

ANSWERS

CHAPTER 9

- 9.1** $v = -54$ cm. The image is real, inverted and magnified. The size of the image is 5.0 cm. As $u \rightarrow f$, $v \rightarrow \infty$; for $u < f$, image is virtual.
- 9.2** $v = 6.7$ cm. Magnification = 5/9, i.e., the size of the image is 2.5 cm. As $u \rightarrow \infty$; $v \rightarrow f$ (but never beyond) while $m \rightarrow 0$.
- 9.3** 1.33; 1.7 cm
- 9.4** $n_{ga} = 1.51$; $n_{wa} = 1.32$; $n_{gw} = 1.144$; which gives $\sin r = 0.6181$ i.e., $r \approx 38^\circ$.
- 9.5** $r = 0.8 \times \tan i_c$ and $\sin i_c = 1/1.33 \approx 0.75$, where r is the radius (in m) of the largest circle from which light comes out and i_c is the critical angle for water-air interface, Area = 2.6 m^2
- 9.6** $n \approx 1.53$ and D_m for prism in water $\approx 10^\circ$
- 9.7** $R = 22$ cm
- 9.8** Here the object is virtual and the image is real. $u = +12$ cm (object on right; virtual)
- (a) $f = +20$ cm. Image is real and at 7.5 cm from the lens on its right side.
- (b) $f = -16$ cm. Image is real and at 48 cm from the lens on its right side.
- 9.9** $v = 8.4$ cm, image is erect and virtual. It is diminished to a size 1.8 cm. As $u \rightarrow \infty$, $v \rightarrow f$ (but never beyond f while $m \rightarrow 0$).
Note that when the object is placed at the focus of the concave lens (21 cm), the image is located at 10.5 cm (not at infinity as one might wrongly think).
- 9.10** A diverging lens of focal length 60 cm
- 9.11** (a) $v_e = -25$ cm and $f_e = 6.25$ cm give $u_e = -5$ cm; $v_o = (15 - 5) \text{ cm} = 10$ cm,
 $f_o = u_o = -2.5$ cm; Magnifying power = 20
- (b) $u_o = -2.59$ cm.
Magnifying power = 13.5.
- 9.12** Angular magnification of the eye-piece for image at 25 cm
 $= \frac{25}{2.5} + 1 = 11$; $|u_e| = \frac{25}{11} \text{ cm} = 2.27 \text{ cm}$; $v_o = 7.2 \text{ cm}$
Separation = 9.47 cm; Magnifying power = 88

- 9.13** 24; 150 cm
- 9.14** (a) Angular magnification = 1500
(b) Diameter of the image = 13.7 cm.
- 9.15** Apply mirror equation and the condition:
(a) $f < 0$ (concave mirror); $u < 0$ (object on left)
(b) $f > 0$; $u < 0$
(c) $f > 0$ (convex mirror) and $u < 0$
(d) $f < 0$ (concave mirror); $f < u < 0$
to deduce the desired result.
- 9.16** The pin appears raised by 5.0 cm. It can be seen with an explicit ray diagram that the answer is independent of the location of the slab (for small angles of incidence).
- 9.17** (a) $\sin i'_c = 1.44/1.68$ which gives $i'_c = 59^\circ$. Total internal reflection takes place when $i > 59^\circ$ or when $r < r_{\max} = 31^\circ$. Now, $(\sin i_{\max} / \sin r_{\max}) = 1.68$, which gives $i_{\max} \simeq 60^\circ$. Thus, all incident rays of angles in the range $0 < i < 60^\circ$ will suffer total internal reflections in the pipe. (If the length of the pipe is finite, which it is in practice, there will be a lower limit on i determined by the ratio of the diameter to the length of the pipe.)
(b) If there is no outer coating, $i'_c = \sin^{-1}(1/1.68) = 36.5^\circ$. Now, $i = 90^\circ$ will have $r = 36.5^\circ$ and $i' = 53.5^\circ$ which is greater than i'_c . Thus, all incident rays (in the range $53.5^\circ < i < 90^\circ$) will suffer total internal reflections.
- 9.18** (a) Rays converging to a point 'behind' a plane or convex mirror are reflected to a point in front of the mirror on a screen. In other words, a plane or convex mirror can produce a real image if the object is virtual. Convince yourself by drawing an appropriate ray diagram.
(b) When the reflected or refracted rays are divergent, the image is virtual. The divergent rays can be converged on to a screen by means of an appropriate converging lens. The convex lens of the eye does just that. The virtual image here serves as an object for the lens to produce a real image. Note, the screen here is not located at the position of the virtual image. There is no contradiction.
(c) Taller
(d) The apparent depth for oblique viewing decreases from its value for near-normal viewing. Convince yourself of this fact by drawing ray diagrams for different positions of the observer.
(e) Refractive index of a diamond is about 2.42, much larger than that of ordinary glass (about 1.5). The critical angle of diamond is about 24° , much less than that of glass. A skilled diamond-cutter exploits the larger range of angles of incidence (in the diamond), 24° to 90° , to ensure that light entering the diamond is totally reflected from many faces before getting out—thus producing a sparkling effect.
- 9.19** For fixed distance s between object and screen, the lens equation does not give a real solution for u or v if f is greater than $s/4$. Therefore, $f_{\max} = 0.75$ m.
- 9.20** 21.4 cm

