R1 -2002 Q1(h)

h) A white light shines vertically down on a horizontal CD ROM disc. The disc is viewed by a teacher whose eye is a horizontal distance 0.50 m from the disc and 0.35 m vertically above its horizontal plane, Figure 1.2. A yellow light of wavelength 590 nm is observed due to first order diffraction.

(i) Deduce the spacing *d* between adjacent tracks of the CD ROM.

(ii) The CD ROM is tilted, clockwise through an angle of 5°.
Determine the wavelength now observed.

[12]

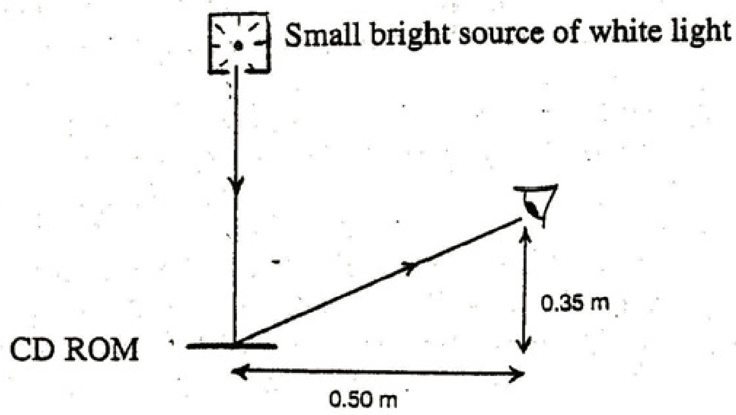


Figure 1.2

R1 -2003 Q1(b)

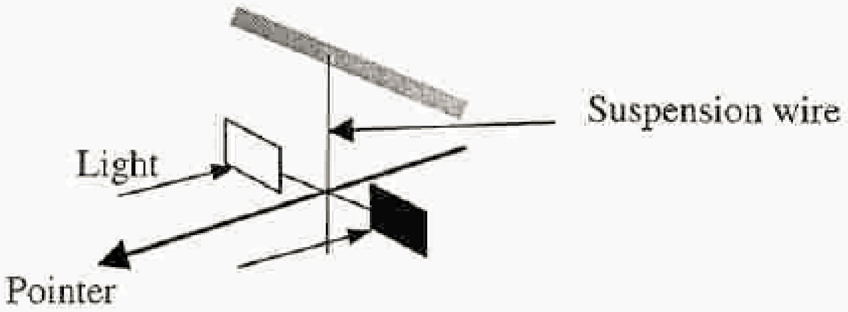
b) Calculate the number of photons produced during a nanosecond (10^{-9}s) pulse from a 0.5 mW laser. The wavelength of the radiation is 639 nm. [6]

R1 -2004 Q1(b)

b) (i) A red, 100 mW, laser beam, wavelength 650 nm, is incident normally on a perfectly black disk. Calculate the force on the disk.

(ii) If the disk is replaced by a mirror that reflects 95% of the incident light, deduce the force exerted on the mirror.

Figure 1.2



(iii) Two rectangular metal vanes are suspended by a wire, Figure 1.2. One is highly reflecting and the other is black. Both vanes are illuminated by identical, high intensity, laser beams normal to their surface. The system is contained in an evacuated chamber. The results observed, looking down the suspension wire, are:

Good vacuum	Anti-clockwise rotation
Ultra high vacuum	Very small clockwise rotation

How will the velocities of molecules in the chamber be affected by collisions with the vanes? Explain the observations.

[10]

R1 -2005 Q1(c(iii)) and Q1(c(iv))

(iii) Why must a hole in a pinhole camera be neither too small nor too large?

(iv) Why does a blue cloth look dark when viewed in sodium light?

R1 -2006 Q1(g)

(g) Use graph paper and a ruler to draw *accurate* ray diagrams for the following two optical situations:

(i) A point object is reflected in a plane mirror. Draw two rays of light from the object that are reflected in the mirror.

(ii) A point object is situated between two plane mirrors that are joined to form a right angle. Draw a ray of light from the object that is reflected in both mirrors.

(iii) If, in (ii), the ray is incident on the first mirror at an angle of incidence θ, determine the angle through which the ray has been rotated after two reflections.

