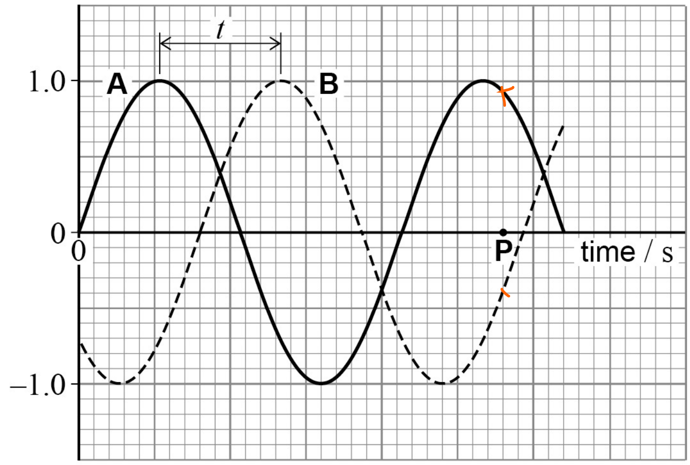
The frequency of the monochromatic light incident on the layer is changed.

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]

A is at +0.95
B is at −0.4
∴ resultant = +0.55

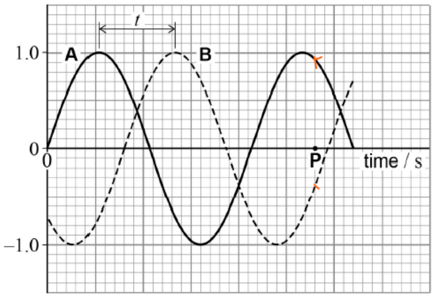
resultant = ____________________

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 of wave is $\frac{1}{4.72\times10^{14}}$ & we at $\frac{137}{360}$

$\therefore t = \frac{1}{4.72\times10^{14}} \times \frac{137}{360}$

$= 8\times10^{-16}$ s

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]

need speed of wave inside layer.

$s = \frac{d}{t} = \frac{2\times89\,\text{nm}}{8\times10^{-16}} = 2.2\times10^{8}$ m/s.

$n = \frac{c}{c_s} = \frac{3\times10^{8}}{2.2\times10^{8}} \Rightarrow n = 1.36$

$= 1.4$

refractive index = ____________

12

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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]

In unpolarised light the plane of vibration/oscillations of the electric/magnetic fields is perpendicular to the direction of travel of the wave energy. The waves can also vibrate in every possible plane (or at least in more than 1 plane),

when a wave is polarised it means that the waves can only oscillate in a single plane - waves vibrating in different planes have been removed. The wave still travels at perpendicular to the plane of vibration and this a

Sunlight reflected from the water is horizontally polarised - ie has only one plane of vibration. Since the intensity of this light is reduced significantly the glasses must block horizontal and allow vertical planes to pass. The sun glasses will therefore block nearly all (if not all) of the reflected light and therefore reduce the intensity of this that reaches his retina. The light from the submerged objects is unpolariased and therefore only the vertical planes are absorbed by the glass meaning that only 50% of their intensity is absorbed. This all means that he can see the submerged objects more clearly

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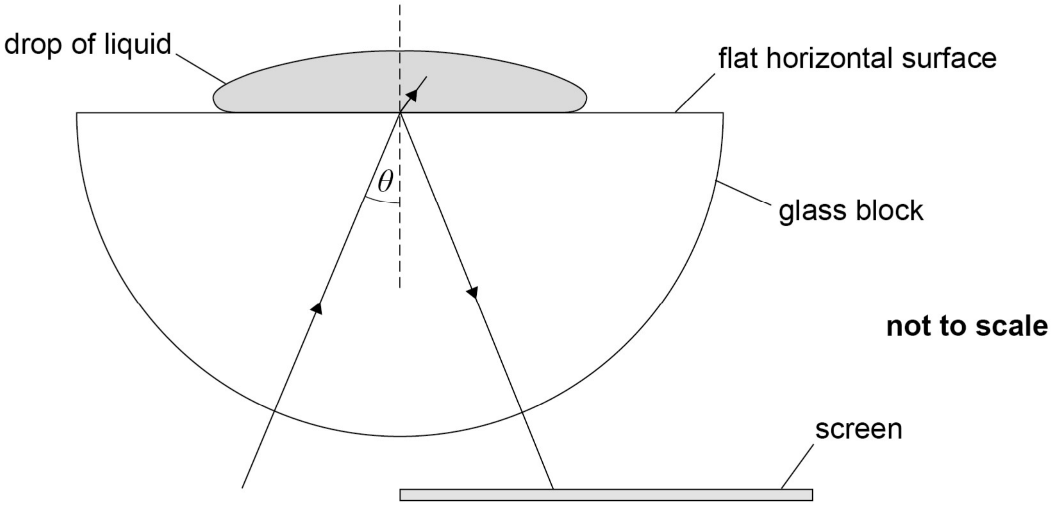
0 4 **Figure 12** shows a type of refractometer.
A semi-circular glass block is arranged so that its semi-circular faces are vertical.
A drop of liquid is placed at the centre of the flat horizontal surface of the block.