- 9.21** (a) (i) Let a parallel beam be the incident from the left on the convex lens first.

$f_1 = 30$ cm and $u_1 = -\infty$, give $v_1 = +30$ cm. This image becomes a virtual object for the second lens.

$f_2 = -20$ cm, $u_2 = + (30 - 8)$ cm = $+22$ cm which gives, $v_2 = -220$ cm. The parallel incident beam appears to diverge from a point 216 cm from the centre of the two-lens system.

- (ii) Let the parallel beam be incident from the left on the concave lens first: $f_1 = -20$ cm, $u_1 = -\infty$, give $v_1 = -20$ cm. This image becomes a real object for the second lens: $f_2 = +30$ cm, $u_2 = - (20 + 8)$ cm = -28 cm which gives, $v_2 = -420$ cm. The parallel incident beam appears to diverge from a point 416 cm on the left of the centre of the two-lens system.

Clearly, the answer depends on which side of the lens system the parallel beam is incident. *Further we do not have a simple lens equation true for all u (and v) in terms of a definite constant of the system (the constant being determined by f_1 and f_2 , and the separation between the lenses). The notion of effective focal length, therefore, does not seem to be meaningful for this system.*

- (b) $u_1 = -40$ cm, $f_1 = 30$ cm, gives $v_1 = 120$ cm.

Magnitude of magnification due to the first (convex) lens is 3.
 $u_2 = + (120 - 8)$ cm = $+112$ cm (object virtual);

$$f_2 = -20 \text{ cm which gives } v_2 = -\frac{112 \times 20}{92} \text{ cm}$$

Magnitude of magnification due to the second (concave) lens = $20/92$.

Net magnitude of magnification = 0.652

Size of the image = 0.98 cm

- 9.22** If the refracted ray in the prism is incident on the second face at the critical angle i_c , the angle of refraction r at the first face is $(60^\circ - i_c)$.

$$\text{Now, } i_c = \sin^{-1} (1/1.524) \simeq 41^\circ$$

Therefore, $r = 19^\circ$

$$\sin i = 0.4962; i \simeq 30^\circ$$

- 9.23** (a) $\frac{1}{v} + \frac{1}{9} = \frac{1}{10}$

$$\text{i.e., } v = -90 \text{ cm,}$$

Magnitude of magnification = $90/9 = 10$.

