AS-2007 Q7 & Q8

7. A thin rectangular block of glass, of thickness t, has a beam of light passing through it along a normal to a face, as shown in fig. 5. The light wave travels at a slower speed in glass than in air. The ratio of the extra number of waves introduced within the length t when the glass is in place, to the number of waves within the same length t in air, is given by

λ = wavelength in air

The **refractive index,** $n = \dfrac{\text{speed of light in air}}{\text{speed of light in glass}}$

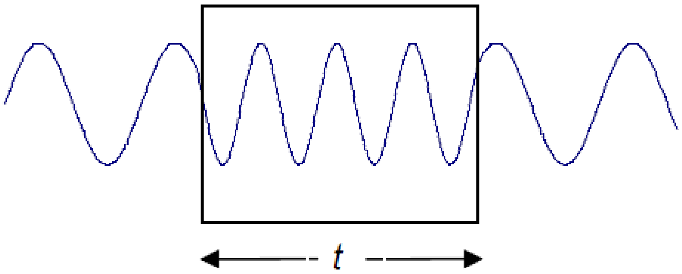


fig. 5

A. (n-1)   B. $\dfrac{1}{(n+1)}$ C. $\dfrac{n}{(n+1)}$ D. $\dfrac{(n-1)}{n}$

8. A narrow beam of light is incident normally upon a thin slit, and the light that passes through is spread out by diffraction. The thin slit is then immersed in a container of water. The beam of light is shone through the water and is again at normal incidence to the slit. The spread of the diffracted beam of light in water will be

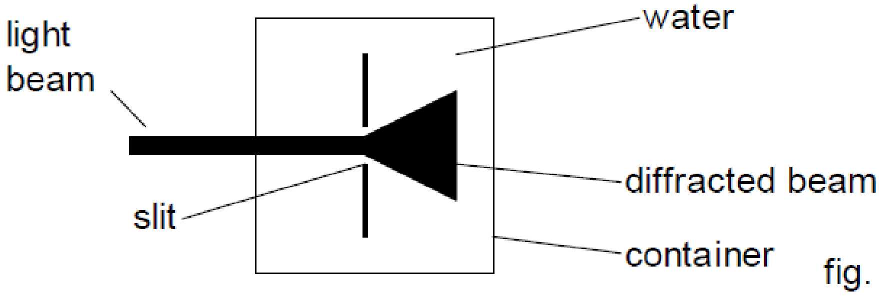
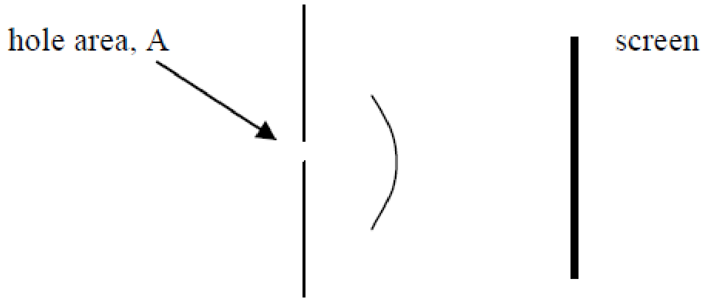


fig. 6

A. The same as in air   B. Diffraction will not occur in water   C. Less spread out than in air   D. More spread out than in air

AS-2008 Q1

1. A beam of light of uniform intensity and of a single wavelength strikes a screen in which there is a small circular hole of area A. Some of the light passes through, and then spreads by diffraction, as shown below.



At the centre of the diffracted wave which reaches the centre of the screen, the intensity of the light is I_o (intensity is the power per unit area). When the hole is made narrower, then the angular width of the beam increases, in such a way that for the diffracted beam, half the diameter of the hole will result in twice the width of the beam. If the diameter of the hole is halved, then what will be the new intensity at the centre of the diffracted beam?