[7]

R1 -2006 Q1(l)

(l) A fibre optic cable, surrounded by air of refractive index n_a, consists of a glass core of refractive index n_g enclosed in cladding of refractive index n_c.

(i) Explain, with a diagram, how light is transmitted down the cable with little loss of intensity.

(ii) What are the limitations on the light paths?

[4]

R1 -2007 Q1(l)

(l) When monochromatic light, wavelength λ, is reflected almost normally from two glass plates, one on top of the other with a very small angle, θ, between them, bright and dark interference fringes are observed.

(i) Explain how these fringes arise.
(ii) How does the separation of the fringes depend on θ?
(iii) What is the effect of filling the volume between the plates with water?

[8]

R1 -2009 Q1(g)

(g) Explain qualitatively how Newton's interference rings are formed using an optical plate and a convex lens.

[4]

R1 -2009 Q1(n)

(n) The maximum kinetic energy of photoelectrons ejected from a tungsten surface, by light of wavelength 248 nm, is 8.6×10^{-20} J. What is the work function, in eV, of tungsten?

[5]

R1 -2010 Q1(d)

(d) A camera, which has a lens of diameter of 2.0 cm, takes a photograph of a 100 W filament lamp from 100 m away. If 1.0 % of the energy is emitted as light and the exposure lasts 0.015 s, estimate the number of photons that strike the film, assuming all have a wavelength of 600 nm.

[5]

R1 -2010 Q1(h)

(h) A plane mirror rotates about a vertical axis in its plane at 35 revs s^{-1} and reflects a narrow beam of light to a stationary mirror 200 m away. This mirror reflects the light normally so that it is again reflected from the rotating mirror. The light now makes an angle of 2.0 minutes with the path it would travel if both mirrors were stationary. Calculate the velocity of light.

[3]

R1 -2011 Q1(e)

e) When the Sun is directly overhead a narrow shaft of light enters an ancient temple through a small hole in the ceiling and produces a light spot, 10m below, on the floor.

(i) At what speed does the spot move across the floor?
(ii) If a mirror is placed on the floor to reflect the beam, at what speed will the reflected spot move across the ceiling?

[4]

R1 -2011 Q1(g)

g) A thin film of glass, refractive index 1.52, and thickness 0.42 μm is viewed by reflection with white light at normal incidence. What *visible* wavelength is most strongly reflected?

[6]

R1 -2012 Q1(f)

(f) MM', Figure 1.f, is a plane mirror. A and B are points in front of the mirror and O is a variable point on the mirror. B' is the image of B in the mirror. Prove *geometrically* that:

(i) the paths AOB and AOB' are equal.
(ii) the path length of the ray reflected in the mirror has the minimum possible value of AOB.

[6]

R1 -2013 Q1(f)

(f) A lithium surface, with work function energy W = 3.7 x 10^{-19} J, is irradiated with photons of frequency f = 6.3 x 10^{14} Hz. The loss of photoelectrons from the surface causes the metal to acquire a positive potential, *V*. What will this potential be when the metal prevents the loss of further electrons?

[4]

R1 -2003 Q8(a) and 8(b)

a) A frequency band of electromagnetic radiation, such as present in white light, is transmitted through a medium. By observing the transmitted radiation, how can one conclude that the refractive index of the medium varies with wavelength? [2]

b)

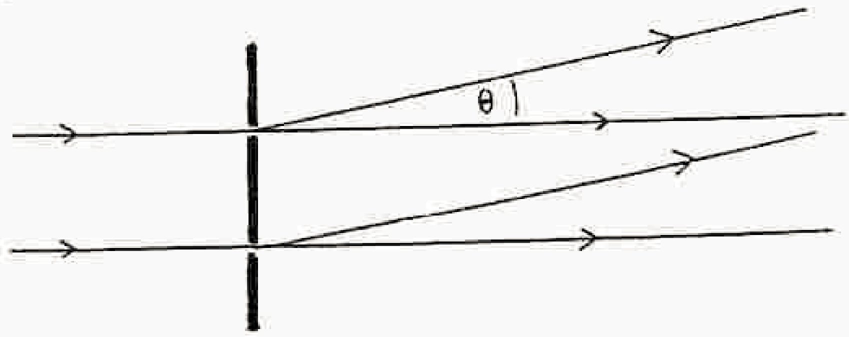


Figure 8.1

A laser beam, wavelength λ, impinges normally on two slits, a distance d apart, producing a diffracted beam at angle θ to the incident beam, Figure 8.1.

