Checkpoints Chapter 16 Light basics.
Multiple choice questions

Question 1

Use $E = \frac{hc}{\lambda}$ to get

$\lambda = \frac{hc}{E}$

$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{1.42}$

$\therefore \lambda = 8.75 \times 10^{-7}$ m

$\therefore \lambda = 875$ nm

This is beyond visible red light.

∴ **A (ANS)**

Question 2

For TIR to occur the angle of incidence must be greater than or equal to the critical angle.

∴ **B (ANS)**

Question 3

Violet has the shortest wavelength in the visible spectrum and red has the longest wavelength.

∴ **A (ANS)**

Question 4

If there is less light coming out, then less light has been totally internally reflected. The angle the light hits the boundary must be less than the critical angle.

∴ **B (ANS)**

Question 5

If there is less light coming out, then less light has been totally internally reflected.

From $n_1 \sin i_c = n_2 \sin r$,

$\therefore n_1 \sin i_c = n_2 \sin 90$,

$\therefore n_1 \sin i_c = n_2 \times 1$,

If $n_2 = n_{water}$ then an increase in n_2 will mean an increase in sin i, if n_1 is constant. This means that the critical angle has increased as sin is an increasing function in the range 0 to 90^0

∴ **A (ANS)**

Question 6

Use $n_1 \sin i_c = n_2 \sin r$,

$\therefore 1.58 \sin i_c = 1.53 \sin 90$,

$\therefore \sin i_c = \frac{1.53}{1.58}$

$\therefore \sin i_c = 0.9684$

$\therefore i_c = 75.5^0$

∴ **B (ANS)**

Question 7

Use $n_1 \sin i_c = n_2 \sin r$,

$\therefore n_1 \sin 83^0 = n_2 \sin 90^0$

$\therefore n_1 \sin 83^0 = n_2$

$\therefore \frac{n_{cladding}}{n_{core}} = 0.9925$

Now it is just a case of finding the nearest answer, where $n_{cladding} < n_{core}$.

Ans C, $\frac{1.71}{1.73} = 0.9884$, Ans D, $\frac{1.31}{1.32} = 0.9924$

∴ **D (ANS)**

Question 8

The process of light emission in a LED is when electrons transition from a higher energy state in the conduction band to a lower energy state in the valence band.

∴ **C (ANS)**

Question 9

The fields are transmitted by the tower to the phone.

∴ **C (ANS)**

Question 10

Both a star, and an incandescent light are sources of wide spectrum incoherent light. The light globe produces light from the random thermal motion of the valence electrons

∴ **B (ANS)**

Question 11

The stem actually asks you to calculate the period of these radiation, this was another question on this exam.

EM radiation does not require a medium for transmission.

∴ **D (ANS)**

Question 12

Both are EM radiations, so both travel at the speed of light. The difference is the wavelength.

$\therefore$ **B (ANS)**

Question 13

EM radiations are transverse, the fields are perpendicular to each other, and vary sinusoidally perpendicular to the direction of motion

$\therefore$ **B (ANS)**

Question 14

Light is an EM radiation, therefore it travels at the same speed in air.

$\therefore$ **B (ANS)**

Question 15

The speed of light in a glass prism is dependent on the wavelength of the light. This change in speed creates dispersion

$\therefore$ **B (ANS)**

Question 1

For TIR to occur light has to bend away from the normal, therefore it must go from high to low refractive index.

$\therefore$ **A (ANS)**

Question 17

Monochromatic light, has only one frequency. Dispersion is when the difference in speeds of the light cause different angles of refraction.

$\therefore$ **D (ANS)**

Extended questions

Question 18a

Use E = hf

$\therefore E = 6.63 \times 10^{-34} \times 6.7 \times 10^{14}$

$\therefore$ **E = 4.4 × 10^{-19} J (ANS)**

Question 18b

Use c = fλ to get $\lambda = \frac{c}{f}$

$\therefore \lambda = \frac{3.0 \times 10^8}{6.7 \times 10^{14}}$

$\therefore$ **λ = 4.47 × 10^{-7} m (ANS)**

Question 19a

The stem actually asks you to calculate the period of these radiation.

