A-Level Physics

Refraction

Mark Scheme

Time available: 55 minutes
Marks available: 40 marks

Mark schemes

1. (a) As angle of refraction greater than angle of incidence

with

reference to Snell's law

OR

light bends away from normal when it speeds up ✓

(Therefore $n_A > n_B$)

1

(b) Calculation of angle of incidence = 90−43 = 47 degrees ✓

Use of Snell's law to give angle of refraction = 61(.4) degrees ✓

2

(c) Ray reflecting off **P** towards 'not to scale' label ✓

Use of sin $C = 1/n$ to get $C = 48$ degrees

OR

Calculation of $i = 180 - 43 - 61.3 = 76$ ✓

Other calculation and i greater than C therefore tir ✓

3

[6]

2. (a) Spreading of pulse / parts of a pulse take different times to travel through the fibre / pulse broadening✓

Do not credit material dispersion.

owtte

Due to different paths through the optical fibre / due to entering the optical fibre at different angles ✓

Accept a diagram showing different paths.

2

(b) speed $\left(= \frac{distance}{time}\right) = \frac{10 \times 10^3}{5.225 \times 10^{-5}}$ ✓ $(= 1.91 \times 10^8)$

1

(c) Reads off Sin θ_R = 0.3391

or

use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$✓

Use of $n = \frac{c}{c_s}$ seen✓

With their Sin θ_R

(Refractive index of core = 1.47)

Allow use of their refractive index where cs is the subject of the formula

$cs = 2.03 \times 10^8$ ✓

Alternative:

Reads off Sin θ_R = 0.3391

or

$\theta = 19.8°$ ✓

$c_s \cos 19.8 = 1.9 \times 10^8$ ✓

$c_s = 2.03 \times 10^8$ ✓

Allow finding θ_R for their read off

Allow use of their θ_R

3

(d) The refractive index of core for blue light is greater than the refractive index for red / The refractive index of core for red light is less than the refractive index for blue✓

Max 1 mark for stating that the refractive indices are different because their speeds are different

MP1 can come from graph or prior knowledge

The speed of the blue light is less than the speed of the red light and travel the same distance / The speed of the red light is greater than the speed of the blue light and travel the same distance✓

2

(e) the blue now travels a shorter distance than the red light (compared to (d))✓

or

the red light now travels a greater distance than the blue light (compared to (d))✓

or

the difference between the blue's velocity parallel to the central axis and the red's velocity (parallel to the central axis) has decreased (compared to (d)). ✓

Allow: now travel different distances whereas previously travelled the same distance.

or

the difference between the horizontal velocity of the red light and the horizontal velocity of the blue light has decreased (compared to (d)).✓

1

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3. (a) Speed = $3.0 \times 10^8/1.47$
$= 2.0(4) \times 10^8$ m s^{-1} ✓

Do not accept 1 sf answer

1

(b) Critical angle calculation ✓
sin $C = n_{clad}/n_{core} = 1.41/1.47 = 0.96$
critical angle = 73.6°
Angle of refraction calculation✓
$r = 90 - C = 16.4$°

Do not give MP2 if calculated answer is given as A

Angle of incidence calculation ✓ sin (i) = 1.47 sin (r)
$i = 24.5$°

Allow 2 sf answer; allow 24.6°

3

(c) Correct path of light drawn showing partial reflection and transmission of ray when it encounters the boundary ✓

Angle of incidence on core–cladding boundary decreases✓
And will now be less than critical angle ✓
(Some light will escape/be refracted into cladding
Some light will continue)

If the diagram is not annotated and no other mark is given, 1 mark can be given for correct description of partial reflection.

3

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4.