(i) What are the conditions for constructive and destructive interference?

(ii) Show that for the first order beam, where θ less than 0.1 radians, constructive interference occurs when $\theta = \lambda / d$.

(iii) How does the condition in (ii) alter if the system is in a medium of refractive index μ ? [6]

R1 -2005 Q5

a) Two identical insulating spheres, A and B radius a, have uniform charge density, each with a total negative charge $-Q$. Their centres are $6a$ apart. The origin of coordinates, O, is midway between the centres. The x – axis is along the line of centres.

(i) What is the electrostatic potential, V, at O?

(ii) At what points along the x – axis is the potential equal to that at O?

(iii) Sketch the electrostatic equipotential curve of magnitude V in the $x-y$ plane and show the spheres on your diagram. [7]

b) (i) Indicate, in a diagram, the point/s on the surface of B with the highest potential, V_H, and calculate its value.

(ii) What is the lowest potential "barrier", V_L, that has to be surmounted by a positively charged particle launched from B in order to reach A ?

(iii) What is the minimum speed with which a positive gas ion, mass m, and positive charge q, emitted from the surface of B, can be captured by A? [8]

c) Calculate the force acting on a particle with charge q, mass m, on the y – axis. [5]

R1 -2005 Q7

a) The relativistic energy E of an electron with momentum p is given by

$$E^2 = p^2c^2 + m_e^2c^4.$$

(i) What is understood by the rest energy of the electron?

(ii) Deduce an expression for the kinetic energy, T, of the electron.

[4]

b) A photon of frequency f is scattered through an angle of 90^0 by an initially stationary electron. After the collision the photon has a frequency f'. The electron acquires relativistic momentum p directed at an angle θ to the incident photon.

(i) Write down the conservation equations for this collision.

(ii) Prove that

$$c^2p^2 = h^2(f^2 + f'^2)$$

and

$$f' = \left(1 + \frac{hf}{m_ec^2}\right)^{-1} f.$$

[13]

Momentum of a photon, frequency f, is hf/c.

[3]

c) What can be deduced about f', θ and p when $hf << m_ec^2$?

Useful relationship: $\sin^2\theta + \cos^2\theta = 1.$

R1 -2008 Q6

In an experiment to investigate the photoelectric effect, light of wavelength λ is incident on a metal surface and a current is produced. The current is suppressed by supplying a potential difference V between the metal surface and the collecting plate.

(a) (i) Derive, with a full explanation, an equation relating λ, V and the work function, W, of the metal.

(ii) Why does the classical explanation of the photoelectric effect fail to explain the experimental results ?

[6]

(b) The results obtained in the experiment are given in Table 6.b.

V/V	λ /10^{-9} m
1.0	200
2.0	196
3.0	158
4.0	144

Table 6.b

(i) Verify graphically that the results follow the relationship derived in (a) (i).
(ii) Determine h and W from the graph, specifying their accuracy.
(iii) Obtain the threashold frequency, ν_0, for photoelectric emission.
(iv) What is the effect of doubling the incident light intensity ? [14]

R1 -2009 Q6

Q6

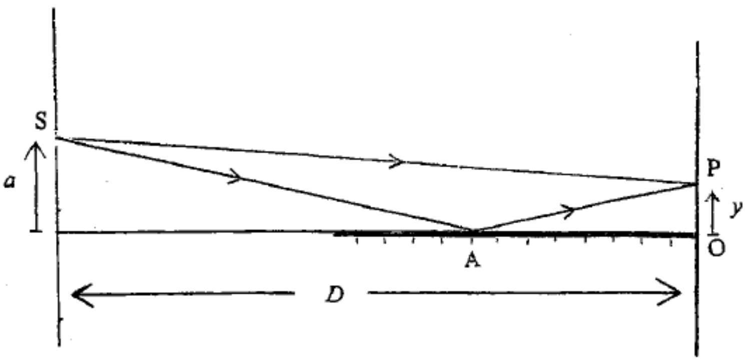


Figure 6.1

In an interference experiment a monochromatic point source of light, S, wavelength λ, produces interference fringes on a distant vertical screen, Figure 6.1. At point P on the screen the direct ray SP and the reflected ray, SAP, produced by a horizontal mirror that meets the screen at O, interfere. The distance OP = y and the source of light is a distance D from the screen . S is a vertical distance a from the horizontal line of the mirror. D is much larger than a.