Each square in the virtual image has an area $10 \times 10 \times 1 \text{ mm}^2$
 $= 100 \text{ mm}^2 = 1 \text{ cm}^2$

- (b) Magnifying power = $25/9 = 2.8$

- (c) No, magnification of an image by a lens and angular magnification (or magnifying power) of an optical instrument are two separate things. The latter is the ratio of the angular size of the object (which is equal to the angular size of the image even if the image is magnified) to the angular size of the object if placed at the near point (25 cm). Thus, magnification magnitude is $|v/u|$ and magnifying power is $(25/|u|)$. Only when the image is located at the near point $|v| = 25$ cm, are the two quantities equal.

- 9.24** (a) Maximum magnifying power is obtained when the image is at the near point (25 cm)
 $u = -7.14$ cm.
 (b) Magnitude of magnification = $(25 / |u|) = 3.5$.
 (c) Magnifying power = 3.5
 Yes, the magnifying power (when the image is produced at 25 cm) is equal to the magnitude of magnification.

9.25 Magnification = $\sqrt{(6.25 / 1)} = 2.5$

$$v = +2.5u$$

$$+\frac{1}{2.5u} - \frac{1}{u} = \frac{1}{10}$$

$$\text{i.e., } u = -6 \text{ cm}$$

$$|v| = 15 \text{ cm}$$

The virtual image is closer than the normal near point (25 cm) and cannot be seen by the eye distinctly.

- 9.26** (a) Even though the absolute image size is bigger than the object size, the angular size of the image is equal to the angular size of the object. The magnifier helps in the following way: without it object would be placed no closer than 25 cm; with it the object can be placed much closer. The closer object has larger angular size than the same object at 25 cm. It is in this sense that angular magnification is achieved.
 (b) Yes, it decreases a little because the angle subtended at the eye is then slightly less than the angle subtended at the lens. The effect is negligible if the image is at a very large distance away. [Note: When the eye is separated from the lens, the angles subtended at the eye by the first object and its image are not equal.]
 (c) First, grinding lens of very small focal length is not easy. More important, if you decrease focal length, aberrations (both spherical and chromatic) become more pronounced. So, in practice, you cannot get a magnifying power of more than 3 or so with a simple convex lens. However, using an aberration corrected lens system, one can increase this limit by a factor of 10 or so.
 (d) Angular magnification of eye-piece is $[(25/f_e) + 1]$ (f_e in cm) which increases if f_e is smaller. Further, magnification of the objective

$$\text{is given by } \frac{v_o}{|u_o|} = \frac{1}{(|u_o|/f_o) - 1}$$

which is large when $|u_o|$ is slightly greater than f_o . The microscope is used for viewing very close object. So $|u_o|$ is small, and so is f_o .

- (e) The image of the objective in the eye-piece is known as 'eye-ring'. All the rays from the object refracted by objective go through the eye-ring. Therefore, it is an ideal position for our eyes for viewing. If we place our eyes too close to the eye-piece, we shall not collect much of the light and also reduce our field of view. If we position

our eyes on the eye-ring and the area of the pupil of our eye is greater or equal to the area of the eye-ring, our eyes will collect all the light refracted by the objective. The precise location of the eye-ring naturally depends on the separation between the objective and the eye-piece. When you view through a microscope by placing your eyes on one end, the ideal distance between the eyes and eye-piece is usually built-in the design of the instrument.

- 9.27** Assume microscope in normal use i.e., image at 25 cm. Angular magnification of the eye-piece

$$= \frac{25}{5} + 1 = 6$$

Magnification of the objective

$$= \frac{30}{6} = 5$$

$$\frac{1}{5u_o} - \frac{1}{u_o} = \frac{1}{1.25}$$

which gives $u_o = -1.5$ cm; $v_o = 7.5$ cm. $|u_e| = (25/6)$ cm = 4.17 cm. The separation between the objective and the eye-piece should be $(7.5 + 4.17)$ cm = 11.67 cm. Further the object should be placed 1.5 cm from the objective to obtain the desired magnification.

- 9.28** (a) $m = (f_o/f_e) = 28$

(b) $m = \frac{f_o}{f_e} \left[1 + \frac{f_o}{25} \right] = 33.6$

- 9.29** (a) $f_o + f_e = 145$ cm

(b) Angle subtended by the tower = $(100/3000) = (1/30)$ rad.