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]

it is incident along the normal or at 90 degrees to the surface.

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]

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ want θ_2

$\frac{1.84 \sin 15}{1.33} = \sin\theta_2 \Rightarrow \theta_2 = 21°$

angle of refraction = 21 °

Turn over ▶

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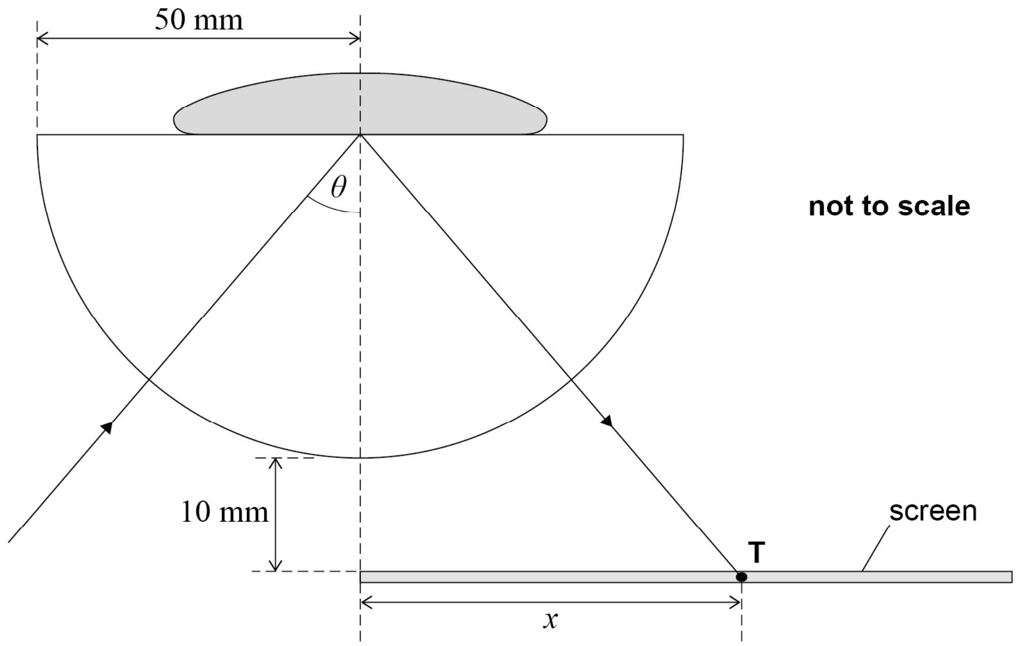
The refractometer is used to determine the critical angle θ_c at the glass–liquid boundary.

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 intensity increases because we have reached above the critical angle meaning that total internal reflection has occured. Before this some of the light was refracted out of the glass so the intensity was less.

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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]

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

since n_2 has increased so has θ_c. This means that T will move to the right

Question 4 continues on the next page

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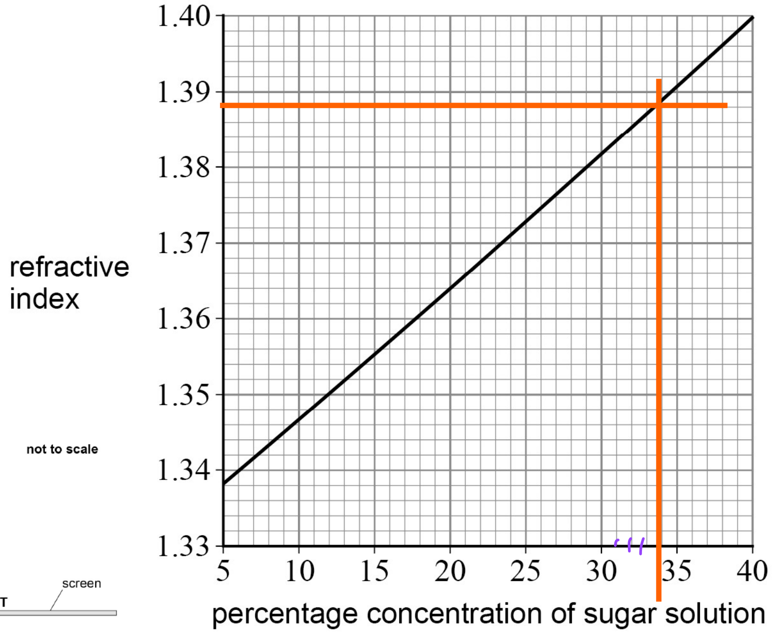
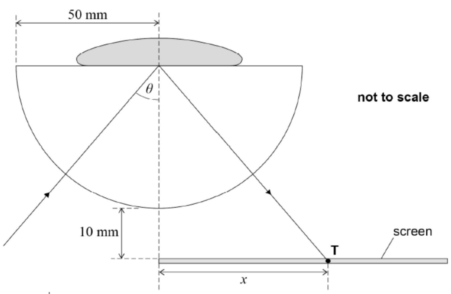
0 4 . 5 The refractometer in **Figure 13** is used to determine the concentration of a sugar solution.