(a)

(i) Explain why the reflected ray can be considered to come from the reflected image of S in the mirror.

(ii) Why is the interference pattern similar to that produced in a Young's double slit experiment ?

(iii) Explain the nature of the zero order fringe. [6]

(b)

(i) Using Pythagoras's theorem , determine the length of the two rays reaching P in terms of y, a and D . Deduce their path difference, p.

(ii) Using the approximation below , obtain a simplified expression for p.

(iii) Write down the conditions for constructive and destructive interference at P using the result obtained in (ii).

(iv) If one replaces the monochromatic source with a white light source, what is observed ?

[14]

$$[D^2 + x^2]^{1/2} = D[1 + (x/D)^2/2 + \dots] \quad \text{if } x \text{ is much smaller than } D.$$

R1 -2010 Q2

(a) A glass block measures 5.0 cm x 5.0 cm x 8.0 cm. When the block stands on one of its smaller faces, and viewed directly from above, it appears to be a cube. Determine the refractive index of the block.

[2]

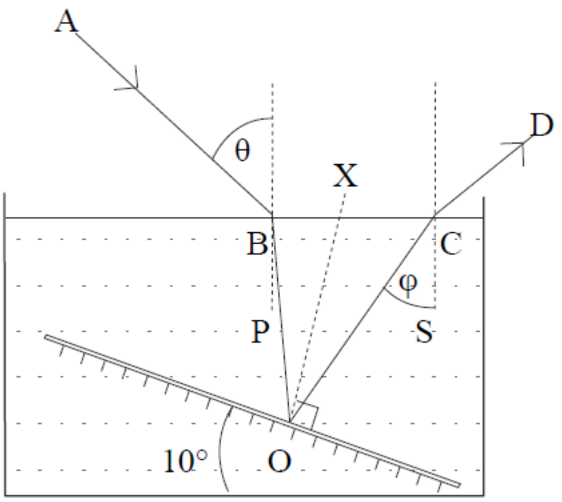


Figure 2.b

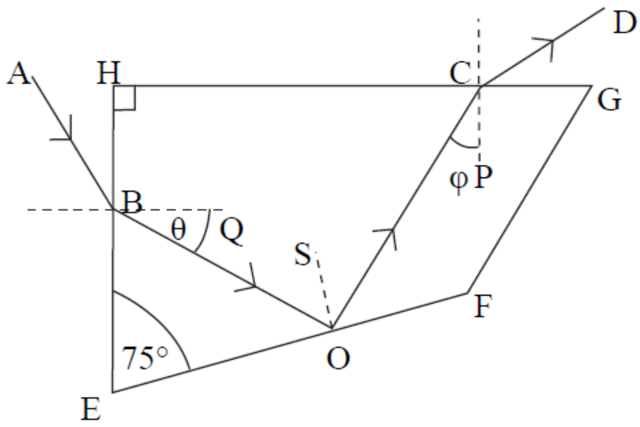


Figure 2.c

(b) A plane, inclined, mirror lies at the bottom of a long flat bottomed tank containing water. The mirror makes an angle of 10° with the horizontal, Figure 2.b. A narrow beam of monochromatic light falls on the surface of the water at an angle of incidence θ. If the refractive index of water is 4/3, determine the maximum value of θ for which light, after reflection from the mirror, would emerge from the upper surface of the water. The angle SCO is indicated by φ. OX is normal to the mirror.

[6]

(c) Figure 2.c shows the cross-section of a glass prism, refractive index *n*, with the angles indicated showing a light ray passing through it. OS is perpendicular to EF.

- (i) Express angle BOC in terms of θ.
- (ii) Determine the angle φ in terms of θ.
- (iii) For what value of θ is θ = φ ? What condition does this impose on *n* if total internal reflection occurs at O?
- (iv) What is the angle between the incident and emergent rays when θ = φ ?

[10]

(d) Why, at night, are the images of lights reflected from a river elongated?

