First Name:_____   Last Name:_____

L04 – Worksheet – Reflection Ray Diagrams

▼ Table 13.4 Absolute Refractive Indexes
(for Sodium Yellow Light, λ = 589 nm)

Medium	Index of Refraction
vacuum	1.0000
air	1.0003
ice	1.31
water	1.33
ethanol	1.37
glycerin	1.47
quartz glass	1.47
crown glass	1.52
light flint glass	1.58
Lucite (plexiglass)	1.52
ruby	1.54
zircon	1.92
diamond	2.42

Pg 668 #1: Light passes from a diamond into air. The angle of refraction as the light emerges from the diamond is 25^0. What was the angle of incidence?
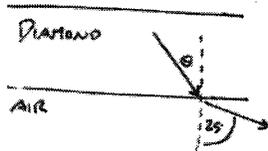
$n_d = 2.42$ $n_{air} = 1.0003$

$\Theta_d = ?$ $\Theta_{air} = 25°$

_____

DIAMOND

AIR

$n_{air} \sin\Theta_{air} = n_d \sin\Theta_d$

$(1.0003)\sin 25° = (2.42)\sin\Theta_d$

$\sin\Theta_d = 0.1747$

$\Theta_d = 10.06°$

Pg 668 #2: Light travelling from air into a transparent material is incident at an angle of 20^0 and refracted at an angle of 17^0. Determine the index of refraction of the transparent material.

$\Theta_i = 20°$ $\Theta_r = 17°$

$n_i = 1.0003$ $n_r = ?$

$n_i \sin\Theta_i = n_r \sin\Theta_r$

$(1.0003)\sin 20° = n_r \sin 17°$

$n_r = 1.17$

Pg 668 #3: A ray of light passes from air into ruby at an incident angle of 15^0. Calculate the angle of refraction.

$\theta_i = 15°$ $\theta_r = ?$

$n_i = 1.0003$ $n_r = 1.54$

$n_i \sin\theta_i = n_r \sin\theta_r$

$(1.0003)\sin 15° = 1.54 \sin\theta_r$

$\sin\theta_r = 0.168$

$\theta_r = 9.67°$

Pg 668 #4: A ray of light, travelling in air, is incident on an unknown sample at an angle of 20^0. If the angle of refraction is 15^0, determine the index of refraction for the unknown sample.

$\theta_i = 20°$ $\theta_r = 15°$

$n_i = 1.0003$ $n_r = ?$

$n_i \sin\theta_i = n_r \sin\theta_r$

$(1.0003)\sin 20° = n_r \sin 15°$

$n_r = 1.32$

Pg 670 #2: Light with a wavelength of 737 nm enters quartz glass at an angle of 25.0^0. Determine the angel of refraction and the wavelength of the light in the quartz glass.

$\lambda_1 = 737nm$ $\lambda_2 = ?$

$\theta_1 = 25.0°$ $\theta_2 = ?$

$n_1 = 1.0003$ $n_2 = 1.47$

(I'm assuming it
was originally
in air).

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

$(1.0003)\sin 25° = (1.47) \sin\theta_2$

$\theta_2 = 16.71°$

$n_1 \lambda_1 = n_2 \lambda_2$

$(1.0003)(737nm) = (1.47)\lambda_2$

$\lambda_2 = 501.51 nm$

Pg 670 #3: Light enters an unknown crystal from air with a wavelength of 500 nm. If the wavelength of the light in the crystal is found to be 450 nm, what is the refractive index of the crystal?