Angle subtended by the image produced by the objective

$$= \frac{h}{f_o} = \frac{h}{140}$$

Equating the two, $h = 4.7$ cm.

(c) Magnification (magnitude) of the eye-piece = 6. Height of the final image (magnitude) = 28 cm.

- 9.30** The image formed by the larger (concave) mirror acts as virtual object for the smaller (convex) mirror. Parallel rays coming from the object at infinity will focus at a distance of 110 mm from the larger mirror. The distance of virtual object for the smaller mirror = $(110 - 20) = 90$ mm. The focal length of smaller mirror is 70 mm. Using the mirror formula, image is formed at 315 mm from the smaller mirror.

- 9.31** The reflected rays get deflected by twice the angle of rotation of the mirror. Therefore, $d/1.5 = \tan 7^\circ$. Hence $d = 18.4$ cm.

- 9.32** $n = 1.33$

CHAPTER 10

- 10.1** (a) Reflected light: (wavelength, frequency, speed same as incident light)

$$\lambda = 589 \text{ nm}, \nu = 5.09 \times 10^{14} \text{ Hz}, c = 3.00 \times 10^8 \text{ m s}^{-1}$$

- (b) Refracted light: (frequency same as the incident frequency)
 $\nu = 5.09 \times 10^{14} \text{ Hz}$
 $v = (c/n) = 2.26 \times 10^8 \text{ m s}^{-1}, \lambda = (v/\nu) = 444 \text{ nm}$

- 10.2** (a) Spherical
 (b) Plane
 (c) Plane (a small area on the surface of a large sphere is nearly planar).

- 10.3** (a) $2.0 \times 10^8 \text{ m s}^{-1}$
 (b) No. The refractive index, and hence the speed of light in a medium, depends on wavelength. [When no particular wavelength or colour of light is specified, we may take the given refractive index to refer to yellow colour.] Now we know violet colour deviates more than red in a glass prism, i.e. $n_v > n_r$. Therefore, the violet component of white light travels slower than the red component.

10.4 $\lambda = \frac{1.2 \times 10^{-2} \times 0.28 \times 10^{-3}}{4 \times 1.4} \text{ m} = 600 \text{ nm}$

10.5 $K/4$

10.6 (a) 1.17 mm (b) 1.56 mm

10.7 0.15°

10.8 $\tan^{-1}(1.5) \simeq 56.3^\circ$

10.9 $5000 \text{ \AA}, 6 \times 10^{14} \text{ Hz}; 45^\circ$

10.10 40 m

10.11 Use the formula $\lambda' - \lambda = \frac{v}{c} \lambda$

$$\text{i.e., } v = \frac{c}{\lambda} (\lambda' - \lambda) = \frac{3 \times 10^8 \times 15}{6563} = 6.86 \times 10^5 \text{ m s}^{-1}$$

- 10.12** In corpuscular (particle) picture of refraction, particles of light incident from a rarer to a denser medium experience a force of attraction normal to the surface. This results in an increase in the normal component of the velocity but the component along the surface is unchanged. This means

$$c \sin i = v \sin r \quad \text{or} \quad \frac{v}{c} = \frac{\sin i}{\sin r} = n. \text{ Since } n > 1, v > c.$$

The prediction is *opposite* to the experimental results ($v < c$). The wave picture of light is consistent with the experiment.

10.13 With the point object at the centre, draw a circle touching the mirror. This is a plane section of the spherical wavefront from the object that has just reached the mirror. Next draw the locations of this same wavefront after a time t in the presence of the mirror, and in the absence of the mirror. You will get two arcs symmetrically located on either side of the mirror. Using simple geometry, the centre of the reflected wavefront (the image of the object) is seen to be at the same distance from the mirror as the object.

10.14 (a) The speed of light in vacuum is a universal constant independent of all the factors listed and anything else. In particular, note the surprising fact that it is independent of the relative motion between the source and the observer. This fact is a basic axiom of Einstein's special theory of relativity.