[2]

R1 -2011 Q3(c)

c) A photon of wavelength λ has momentum p and energy E_λ .

(i) Determine the relation between p and E_λ .
An electric light bulb emits 20 W of radiation uniformly in all directions.

(ii) What is the maximum radiation pressure on a surface placed 2.0 m away from the bulb?

(iii) State the conditions under which this occurs.

[8]

R1 -2011 Q6

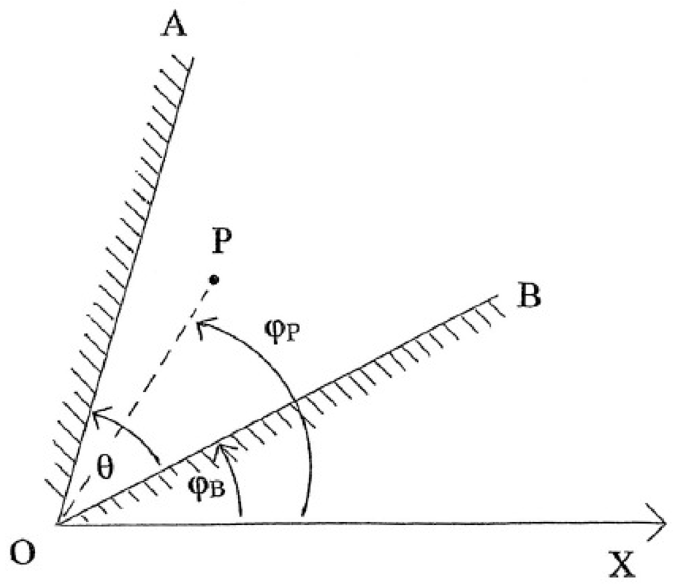


Figure 6.1

Two mirrors, OA and OB, (*Figure 6.1*), are rigidly set at a constant fixed angle θ, but can rotate about O. A fixed point P is situated between the mirrors. OP makes an angle φ_P with the fixed axis OX.

a) Draw , using graph paper , an accurate diagram showing two light rays from P that are first reflected from mirror OA and then reflected from mirror OB, indicating any real or virtual images, I_{AP} in mirror OA, and I_{BP} in mirror OB.

[6]

b) OB makes an angle φ_B with the fixed axis OX. If the mirrors are rotated, by changing φ_B , show:

(i) That P and the images of P remain at a fixed distance from O.
(ii) How the angle IAPOX varies with φB.
(iii)How the angle I_{BP}OX varies with φ_B , providing P remains within AOB.

[9]

c) Explain qualitatively how a rainbow is produced by spherical water droplets.

[5]

R1 -2011 Q7

a)

(i) Explain the photoelectric effect.
(ii) Derive a relation between the incident photon frequency, v, and the electron kinetic energy for a photocathode with work function φ.
(iii) How does the classical explanation of this phenomenon differ from the quantum explanation?
(iv) Sketch a graph of current, I, against voltage, V, from anode to cathode, for positive and negative V, in the presence of a constant beam of photons in a photoelectric experiment.
(v) How could one graphically determine φ from measurements of photon wavelength and electron velocity?

[12]

(b) In a photoelectric experiment the measurements of stopping potential, V_s, against frequency, f, were obtained and are contained in the table below.

V_s / V	0.60	1.0	1.4	1.8	2.2
f / 10^{14} Hz	6.0	7.0	8.0	9.0	10

Plot a graph and deduce:

(i) The threshold frequency f_0.
(ii) The value of h.

[8]

R1 -2012 Q5

A technician is measuring the quality of rectangular medical thin glass plates by looking at the interference of light between two plates. One plate has a straight length of wire, diameter 0.0050 cm, resting on it parallel to an edge at one end. Another identical glass plate is supported by the wire at one end, with the other end resting on the horizontal plate, forming an air wedge of angle θ. Interference fringes are produced by monochromatic light of wavelength λ, incident normally on the plates.

(a) Explain, with a diagram, how the interference arises assuming the incident and reflected light is normal to the horizontal plate, and derive the conditions for constructive and destructive interference when the air gap is of thickness t. If 200 fringes are observed across the glass plate, what is the wavelength λ of the light?