$n_1 = 1.0003$
$\lambda_1 = 500 nm$
$\lambda_2 = 450 nm$
$n_2 = ?$

$n_1 \lambda_1 = n_2 \lambda_2$
$(1.0003)(500 nm) = n_2 (450 nm)$
$n_2 = 1.11$

Pg 673 #1: Determine the critical angle of the following interfaces:

a. Water and air
b. Diamond and air
c. Diamond and water

$n_{water} = 1.33$
$n_{air} = 1.0003$
$n_{diamond} = 2.42$

(A) $n_w = 1.33$
$n_a = 1.0003$
$\Theta_a = 90°$
$\Theta_w = ?$

$n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
$(1.33)\sin\Theta_w = (1.0003)\sin 90°$
$\Theta_w = 48.773°$

(B) $n_d = 2.42$
$\Theta_d = ?$
$n_a = 1.0003$
$\Theta_a = 90°$

$n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
$(2.42)\sin\Theta_d = (1.0003)\sin 90°$
$\Theta_d = 24.415°$

(C) $n_d = 2.42$
$\Theta_d = ?$
$n_w = 1.33$
$\Theta_w = 90°$

$n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
$(2.42)\sin\Theta_d = (1.33)\sin 90°$
$\Theta_d = 33.339°$

Diploma Questions – Refraction (Basic Concepts)

Q514: A ray of visible light passes from air into glass and undergoes a change in its

a. Frequency and speed
b. Wavelength and speed
c. Wavelength and frequency
d. Frequency, wavelength, and speed

$$\frac{\sin \Theta_1}{\sin \Theta_2} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Q516: White light can be dispersed into its component colors because

a. The speed of light is independent of wavelength
b. Long wavelengths refract less than short wavelengths
c. Long wavelengths diffract more than short wavelengths
d. Long wavelengths do not travel as fast as short wavelengths

low f ————————→ High f
RMI V U X G
↓
RoY G. BIV
750nm   400nm
Blue Bends Better
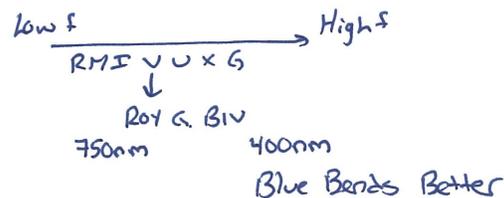
Q520: Wavelength is **not** a good criterion for categorizing light because wavelength

a. Is inversely proportional to frequency
b. Is directly proportional to frequency
c. Changes during diffraction
d. Changes during refraction
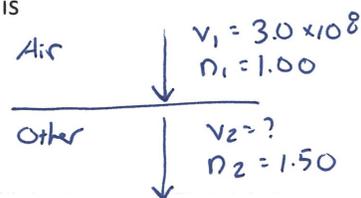
Diploma Questions – Refraction (Simple Calculations)

Q528: The speed of light in a medium with an index of refraction of 1.5 is

a. 4.5×10^8 m/s
b. 3.0×10^8 m/s
c. 2.0×10^8 m/s
d. 1.5×10^8 m/s

$$\frac{n_2}{n_1} = \frac{v_1}{v_2}$$

$$\frac{1.50}{1.00} = \frac{3.0 \times 10^8}{v_2}$$

$$v_2 = 2.0 \times 10^8 \text{ m/s}$$

Air $\quad v_1 = 3.0 \times 10^8$
$\quad n_1 = 1.00$

Other $\quad v_2 = ?$
$\quad n_2 = 1.50$

Q529: The refractive indices of water and glass are 1.33 and 1.52 respectively. If the angle of incidence is 40.0^0 for light travelling from water into glass, the angle of refraction is

a. 47.3^0
b. 34.2^0
c. 28.9^0
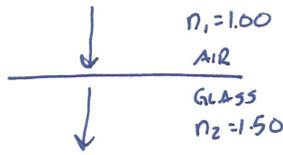d. 25.0^0

40ᵢ
θᵢ
water $n_1 = 1.33$
glass $n_2 = 1.52$
θ₂
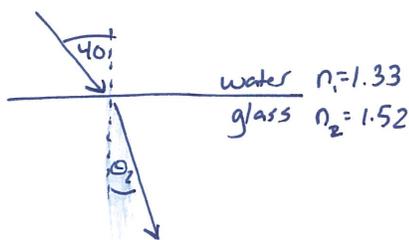
$$\frac{\sin \Theta_1}{\sin \Theta_2} = \frac{n_2}{n_1}$$