(a) Max one from: ✓
internal ray is a <u>radius</u> (of the block)
OR
internal ray travels along a <u>normal</u>
OR
ray meets (glass-air) boundary at 90°
OR
angle of incidence is zero
(so angle of emergence/refraction is zero)

1

(b) Straight line ruled from centre of protractor through **ABC** ✓

*for $_1$✓ line must be reasonable and must pass through intersection of the cross-wires and must not pass above the centre of **A** or below the centre of **B***

Takes a pair of readings: 24 or 66; and angle consistent with their line ✓

Must be between 0° and 90°

Use of Snell's Law with their angles ✓

1.48 or 1.52 ✓

Must be a positive value to 3 sf.

4

(c) 1.47 or 1.471 ✓

Reject 1.5 or >4 sf; ignore any unit written

1

(d) 0.08 (mm) ✓

Only acceptable answer

1

(e) Calculates one percentage uncertainty

For $_1$✓ *allow ecf from* **(d)***; expected answers are*

% uncertainty in $(R_2 - R_0)$ =

$$100 \times \frac{0.08}{14.28} = 0.56(0)\%$$

% uncertainty in $(R_2 - R_1)$ =

$$100 \times \frac{0.08}{9.71} = 0.82(4)\%$$

OR

Calculates max or min value ✓

$$n_{min} = \frac{14.28 - 0.08}{9.71 + 0.08} = 1.45(0);$$

$$n_{max} = \frac{14.28 + 0.08}{9.71 - 0.08} = 1.49(1);$$

Adds their percentage uncertainties

OR

attempt to use percentage $n = \frac{0.5(\max - \min)}{1.47} \times 100$ ✓

Ecf for $_2$✓ *from wrong percentage uncertainties or wrong max or min values*

1.4(%) ✓

Condone 3 or 4 sf

3

[10]

5. (a) Use of $n_A = \frac{c}{c_A}$ to make c_A the subject of the equation

Condone truncation without appropriate rounding mid-calculation

OR

speed in glass **A** = 2.05(2) × 10^8 ms^{-1} $_1$✓

Speed in glass **B** = 1.985(3) × 10^8

Condone use of c = 3 × 10^8

But must see answer to 4 sf answer

OR

their speed in glass **A** × 0.96748 (or equivalent) $_2$✓

Values obtained using c = 3×10^8:

- *speed in glass A = 2.05(3)× 10^{8} ms^{-1}*
- *speed in glass B = 1.98(7) × 10^{8}*
- *n = 1.510*

OR

Alternative 1st and 2nd marks

Use of $n_A/n_B = c_B/c_A$ by substitution for n_A $_1$✓

Use of $n_A/n_B = c_B/c_A$ by substitution for n_A and $c_B = c_A \times 0.96748$ $_2$✓

OR

$n_B = 1.461 / 0.96748$ $_1$✓$_2$✓

Watch for maths errors:

Dividing by 1.03252 ≠ multiplying by 0.96748

Multiplying by 1.03252 ≠ dividing by 0.96748

1.510 cao to 4 sf only $_3$✓

Correct answer to 4 sf obtains all 3 marks

Penalise any unit on final answer

3

(b) **Relationship:**

Increase in tension (or stress) in cable produces increase in strain resulting in increase in λ_R

OR

Decrease in tension (or stress) causes decrease in strain resulting in decrease in λ_R $_1$✓

Variation due to motion:

As the lift accelerates downwards, (the tension is less than the weight in the cable, a decrease in tension results) in λ_R decreasing $_2$✓

At constant velocity (the tension again equals the weight and) λ_R returns to the initial, at rest value $_3$✓

Allow a correct comment on the directional relationship between tension, strain and λ_R independent of the motion of the lift for first mark

3

(c) **P** because it will produce a larger increase in λ_R for the (same) <u>increase</u> in strain

OR

P because it has a larger gradient (must be a sense of larger increase in λ_R for the (same) increase in strain) ✓

Hence smaller accelerations (which produce small changes in strain) can produce measurable changes in λ_R

OR

Hence gauge **P** will have a higher resolution ✓

Selecting Q gains zero marks

Linking steeper gradient to being able to withstand a larger force negates this mark

Allow more accurate measurement of acceleration

Allow more readings of acceleration can be taken (over the range)

More sensitive treat as neutral

2

[8]