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

Figure 14



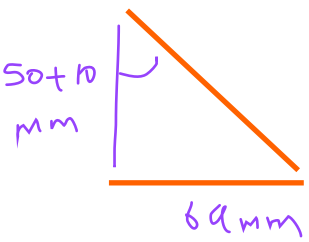


For a drop of a particular sugar solution, $x = 69$ mm.

Determine the percentage concentration of the sugar solution.

refractive index of glass block = 1.84

[3 marks]



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

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

$\Rightarrow n_2 = 1.388$

$\therefore$ 34%

(or 33.5% from MS)

percentage concentration = ____

END OF SECTION B

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Section C

Each of Questions **05** to **34** is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD   WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 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]

A 13.3°

B 16.2°

C 36.9°

D 53.1°

$n\lambda = d\sin\theta$ ← const $= 5\lambda$

$3\lambda = 5\lambda\sin\theta \Rightarrow \theta = 36°\ldots$

$4\lambda = 5\lambda\sin\theta \Rightarrow \theta = 53°\ldots$

$\Delta\theta = \sin^{-1}\left(\frac{4}{5}\right) - \sin^{-1}\left(\frac{3}{5}\right)$

$= 16.2°$

Turn over for the next question

Turn over ►

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0 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?

[1 mark]

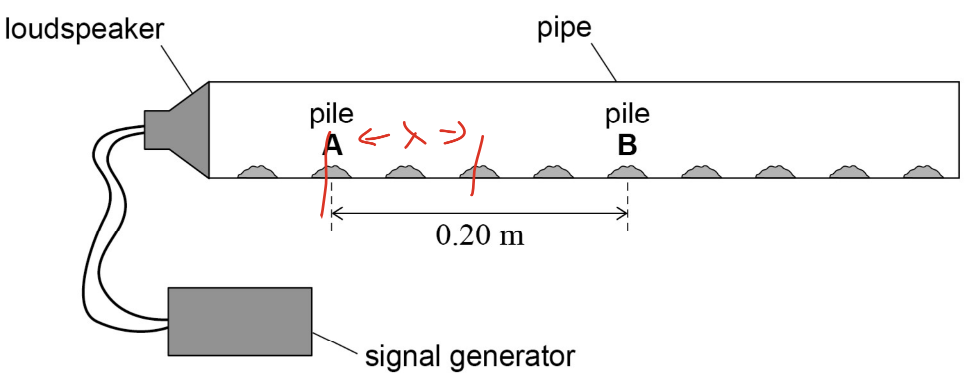
A zero ○

B 1.6 rad ○

C 3.1 rad ○

D 6.3 rad ○

0 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]

A 0.04 m ○

B 0.05 m ○

C 0.10 m ○

D 0.20 m ○

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1 5 Which exchange particle transfers charge during electron capture?

[1 mark]

A meson ⬭

B pion ⬭

C virtual photon ⬭

D W boson ⬭

1 6 A free neutron decays to produce a proton and

[1 mark]

A an electron and an antineutrino. ⬭

B an electron and a neutrino. ⬭

C a positron and an antineutrino. ⬭

D a positron and a neutrino. ⬭

1 7 Two aerials $\mathbf{A_1}$ and $\mathbf{A_2}$ 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 $\mathbf{A_1}$ and $\mathbf{A_2}$ is 6.6 rad.

What is the distance $\mathbf{A_1T} - \mathbf{A_2T}$?

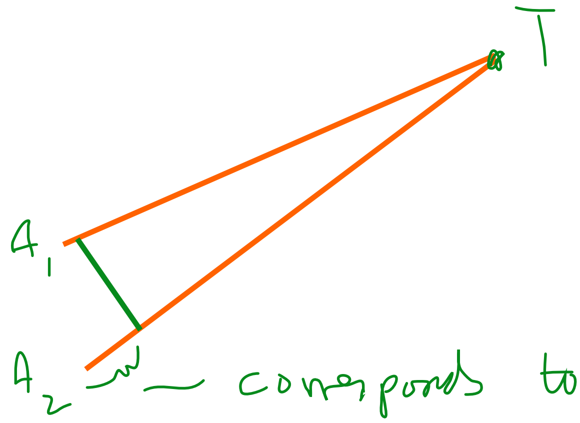
[1 mark]

A 1.6 m ⬭

B 3.2 m ⬭

C 3.6 m ⬭

D 7.2 m ⬭



— corresponds to 6.6 rad

$c = f\lambda$

λ of wave $= \frac{c}{f} = 3.41\,m$. we have $\frac{6.6}{2\pi}$ of a cycle

$\therefore$ distance $= \frac{6.6}{2\pi} \times 3.41$.

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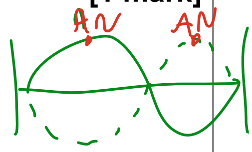
2 4 A stationary wave of wavelength λ is produced on a string.

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

[1 mark]



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

phase = π or 180

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

2 5 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]

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

	Change to λ	Change to s	
A	decrease	decrease	⬭
B	decrease	increase	⬭
C	increase	decrease	⬭
D	increase	increase	⬭