$$\frac{\sin 40}{\sin \Theta_2} = \frac{1.52}{1.33}$$

$$\Theta_2 = 34.2°$$

Q537: In glass (n = 1.50), a certain infra-red source has a wavelength of 8.00×10^{-7} m. Its frequency is

a. 8.44×10^{14} Hz

b. 5.63×10^{14} Hz

c. 3.75×10^{14} Hz

d. 2.50×10^{14} Hz

$n_1 = 1.00$ AIR

GLASS $n_2 = 1.50$

$$\frac{n_2}{n_1} = \frac{V_1}{V_2} \qquad \frac{1.50}{1.00} = \frac{3.0 \times 10^8}{V_2}$$
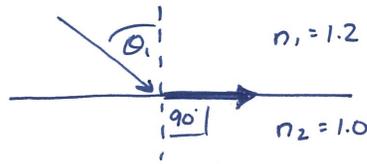
$$V_2 = 2.0 \times 10^8$$

$$V = f\lambda$$

$$(2.0 \times 10^8) = f(8.00 \times 10^{-7})$$

$$f = 2.50 \times 10^{14} \text{ Hz}$$

Diploma Questions – Refraction (Total Internal Reflection)

Q548: A ray of light passes through a medium that has a refractive index of 1.2. An angle of refraction of 90^0 in air will occur when the angle of incidence in the medium is

a. 75^0

b. 56^0

c. 34^0

d. 15^0

$n_1 = 1.2$

$90°$ $n_2 = 1.0$

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

$$\frac{1.0}{1.2} = \frac{\sin \theta_1}{\sin 90}$$

$$\theta_1 = 56.44°$$

Use the following information to answer Q550:

n_1 n_2 n_3 θ_1 68.68 θ_2 51.32 θ_3 θ_4

60

glass

$60°$ $n = 1.6$ $60°$

air

$n = 1.0$

$$\frac{\sin \theta_3}{\sin 90} = \frac{1.00}{1.60}$$

Diagram

$$\theta_3 = 38.68°$$

$$\theta_2 = 21.32°$$

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{n_2}{n_1}$$
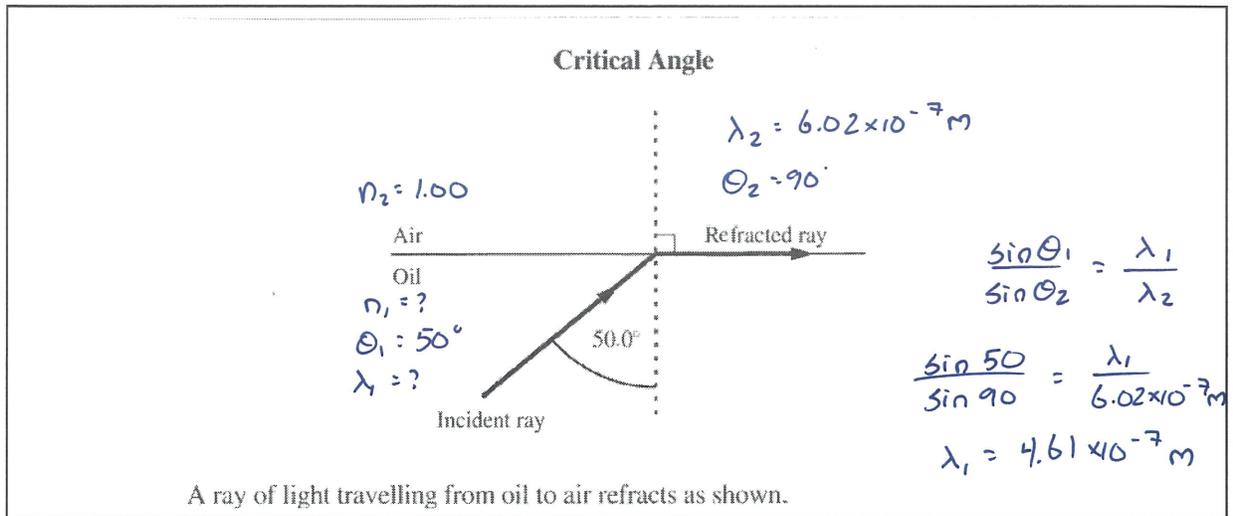
$$\frac{\sin \theta_1}{\sin 21.32} = \frac{1.6}{1.0}$$