(b) Dependence of the speed of light in a medium:

- (i) does not depend on the nature of the source (wave speed is determined by the properties of the medium of propagation. This is also true for other waves, e.g., sound waves, water waves, etc.).
- (ii) independent of the direction of propagation for *isotropic* media.
- (iii) independent of the motion of the source relative to the medium but depends on the motion of the observer relative to the medium.
- (iv) depends on wavelength.
- (v) independent of intensity. [For high intensity beams, however, the situation is more complicated and need not concern us here.]

10.15 Sound waves require a medium for propagation. Thus even though the situations (i) and (ii) may correspond to the same relative motion (between the source and the observer), they are not identical physically since the motion of the observer *relative to the medium* is different in the two situations. Therefore, we cannot expect Doppler formulas for sound to be identical for (i) and (ii). For light waves in vacuum, there is clearly nothing to distinguish between (i) and (ii). Here only the relative motion between the source and the observer counts and the relativistic Doppler formula is the same for (i) and (ii). For light propagation in a medium, once again like for sound waves, the two situations are *not* identical and we should expect the Doppler formulas for this case to be different for the two situations (i) and (ii).

10.16 3.4×10^{-4} m.

10.17 (a) The size reduces by half according to the relation: size $\sim \lambda/d$. Intensity increases four fold.

(b) The intensity of interference fringes in a double-slit arrangement is modulated by the diffraction pattern of each slit.

(c) Waves diffracted from the edge of the circular obstacle interfere constructively at the centre of the shadow producing a bright spot.

(d) For diffraction or bending of waves by obstacles/apertures by a large angle, the size of the latter should be comparable to wavelength. If the size of the obstacle/aperture is much too large compared to wavelength, diffraction is by a small angle. Here the size is of the order of a few metres. The wavelength of light is about 5×10^{-7} m, while sound waves of, say, 1 kHz frequency

have wavelength of about 0.3 m. Thus, sound waves can bend around the partition while light waves cannot.

- (e) Justification based on what is explained in (d). Typical sizes of apertures involved in ordinary optical instruments are much larger than the wavelength of light.

10.18 12.5 cm.

10.19 0.2 nm.

- 10.20** (a) Interference of the direct signal received by the antenna with the (weak) signal reflected by the passing aircraft.
 (b) Superposition principle follows from the linear character of the (differential) equation governing wave motion. If y_1 and y_2 are solutions of the wave equation, so is any linear combination of y_1 and y_2 . When the amplitudes are large (e.g., high intensity laser beams) and non-linear effects are important, the situation is far more complicated and need not concern us here.

- 10.21** Divide the single slit into n smaller slits of width $a' = a/n$. The angle $\theta = n\lambda/a = \lambda/a'$. Each of the smaller slits sends zero intensity in the direction θ . The combination gives zero intensity as well.

CHAPTER 11

11.1 (a) 7.24×10^{18} Hz (b) 0.041 nm

11.2 (a) $0.34 \text{ eV} = 0.54 \times 10^{-19} \text{ J}$ (b) 0.34 V (c) 344 km/s

11.3 $1.5 \text{ eV} = 2.4 \times 10^{-19} \text{ J}$

11.4 (a) $3.14 \times 10^{-19} \text{ J}$, $1.05 \times 10^{-27} \text{ kg m/s}$ (b) 3×10^{16} photons/s
 (c) 0.63 m/s

11.5 4×10^{21} photons/ $\text{m}^2 \text{ s}$

11.6 $6.59 \times 10^{-34} \text{ Js}$

11.7 (a) $3.38 \times 10^{-19} \text{ J} = 2.11 \text{ eV}$ (b) 3.0×10^{20} photons/s