A $I_o/2$ B $I_o/4$ C $I_o/8$ D $I_o/16$

AS-2009 Q4

4. Light is an electromagnetic wave and can travel through a vacuum. There is a constant that appears in formulae which involve magnetism and is denoted by the letter μ_o "mu zero", whilst in electrostatic formulae another constant ε_o "epsilon zero" will appear.

The speed of light in a vacuum is given by $c = \dfrac{1}{\sqrt{\varepsilon_o \mu_o}}$.

The units of ε_o are $N^{-1}\ C^2\ m^{-2}$
The units of μ_o are:

A. $kg^{-1}\ m^{-1}\ C^2$ B. $kg\ m\ C^{-2}$ C. $kg\ m\ s^{-4}\ C^{-2}$ D. $kg^{-1}\ s^{-3}\ C^{-2}$

AS-2011 Q4

4. When light passes through a prism and is split into the colours of the spectrum, this is an example of :

A. Dispersion B. Diffraction C. Reflection D. Refraction

AS-2011 Q7

7. A high power laser produces a 20 TW pulse of radiation but for the short duration of only 3 fs. How much energy is contained in a single laser pulse?

$$\text{tera} = 10^{12}$$
$$\text{femto} = 10^{-15}$$

A. 0.006 J B. 0.06 J C. 0.6 J D. 60 J

AS-2012 Q4

Two plane mirrors are at an angle of 15° as shown in figure 1 below. A small object O is placed between them at an equal distance from mirror A and from mirror B. How many images can be seen (including the original)? (You can fit your eyeball between the mirrors if you want to)

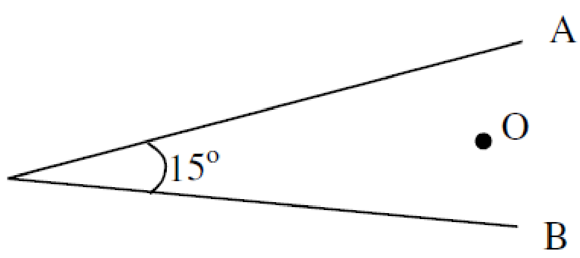
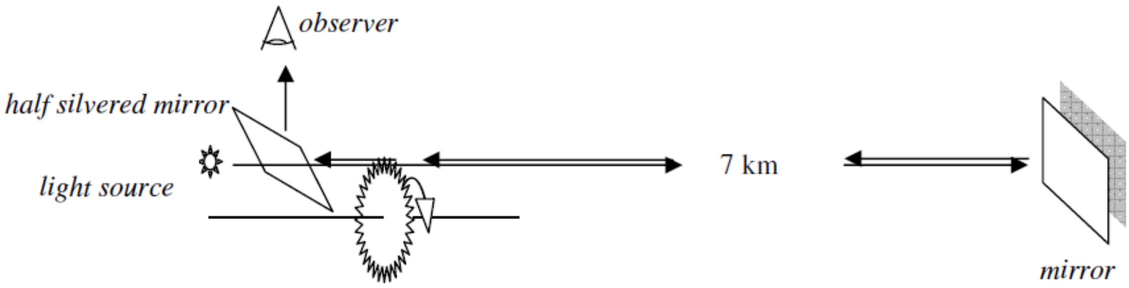


Figure 1.

A. None B. 24 C. 36 D. 48

AS-2011 Q11

In one of the original experiments to measure the speed of light, carried out by Fizeau in 1849, a beam of light was sent to a distant mirror 7 km away and reflected back, passing through the teeth of a rapidly rotating cogwheel. It is easy to detect when the light is obscured by a tooth on its return path and a reduction in intensity is observed. A simplified diagram of the setup is shown below. The toothed cog has 720 teeth and rotates several hundred times per second.



a) At a rate of rotation of 283rps (rotations per second) extinction is observed. Speeding up the cog, extinction is next observed at 313 rps. Explain why the light is extinguished at a particular rate of rotation.

____

____ [2]

b) Explain why there are two (or more) rates at which extinction is observed.