$$\theta_1 = 35.57°$$

A ray of monochromatic light enters a glass prism and follows the path shown.

Q550: The angle of incidence at the first interface is

a. 13^0

b. 21^0

c. 36^0

d. 39^0

Use the following information to answer Q551:

Critical Angle

$\lambda_2 = 6.02 \times 10^{-7}\,m$

$\Theta_2 = 90°$

$n_2 = 1.00$

Air   Refracted ray

Oil

$n_1 = ?$

$\Theta_1 = 50°$ 50.0°

$\lambda = ?$

Incident ray

$\dfrac{\sin \Theta_1}{\sin \Theta_2} = \dfrac{\lambda_1}{\lambda_2}$

$\dfrac{\sin 50}{\sin 90} = \dfrac{\lambda_1}{6.02 \times 10^{-7}\,m}$

$\lambda_1 = 4.61 \times 10^{-7}\,m$
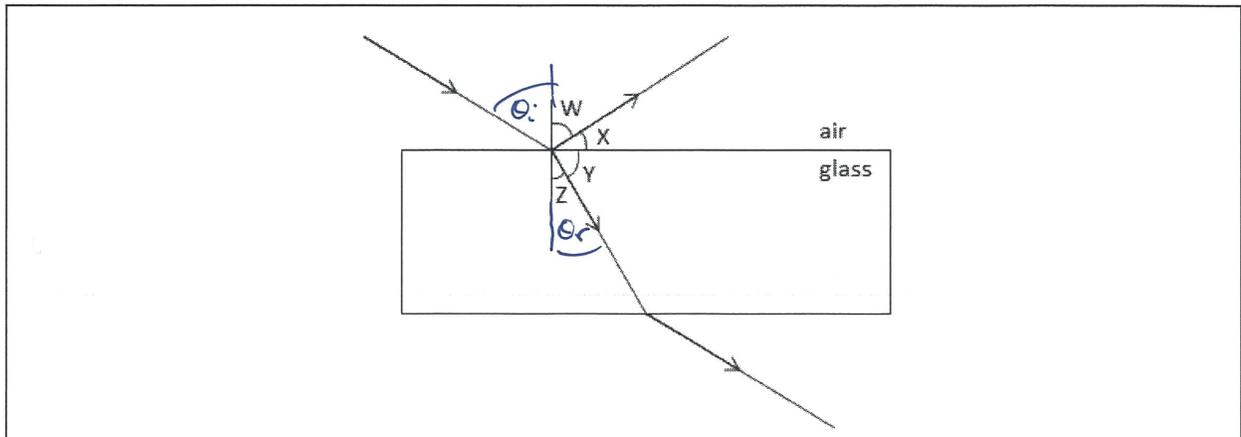
A ray of light travelling from oil to air refracts as shown.