[6]

(b) What would be observed if white light replaced the monochromatic light? How would the conditions for monochromatic interference alter if a transparent liquid of refractive index μ replaced the air in the wedge?

[4]

(c) If you had an optically flat glass slide of thickness t and a similar one that was defective in this respect, containing areas with thickness less than t, how would you determine the extent of its deviation from an optical flat and produce a contour map of its surface deviation from a plane surface?

[4]

(d) If you were provided with two monochromatic sources, of different wavelengths, one of which was known, how could you determine the wavelength of the unknown source?

[6]

R1 -2013 Q5

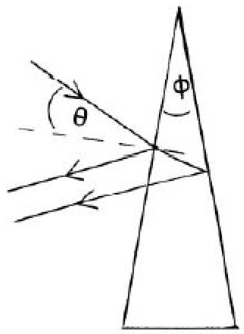


Figure 5.1

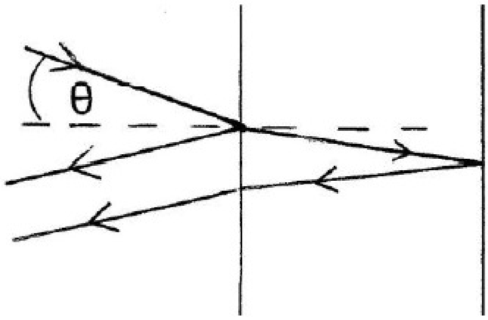


Figure 5.2

A soap film, with constant refractive index $\mu = 1.45$, is contained within a vertical rectangular wire frame and has a wedge shaped profile, small wedge angle ϕ, Figure 5.1. The film drains under gravity, being thicker at the bottom than at the top, where the thickness can be considered to be zero. The film is viewed, by reflection, with red and violet light at near normal incidence; the angle of incidence being exceedingly small. Interference results from light reflected from the outer surface and that emerging after reflection at the inner surface of the film. The optical path difference between the two rays can be determined, to a good approximation, by assuming the film is of constant thickness, t , in the region of these two reflections, Figure 5.2; t will increase with position down the film. The first violet, wavelength 420 nm, constructive interference band is observed at a distance $x_V = 3.0$ cm from the top edge of the film. The wavelength of the red light is 680 nm.

Determine:

(i) the thickness of the film at the lowest order constructive violet interference band, t_V.

[4]

(ii) the film wedge angle ϕ in degrees.

[3]

(iii) for the red light, the lowest order constructive interference film thickness, t_R, and distance, x_R from the top of the film.

(iv) The soap film drains so that the rate of change of decreases in angle by 8.3 x 10^{-5} degrees in one minute. Determine the initial speed, ($\Delta x_V/\Delta t$) , in cm per minute, of the observed violet interference fringe by considering a small time interval, Δt, in which ϕ changes by $\Delta\phi$ and x_V changes by Δx_V, by first showing

$$x_V\Delta\phi + \phi\Delta x_V = 0 \text{ , or otherwise.}$$

[10]

R1 -2013 Q8(a)

(a) A glass prism in the shape of a quarter- cylinder, Figure 8.a, radius R = 5.00 cm and refractive index μ = 1.50, lies on a horizontal table. A uniform horizontal beam of light is incident, from the left, on its vertical plane face.

(i) Where, beyond the cylinder, will the table be illuminated?

(ii) If the horizontal beam is incident from the right, *verify* that for angles of incidence, on the circular surface, greater than 83.27°, no light will emerge directly from the vertical face of the prism.

[10]

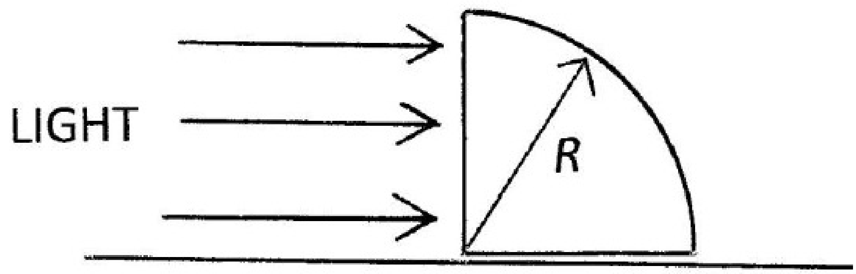


Figure 8.a