____

____ [1]

c) If $n + ½$ teeth cross the beam at 283 rps, state how many teeth must cross the beam at 313 rps? Calculate the number of teeth that cross the beam per second at each of the two speeds, the difference in the number of teeth crossing per second, and thus the time interval for one extra tooth to cross. (This is the travel time of the light beam)

____

____

____ [3]

d) Calculate the speed of light from these measurements.

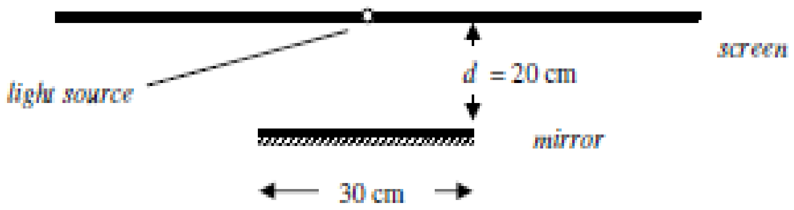
____

____ [1]

/7

AS-2011 Q14

A point source of light is embedded in a large screen. A circular mirror of diameter 30 cm is placed 20 cm in front of the screen, parallel to it and with the centre of the mirror lying along the normal to the screen which passes through the point light source.



a) Sketch the path of the light rays on the diagram above.

______________________________ [2]

b) Calculate the area of illumination on the screen.

____

____

______________________________ [2]

c) If the distance from the screen to the mirror is now given by d, how does the area of illumination depend upon separation d?

____

____

______________________________ [2]

d) Describe qualitatively how the intensity of light reaching the screen depends upon the separation d for smaller and larger values of d.

____

____

____

______________________________ [3]

/9

AS-2011 Q15

In an experiment carried out in 1959 by Pound and Rebka at Harvard University, Einstein's General theory of Relativity was tested by measuring the change in frequency of a photon of the electromagnetic spectrum when it went downwards in the gravitational field of the earth. A 14 keV γ-ray is emitted downwards by a radioactive isotope of iron (Fe-57), and as it falls down in the gravitational field of the earth its energy and hence its frequency increases. A relatively simple classical calculation turns out to give the right result for the frequency change.

a) To determine the frequency of the initial 14 keV photon, convert the energy into joules and, using the relation between energy and frequency of photon $E = hf$, calculate the frequency.

____

____ [2]

b) If we associate a fictitious mass m to the gamma ray photon, given by $m = \frac{E}{c^2}$ then the energy change of the photon as it falls in the earth's field through a distance d is given by the familiar potential energy change in a gravitational field, $\Delta E = mg\Delta d$. Express this as a change of frequency of the gamma ray photon Δf .

____

____ [2]

c) If the distance the photon falls is 22.5 m, calculate both the change in frequency and the fractional change in frequency $\frac{\Delta f}{f}$ of the gamma ray photon.

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____

____ [3]

d) This small frequency change is detected by using the Doppler effect in which a moving source emits a wave whose frequency is modified by its motion. The fractional change of frequency emitted is given by the ratio v/c where v is the speed o the source required. Calculate v.

____

____ [1]

speed of light, $c = 3.0 \times 10^8$ ms^{-1}
Planck's constant, $h = 6.6 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C

/8

AS-2012 Q15

In a particle physics experiment, light from a particle detector is to be collected and concentrated by reflecting it between a pair of plane mirrors with angle 2α between them, as shown in figure 5 below. A faint parallel beam of light consisting of rays parallel to the central axis is to be narrowed down by reflection off the mirrors, as shown by the single ray illustrated, for which angle $a = \alpha$.