Q551: If the wavelength of the light is 6.02×10^{-7} m in air, its wavelength in oil was

   a. 7.86×10^{-7} m
   b. 6.02×10^{-7} m
   (c.) 4.61×10^{-7} m
   d. 3.87×10^{-7} m
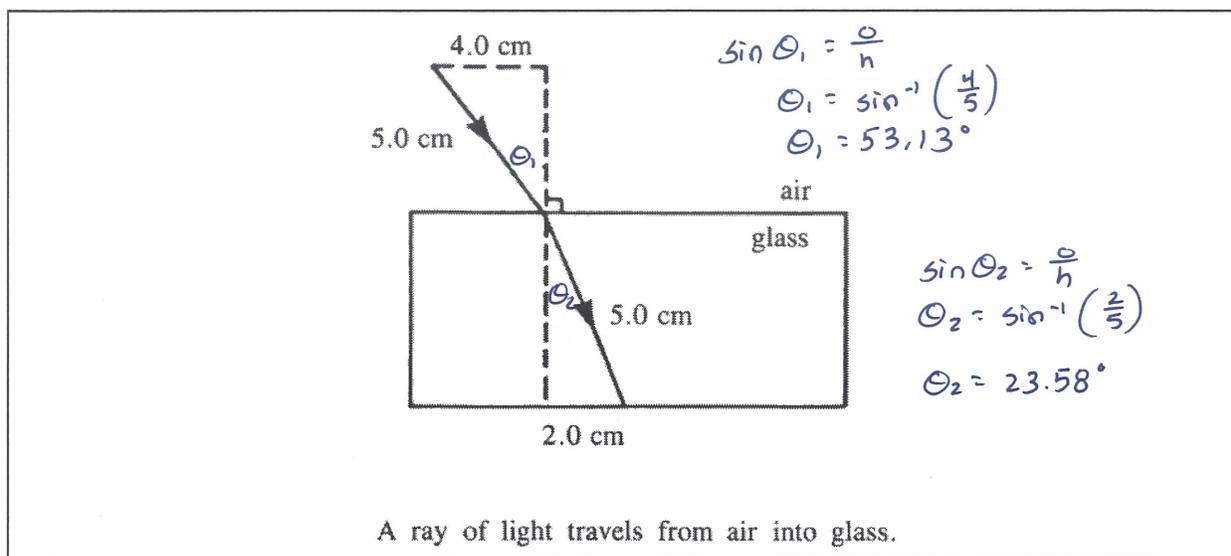
Diploma Questions – Refraction (Refraction Diagrams)

Use the following information to answer Q552:

Θ_i W

X   air

Y   glass

Z

Θ_r

Q552: The angle of refraction is

   a.   W
   b.   X
   c.   Y
   (d.)   Z

Use the following information to answer Q559:

4.0 cm

5.0 cm

air

glass

5.0 cm

2.0 cm

$\sin \Theta_1 = \dfrac{o}{h}$

$\Theta_1 = \sin^{-1}\left(\dfrac{4}{5}\right)$

$\Theta_1 = 53.13°$

$\sin \Theta_2 = \dfrac{o}{h}$

$\Theta_2 = \sin^{-1}\left(\dfrac{2}{5}\right)$

$\Theta_2 = 23.58°$

A ray of light travels from air into glass.