11.8 2.0 V

11.9 No, because $v < v_0$

11.10 $4.73 \times 10^{14} \text{ Hz}$

11.11 $2.16 \text{ eV} = 3.46 \times 10^{-19} \text{ J}$

11.12 (a) $4.04 \times 10^{-24} \text{ kg m s}^{-1}$ (b) 0.164 nm

11.13 (a) $5.92 \times 10^{-24} \text{ kg m s}^{-1}$ (b) $6.50 \times 10^6 \text{ m s}^{-1}$ (c) 0.112 nm

11.14 (a) $6.95 \times 10^{-25} \text{ J} = 4.34 \text{ } \mu\text{eV}$ (b) $3.78 \times 10^{-28} \text{ J} = 0.236 \text{ neV}$

11.15 (a) $1.7 \times 10^{-35} \text{ m}$ (b) $1.1 \times 10^{-32} \text{ m}$ (c) $3.0 \times 10^{-23} \text{ m}$

11.16 (a) $6.63 \times 10^{-25} \text{ kg m/s}$ (for both) (b) 1.24 keV (c) 1.51 eV

11.17 (a) $6.686 \times 10^{-21} \text{ J} = 4.174 \times 10^{-2} \text{ eV}$ (b) 0.145 nm

11.18 $\lambda = h/p = h/(hv/c) = c/v$

11.19 0.028 nm

11.20 (a) Use $eV = (mv^2/2)$ i.e., $v = [(2eV/m)]^{1/2}$; $v = 1.33 \times 10^7 \text{ m s}^{-1}$.

- (b) If we use the same formula with $V = 10^7 \text{ V}$, we get $v = 1.88 \times 10^9 \text{ m s}^{-1}$. This is clearly wrong, since nothing can move with a speed greater than the speed of light ($c = 3 \times 10^8 \text{ m s}^{-1}$). Actually, the above formula for kinetic energy ($mv^2/2$) is valid only when $(v/c) \ll 1$. At very high speeds when (v/c) is comparable to (though always less than) 1, we come to the relativistic domain

where the following formulae are valid:

Relativistic momentum $p = m v$

Total energy $E = m c^2$

Kinetic energy $K = m c^2 - m_0 c^2$,

where the relativistic mass m is given by $m = m_0 \left(1 - \frac{v^2}{c^2}\right)^{-1/2}$

m_0 is called the rest mass of the particle. These relations also imply:

$$E = (p^2 c^2 + m_0^2 c^4)^{1/2}$$

Note that in the relativistic domain when v/c is comparable to 1, K or energy $\geq m_0 c^2$ (rest mass energy). The rest mass energy of electron is about 0.51 MeV. Thus a kinetic energy of 10 MeV, being much greater than electron's rest mass energy, implies relativistic domain. Using relativistic formulas, v (for 10 MeV kinetic energy) = $0.999 c$.

11.21 (a) 22.7 cm

(b) No. As explained above, a 20 MeV electron moves at relativistic speed. Consequently, the non-relativistic formula $R = (m_0 v / e B)$ is not valid. The relativistic formula is

$$R = p / e B = m v / e B \quad \text{or} \quad R = m_0 v / (e B \sqrt{1 - v^2 / c^2})$$

11.22 We have $e V = (m v^2 / 2)$ and $R = (m v / e B)$ which gives $(e / m) = (2V / R^2 B^2)$; using the given data $(e / m) = 1.73 \times 10^{11} \text{ C kg}^{-1}$.

11.23 (a) 27.6 keV (b) of the order of 30 kV

11.24 Use $\lambda = (hc / E)$ with $E = 5.1 \times 1.602 \times 10^{-10} \text{ J}$ to get $\lambda = 2.43 \times 10^{-16} \text{ m}$.

11.25 (a) For $\lambda = 500 \text{ m}$, $E = (h c / \lambda) = 3.98 \times 10^{-28} \text{ J}$. Number of photons emitted per second

$$= 10^4 \text{ J s}^{-1} / 3.98 \times 10^{-28} \text{ J} \simeq 3 \times 10^{31} \text{ s}^{-1}$$

We see that the energy of a radiophoton is exceedingly small, and the number of photons emitted per second in a radio beam is enormously large. There is, therefore, negligible error involved in ignoring the existence of a minimum quantum of energy (photon) and treating the total energy of a radio wave as continuous.