Use $f = \frac{1}{T}$ to get $T = \frac{1}{f}$

$\therefore T = \frac{1}{406 \times 10^6}$

$\therefore T = 2.46 \times 10^{-9}$ s

$\therefore$ **T = 2.46 ns**

Question 19b

Use c = fλ to get $\lambda = \frac{c}{f}$

$\therefore \lambda = \frac{3.0 \times 10^8}{4.06 \times 10^8}$

$\therefore \lambda = 0.739$.

$\therefore$ **λ = 73.9 cm (ANS)**

Question 20

Use c = fλ to get $\lambda = \frac{c}{f}$

$\therefore \lambda = \frac{3.0 \times 10^8}{1.003 \times 10^8}$

$\therefore$ **λ = 2.99 m (ANS).**

Question 21

Power is the rate of using energy.
So the photons leaving the searchlight are taking 5.0 kJ of energy every second.
If we find the energy of each photon, then we can use this, to find the number of photons leaving the light each second.
The energy of a photon is given by

$E = \frac{hc}{\lambda}$

$\therefore E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{520 \times 10^{-9}}$

$= 3.825 \times 10^{-19}$ J.

To find the number of photons, use

$5.0 \times 10^3 = n \times 3.825 \times 10^{-19}$ J.

$\therefore n = 5.0 \times 10^3 \div 3.825 \times 10^{-19}$

$\therefore n = 1.3 \times 10^{22}$ photons per second.

1.3×10^{22} photons/sec (ANS)

Question 22

The energy of a photon is given by $E = \frac{hc}{\lambda}$.

$\therefore$ the energy of each photon

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{5.0 \times 10^{-7}}$

$= 3.978 \times 10^{-19}$J

To get 1.0 mW, you need 1.0×10^{-3} Joules every second.

$\therefore 1.0 \times 10^{-3} = \text{'n'} \times 3.978 \times 10^{-19}$J

$\therefore n = 1.0 \times 10^{-3} \div 3.978 \times 10^{-19}$J

2.5×10^{15} photons/sec (ANS)

Question 23

Use $E = \frac{hc}{\lambda}$.

$\therefore$ the energy of the photon

$= \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{580 \times 10^{-9}}$

$= 2.14$ eV

$\therefore$ 2.14 eV (ANS)

Question 24

The critical angle for water/air interface is given by $n_1 \sin i_c = n_2 \sin r$,

$\therefore 1.33 \sin i_c = 1.00 \sin 90$,

$\therefore \sin i_c = \frac{1.00}{1.33}$

$\therefore \sin i_c = 0.7519$

$\therefore i_c = 48.8^0$

For the ray on the left, the angle of incidence is 45^0, which is less than the critical angle, so some of the ray will reflect but most will refract out of the water.

Use $n_1 \sin i = n_2 \sin r$,

$\therefore 1.33 \sin 45 = 1.00 \sin \theta$,

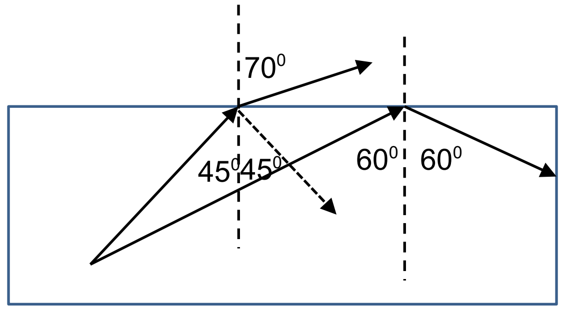
$\therefore \sin \theta = \frac{1.33 \times 0.7071}{1.58}$

$\therefore \sin \theta = \frac{0.9405}{1.0}$

$\therefore \sin \theta = 0.9405$

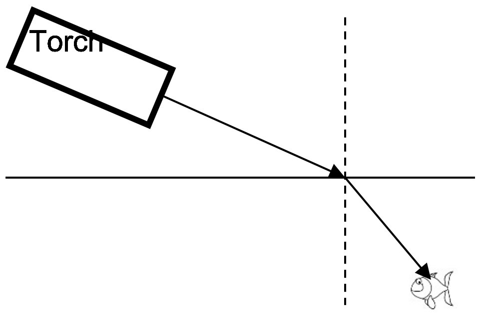
$\therefore \theta = 70.1^0$ (ANS)

For the ray on the right the angle of incidence is 60^0, this is greater than the critical angle, so, all of this ray will totally internally reflect.