Q559: The speed of light in the glass is

    a. 1.5 x 10⁸ m/s
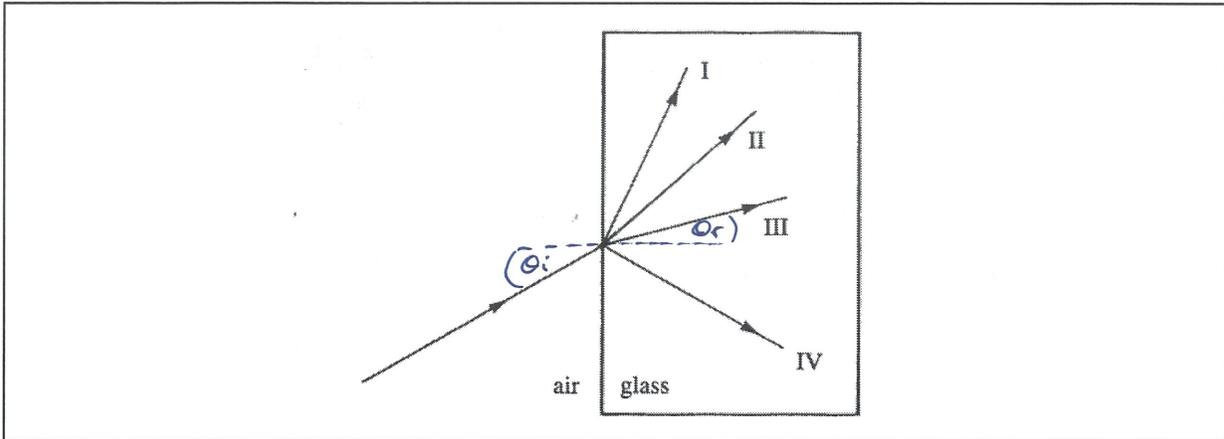   b. 2.0 x 10⁸ m/s
    c. 2.3 x 10⁸ m/s
    d. 2.6 x 10⁸ m/s

$$\frac{\sin \Theta_1}{\sin \Theta_2} = \frac{V_1}{V_2}$$

$$\frac{\sin 53.13}{\sin 23.58} = \frac{3.0 \times 10^8}{V_2}$$

$$V_2 = 1.50 \times 10^8 \, m/s$$

KEY

Use the following information to answer Q560:
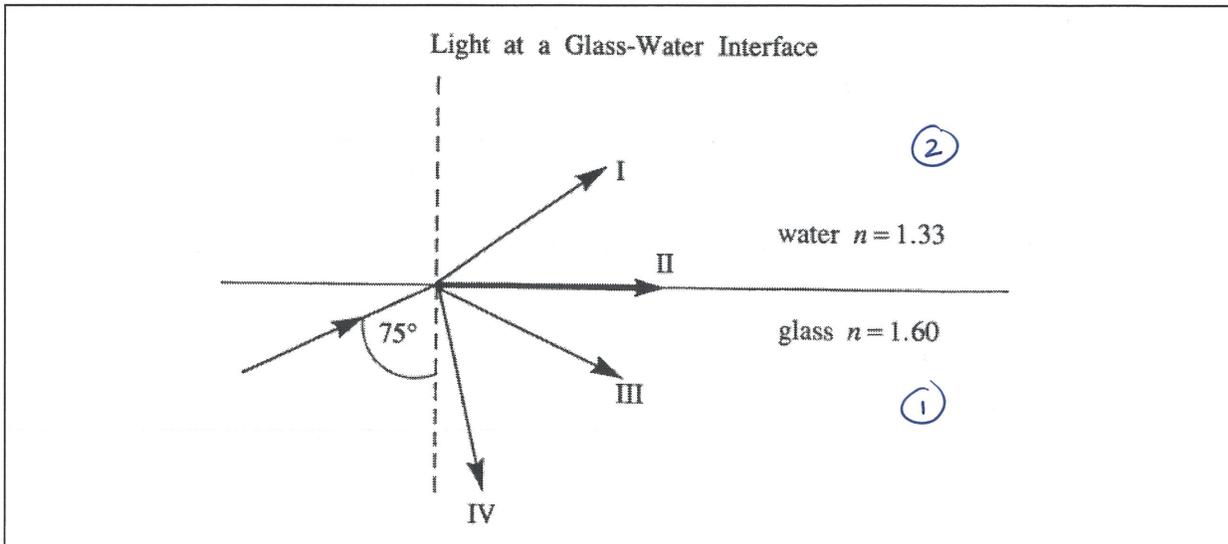

air | glass

Q560: The most probable refracted ray is represented by path

Slows down and bends toward the normal.

a. I
b. II
ⓒ III
d. IV

Use the following information to answer Q561:

Light at a Glass-Water Interface

water $n = 1.33$

glass $n = 1.60$

75°

Q561: The correct path of the ray is shown by

a. I
b. II
ⓒ III
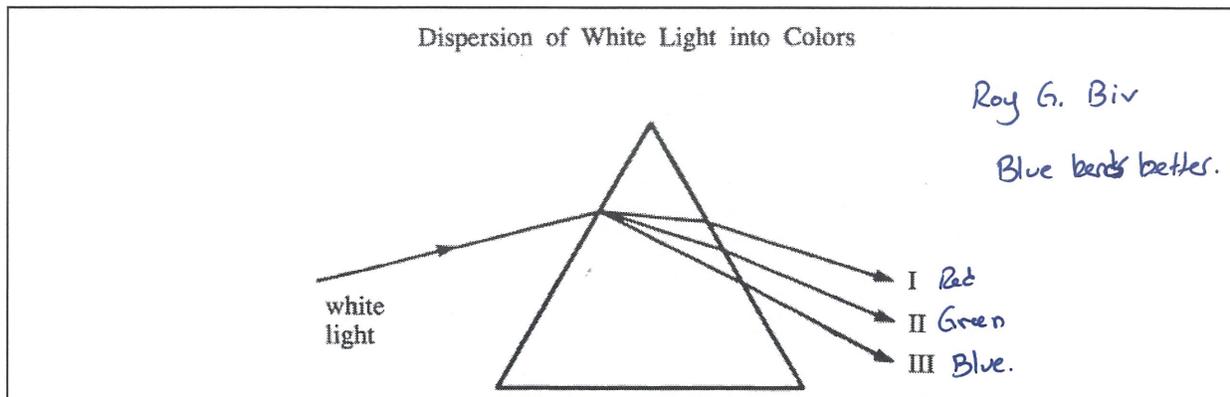d. IV

$$\frac{\sin\Theta_1}{\sin\Theta_2} = \frac{n_2}{n_1}$$

$$\frac{\sin 75}{\sin\Theta_2} = \frac{1.33}{1.60}$$

$\Theta_2 =$ Undefined.

Okay, common sense time. Going into smaller index of refraction, so bends away from normal. Can't be I. So II. or III. If 90°, then actually experiences total internal reflection, so III it is.

KEY

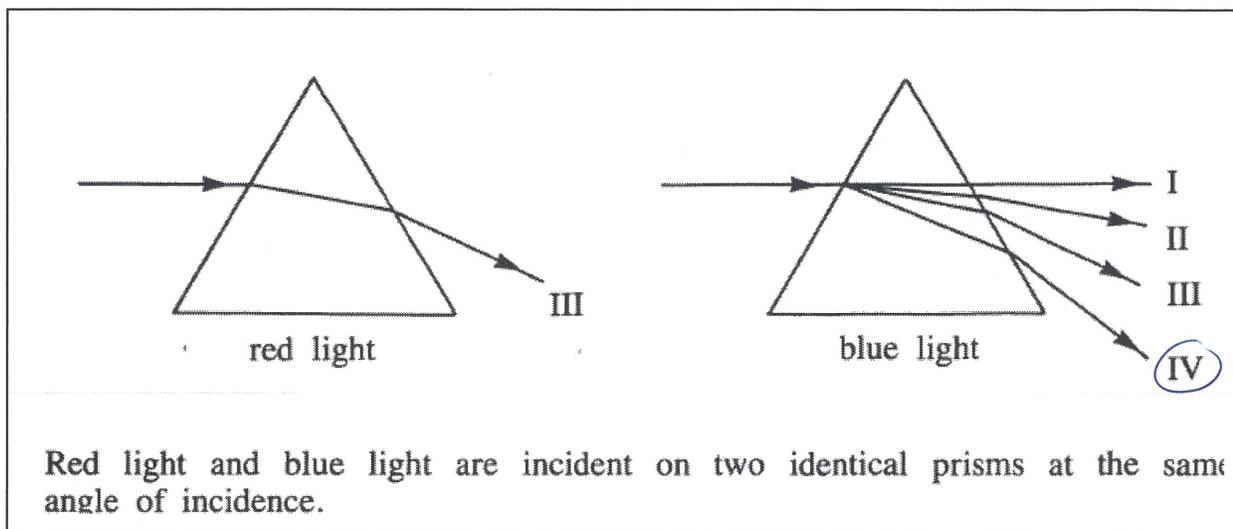**Diploma Questions – Refraction (Multiple Frequencies)**