(b) For $\nu = 6 \times 10^{14} \text{ Hz}$, $E \simeq 4 \times 10^{-19} \text{ J}$. Photon flux corresponding to minimum intensity

$$= 10^{-10} \text{ W m}^{-2} / 4 \times 10^{-19} \text{ J} = 2.5 \times 10^8 \text{ m}^{-2} \text{ s}^{-1}$$

Number of photons entering the pupil per second = $2.5 \times 10^8 \times 0.4 \times 10^{-4} \text{ s}^{-1} = 10^4 \text{ s}^{-1}$. Though this number is not as large as in (a) above, it is large enough for us never to 'sense' or 'count' individual photons by our eye.

11.26 $\phi_0 = h \nu - e V_0 = 6.7 \times 10^{-19} \text{ J} = 4.2 \text{ eV}$; $\nu_0 = \frac{\phi_0}{h} = 1.0 \times 10^{15} \text{ Hz}$; $\lambda = 6328 \text{ \AA}$

corresponds to $\nu = 4.7 \times 10^{14} \text{ Hz} < \nu_0$. The photo-cell will not respond howsoever high be the intensity of laser light.

11.27 Use $e V_0 = h \nu - \phi_0$ for both sources. From the data on the first source, $\phi_0 = 1.40 \text{ eV}$. Use this value to obtain for the second source $V_0 = 1.50 \text{ V}$.

11.28 Obtain V_0 versus ν plot. The slope of the plot is (h/e) and its intercept on the ν -axis is ν_0 . The first four points lie nearly on a straight line which intercepts the ν -axis at $\nu_0 = 5.0 \times 10^{14}$ Hz (threshold frequency). The fifth point corresponds to $\nu < \nu_0$; there is no photoelectric emission and therefore no stopping voltage is required to stop the current. Slope of the plot is found to be 4.15×10^{-15} V s. Using $e = 1.6 \times 10^{-19}$ C, $h = 6.64 \times 10^{-34}$ J s (standard value $h = 6.626 \times 10^{-34}$ J s), $\phi_0 = h \nu_0 = 2.11$ V.

11.29 It is found that the given incident frequency ν is greater than ν_0 (Na), and ν_0 (K); but less than ν_0 (Mo), and ν_0 (Ni). Therefore, Mo and Ni will not give photoelectric emission. If the laser is brought closer, intensity of radiation increases, but this does not affect the result regarding Mo and Ni. However, photoelectric current from Na and K will increase in proportion to intensity.

11.30 Assume one conduction electron per atom. Effective atomic area $\sim 10^{-20} \text{ m}^2$

Number of electrons in 5 layers

$$= \frac{5 \times 2 \times 10^{-4} \text{ m}^2}{10^{-20} \text{ m}^2} = 10^{17}$$

Incident power

$$= 10^{-5} \text{ W m}^{-2} \times 2 \times 10^{-4} \text{ m}^2 = 2 \times 10^{-9} \text{ W}$$

In the wave picture, incident power is uniformly absorbed by all the electrons continuously. Consequently, energy absorbed per second per electron

$$= 2 \times 10^{-9} / 10^{17} = 2 \times 10^{-26} \text{ W}$$

Time required for photoelectric emission

$$= 2 \times 1.6 \times 10^{-19} \text{ J} / 2 \times 10^{-26} \text{ W} = 1.6 \times 10^7 \text{ s}$$

which is about 0.5 year.

Implication: Experimentally, photoelectric emission is observed nearly instantaneously ($\sim 10^{-9}$ s): Thus, the wave picture is in gross disagreement with experiment. In the photon-picture, energy of the radiation is not continuously shared by all the electrons in the top layers. Rather, energy comes in discontinuous 'quanta'. and absorption of energy does not take place gradually. A photon is either not absorbed, or absorbed by an electron nearly instantly.