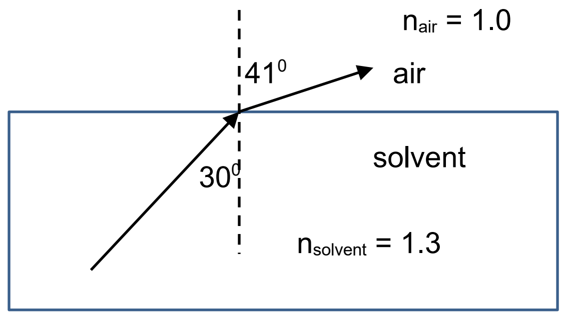


Question 25

The ray of light will bend towards the normal as it enters the water.



Question 26



Use $n_1 \sin i = n_2 \sin r$,

$\therefore 1.3 \sin 30 = 1.00 \sin \theta$,

$\therefore \sin \theta = \frac{1.3 \times 0.5}{1.0}$

$\therefore \sin \theta = 0.65$

$\therefore \theta = 40.5^0$ (ANS)

Question 27

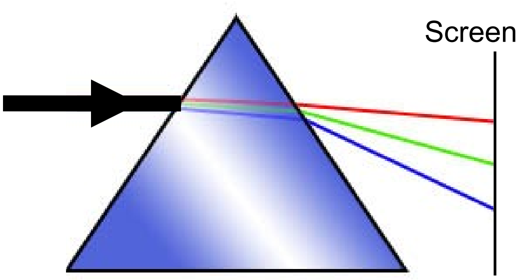
Use $n_1 \sin i_c = n_2 \sin r$,

$\therefore n_1 \sin 64 = 1.33 \sin 90$,

$\therefore n_1 = \frac{1.33}{\sin 64^0}$

$\therefore$ **n_1 = 1.48 (ANS)**

Question 28



The red light will bend less, the blue light will bend the most. There will be spots of red, green and blue light on the screen.

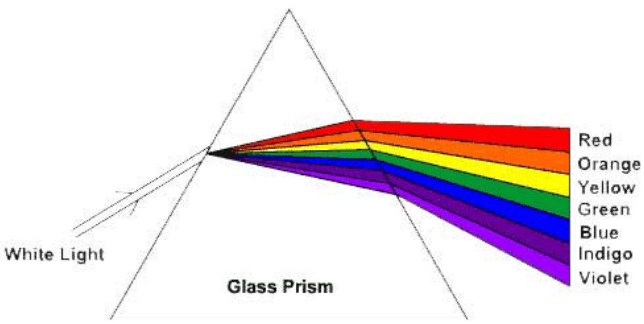
Question 29

Under white light the object will look red, under red light the object will look red. Under blue light, no light will be reflected, so the object will look black.

Question 30

They are all EM radiations, therefore they all travel at the speed of light in a vacuum. They have different wavelengths and frequencies. Ultraviolet will have the most energy, and infrared will carry the least energy per photon.