Use the following information to answer Q570:

Dispersion of White Light into Colors

Roy G. Biv

Blue bends better.

white
light

I Red
II Green
III Blue.

Q570: The colors of rays I, II, and III respectively are most likely to be

(a) Red, green, blue
b. Red, violet, blue
c. Blue, yellow, red
d. Violet, green, blue

Use the following information to answer Q571:

III

red light

I
II
III
(IV)

blue light

Red light and blue light are incident on two identical prisms at the same angle of incidence.

Q571: Which ray represents the path taken by the refracted blue light?
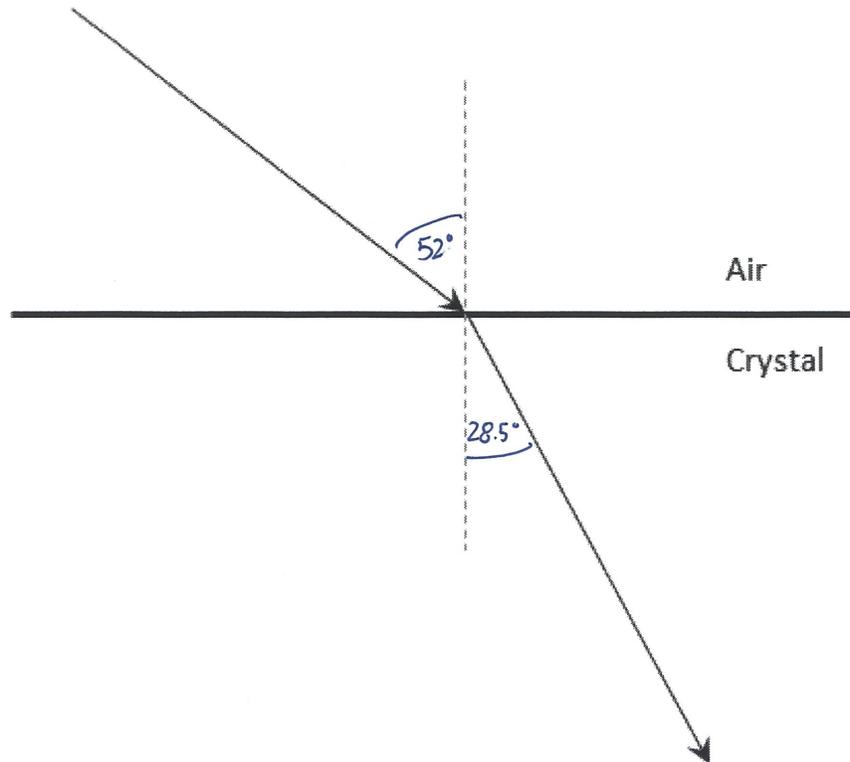
a. I
b. II
c. III
Blue bends better.
(d.) IV

Challenge Questions

Use the following information to answer Q1:

Light passes from air to a crystal with an unknown index of refraction.

52°

Air

Crystal

28.5°

Note: The diagram **is** drawn to scale.

Angles measured with a protractor.

Q1: The index of refraction of the crystal is _____.

*(Record your **three-digit** answer in the numerical response boxes below.)*

1	.	6	5

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

$(1.00)(\sin 52) = n_2 (\sin 28.5)$

$n_2 = 1.65$