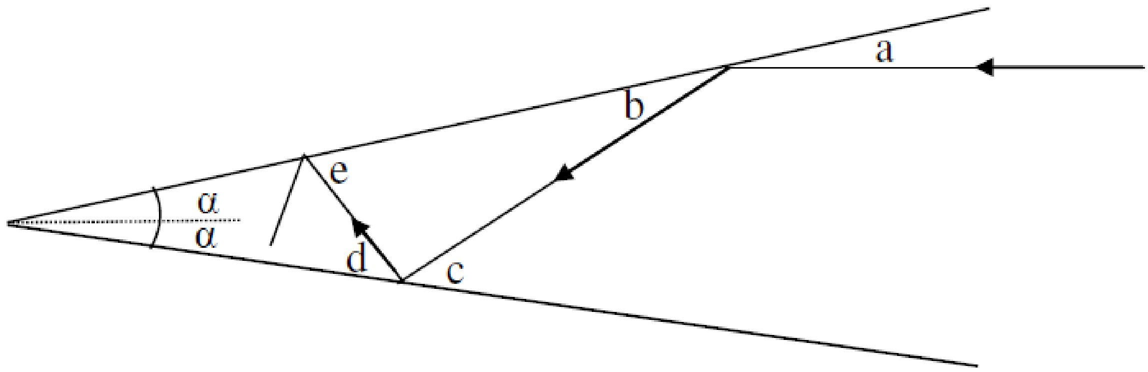

Figure 5.

a) Determine angles b, c, d, and e in terms of angle α.

____

____

____

____ [3]

b) Explain what happens after several reflections of the light down the mirror funnel.

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____ [2]

c) If angle α is 10^{o} what is the total number of reflections between the mirrors that will be made by a beam, of light entering parallel to the axis of symmetry as shown?

____

____

____ [1]

d) If the mirrors are replaced by an internally silvered circular cone whose cross-section is the same as that shown above, why will this not make any difference to the calculations given above for the plane angled mirrors with a beam of light parallel to the axis?

____

____

____ [1]

e) An ear trumpet is not very common now, but it was used to collect sound and focus it into the ear. It was a cone about 0.5 metres long with an angle 2α of about 30^o. Sound might have a frequency of 400 Hz and the speed of sound is 330 m/s. Why is the model above that we have used for light not valid for an ear trumpet used to collect sound?

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____ [2]

/9

AS-2008 Q8

A fibre optic cable is used to transmit signals. When a short pulse of light passes along a fibre, it spreads out, which limits the rate of transmission of signals down the fibre.

a) Suggest two reasons why the pulse of light might spread out.

[2]

b) A fibre of length 10.0 km is illuminated with red light from an led which is turned on and off repeatedly for equal amounts of time. The speed of the pulse of light ranges from 1.95×10^8 m/s to 2.05×10^8 m/s. Calculate the range of times taken for the pulse to travel down the fibre optic.

[1]

c) What is the maximum frequency of the led so that the pulses arrive without overlapping?

[3]

d) The wavelength the LED emits is 1310 nm in air. Calculate the frequency of the light used.

$$(c = 3.0 \times 10^8 \text{ m/s})$$

e) The frequency of light at the red end of the spectrum is 4 x 10^{14} Hz. Explain in what part of the spectrum the 1310 nm of part (d) is to be found.

____

____ [2]

/9

AS-2009 Q14

a) A laser produces light pulses of energy 5 J and duration 2×10^{-9} s. If the beam is circular in cross section and of diameter 2 mm, calculate the intensity (the power per unit area) of a laser pulse.

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____

____ [1]

b) State one significant difference in the nature of the light emitted by a laser from that emitted by an ordinary light bulb.

____

____ [1]

c) The wavelength of the laser is 400 nm. Light can be seen either as a wave or a particle (a photon). The energy E of a photon of light is given by $E = hf$, where f is the frequency of the light and h is Planck's constant. Calculate the number of photons in a single pulse from the laser.

Planck's constant $h = 6.6 \times 10^{-34}$ Js
speed of light $c = 3.0 \times 10^{8}\ \mathrm{ms^{-1}}$

____

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____ [2]

d) Calculate the volume of a single pulse of light from the laser, and hence the density of photons in the laser pulse.

____

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____ [3]

e) If the photons in the pulse were equally spaced, rather like ball bearings packed uniformly in a box, what would be the volume occupied by a single photon?

____

____ [1]

f) If the volume occupied by a photon was a cube, what would be the length of a side of the cube?

____

____ [1]

/9

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/9