Question 31



$\therefore$ **(ii) (ANS**

Question 32

A False

B True

C False

D True

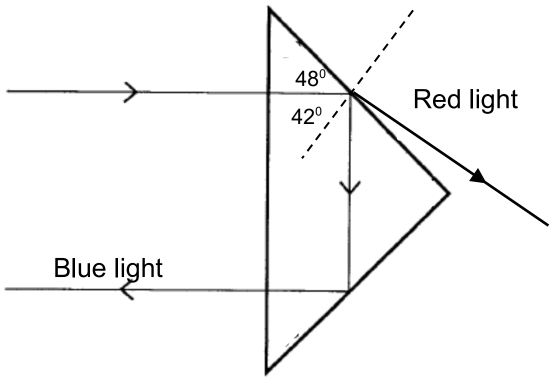
E False

F True

G True

H False

Question 33



The critical angle for red light is given by

$n_1 \sin i = n_2 \sin r$,

$\therefore 1.48 \sin i_c = 1.00 \sin \theta$,

$\therefore \sin i_c = \frac{1.0}{1.48}$

$\therefore \sin \theta = 0.6757$

$\therefore$ **$\theta_{c\ red} = 42.5^0$**

The critical angle for blue light is given by

$n_1 \sin i = n_2 \sin r$,

$\therefore 1.52 \sin i_c = 1.00 \sin \theta$,

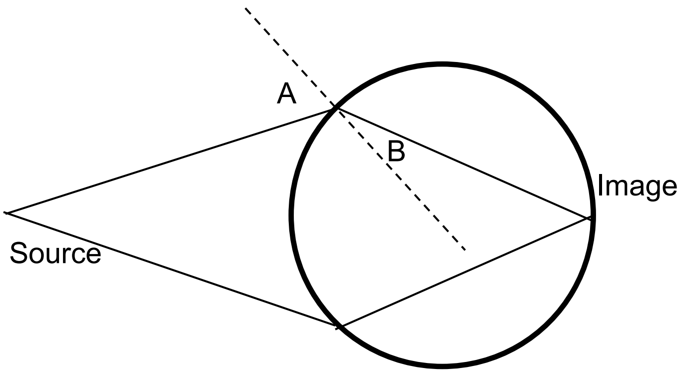
$\therefore \sin i_c = \frac{1.0}{1.52}$

$\therefore \sin \theta = 0.6579$

$\therefore$ **$\theta_{c\ blue} = 41.1^0$ (ANS)**

The angle of incidence in this case is 42^0. This is below the critical angle for red light, so the red light will refract out of the block. The angle of 42^0 is greater than the critical angle for blue light, so it will TIR.

Question 34a



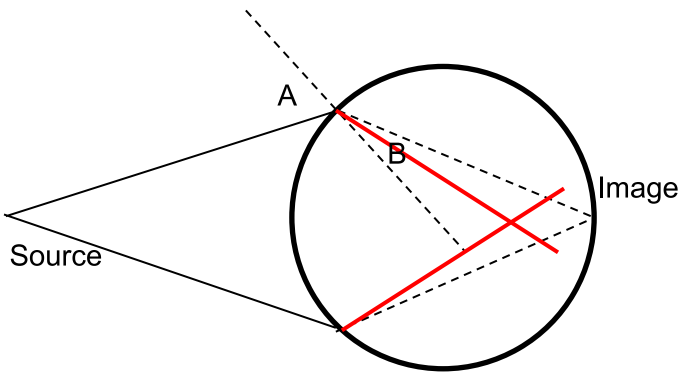
Use $n_1 \sin i = n_2 \sin r$,

$\therefore$ 1.00 sin 55^0 = n sin 25^0

$\therefore n = \frac{1.0 \times \sin 55}{\sin 25}$

$\therefore$ **n = 1.94 (ANS)**

Question 34b



Question 35

A light year is the distance that light travels in a year. The speed of light is 3.0×10^8 m s^{-1}.

In one day it will travel

$3.0 \times 10^8 \times 60 \times 60 \times 24$ m

In one year it will travel

$3.0 \times 10^8 \times 60 \times 60 \times 24 \times 365.25$ m

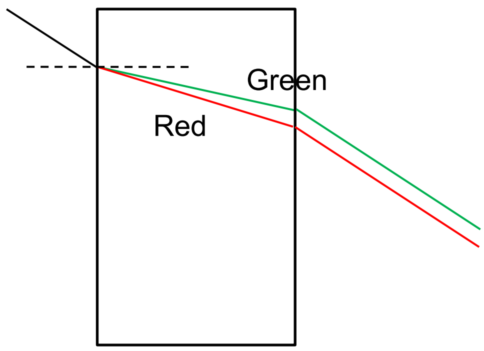
$\therefore 9.46728 \times 10^{15}$ m

$\therefore$ in 4.3 light years it will travel

$4.3 \times 9.46728 \times 10^{15}$ m

$\therefore$**4.1×10^{16} m (ANS)**

Question 36



Red bends less.

This answer differs from the one in the back of the book.

Question 37a

Red bends less.
Therefore the red will be at the point B.
From A to B
Violet, Blue, Green, Yellow, Orange, Red.
There must be a mistake with the values of the refractive indices, as Green and Yellow seem to be in the wrong order.

Question 37b

Use $n_1 \sin i = n_2 \sin r$, for red light

$\therefore$ 1.0 sin 45 = 1.332 sin θ,

$\therefore \sin\theta = \frac{1.0 \times 0.7071}{1.332}$

$\therefore$ sin θ = 0.5309

$\therefore$ **$\theta_{red} = 32.06^0$ (ANS)**

Use the triangle (normal, base, ray_B)

$\therefore \tan 32.06 = \frac{B}{50}$

$\therefore$ the $length_B$ = 50 tan 32.06

$\therefore$ $Length_B$ = 31.32 cm.

Use $n_1 \sin i = n_2 \sin r$, for violet light

$\therefore$ 1.0 sin 45 = 1.345 sin θ,

$\therefore \sin\theta = \frac{1.0 \times 0.7071}{1.345}$

$\therefore$ sin θ = 0.5257

$\therefore$ **$\theta_{red} = 31.72^0$ (ANS)**

Use the triangle (normal, base, ray_A)

$\therefore \tan 31.72 = \frac{B}{50}$

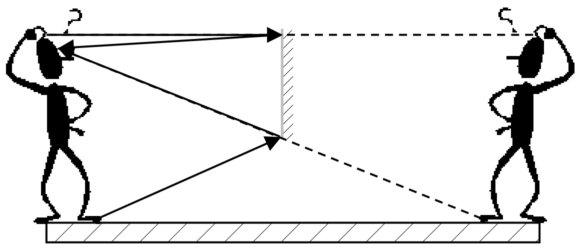
$\therefore$ the $length_B$ = 50 tan 31.72

$\therefore$ $Length_B$ = 30.90 cm.

The difference between these two points is
31.32 – 30. 90 = 0.42

$\therefore$ **4.2 mm (ANS)**

Question 38



To see your complete image, you need a mirror that is half your height. This is as the image is equidistant behind the mirror as the object is in front of the mirror.
For a 110 cm person, the mirror needs to be 55 cm above the floor, and for a 210 cm person it needs to be 105 cm above the floor.

∴ 55 cm above the floor (ANS)

The mirror will need to be at least 110 cm long for the tallest person to see all of themselves.

Question 39a

Since b = 30^0 and a = d = 60^0 (from triangle laws). This means that c = 30^0 as well.

∴ c = 30^0 (ANS)

Question 39b

Use $n_1 \sin i = n_2 \sin r$, for yellow light,
The angle of incidence is 60^0 and the angle of refraction is 30^0

∴ $1.0 \sin 60 = n_{glass} \sin 30$

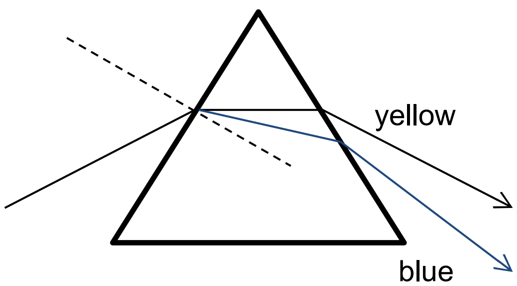
∴ $n_{glass} = \frac{0.8660}{0.5}$

∴ $n_{glass} = 1.732$

∴ $n_{glass} = 1.73$ (ANS)

Question 39c

The blue light will refract more than the yellow light.



Question 40a (2017 Q14a, 1 m, %)

Use $n_1 \sin i_c = n_2 \sin 90$

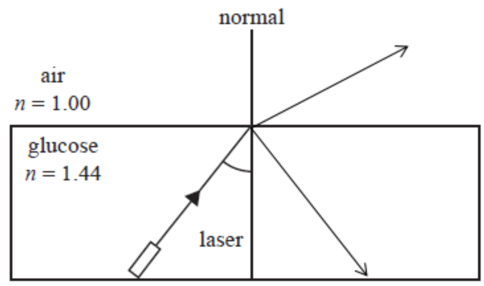
∴ $1.44 \times \sin i = 1.00 \times 1.0$

∴ $\sin i = 0.6944$

∴ $i = 43.98$

∴ i = 44^0 (ANS)

Question 40b (2017 Q14b, 2 m, %)



Question 40c (2017 Q14c, 2 m, %)

Since the angle of incidence is greater than the critical angle, Total internal reflection will occur, so no light will escape the glucose.

Please note that this experiment is extremely unsafe. You NEVER look at a laser.