11.31 For $\lambda = 1 \text{ \AA}$, electron's energy = 150 eV; photon's energy = 12.4 keV. Thus, for the same wavelength, a photon has much greater energy than an electron.

11.32 (a) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2 m K}}$ Thus, for same K , λ decreases with m as $(1/\sqrt{m})$. Now $(m_n/m_e) = 1838.6$; therefore for the same energy, (150 eV) as in Ex. 11.31, wavelength of neutron = $(1/\sqrt{1838.6}) \times 10^{-10} \text{ m} = 2.33 \times 10^{-12} \text{ m}$. The interatomic spacing is about a hundred times greater. A neutron beam of 150 eV energy is therefore not suitable for diffraction experiments.

(b) $\lambda = 1.45 \times 10^{-10} \text{ m}$ [Use $\lambda = (h / \sqrt{3 m k T})$] which is comparable to interatomic spacing in a crystal.

Clearly, from (a) and (b) above, thermal neutrons are a suitable probe for diffraction experiments; so a high energy neutron beam should be first thermalised before using it for diffraction.

11.33 $\lambda = 5.5 \times 10^{-12} \text{ m}$

λ (yellow light) $= 5.9 \times 10^{-7} \text{ m}$

Resolving Power (RP) is inversely proportional to wavelength. Thus, RP of an electron microscope is about 10^5 times that of an optical microscope. In practice, differences in other (geometrical) factors can change this comparison somewhat.

$$\mathbf{11.34} \quad p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34} \text{ Js}}{10^{-15} \text{ m}} = 6.63 \times 10^{-19} \text{ kg m s}^{-1}$$

Use the relativistic formula for energy:

$$E^2 = c^2 p^2 + m_0^2 c^4 = 9 \times (6.63)^2 \times 10^{-22} + (0.511 \times 1.6)^2 \times 10^{-26} \\ \approx 9 \times (6.63)^2 \times 10^{-22},$$

the second term (rest mass energy) being negligible.

Therefore, $E = 1.989 \times 10^{-10} \text{ J} = 1.24 \text{ BeV}$. Thus, electron energies from the accelerator must have been of the order of a few BeV.

$$\mathbf{11.35} \quad \text{Use } \lambda = \frac{h}{\sqrt{3 m k T}} ; m_{\text{te}} = \frac{4 \times 10^3}{6 \times 10^{23}} \text{ kg}$$

This gives $\lambda = 0.73 \times 10^{-10} \text{ m}$. Mean separation

$$r = (V/N)^{1/3} = (kT/p)^{1/3}$$

For $T = 300 \text{ K}$, $p = 1.01 \times 10^5 \text{ Pa}$, $r = 3.4 \times 10^{-9} \text{ m}$. We find $r \gg \lambda$.

11.36 Using the same formula as in Exercise 11.35, $\lambda = 6.2 \times 10^{-9} \text{ m}$ which is much greater than the given inter-electron separation.

11.37 (a) Quarks are thought to be confined within a proton or neutron by forces which grow stronger if one tries to pull them apart. It, therefore, seems that though fractional charges may exist in nature, observable charges are still integral multiples of e .

(b) Both the basic relations $eV = (1/2) m v^2$ or $eE = m a$ and $eBv = m v^2/r$, for electric and magnetic fields, respectively, show that the dynamics of electrons is determined not by e , and m separately but by the combination e/m .

(c) At low pressures, ions have a chance to reach their respective electrodes and constitute a current. At ordinary pressures, ions have no chance to do so because of collisions with gas molecules and recombination.

(d) Work function merely indicates the minimum energy required for the electron in the highest level of the conduction band to get out of the metal. Not all electrons in the metal belong to this level. They occupy a continuous band of levels. Consequently, for the same incident radiation, electrons knocked off from different levels come out with different energies.

(e) The absolute value of energy E (but not momentum p) of any particle is arbitrary to within an additive constant. Hence, while λ is physically significant, absolute value of v of a matter wave of an electron has no direct physical meaning. The phase speed $v\lambda$

is likewise not physically significant. The group speed given by

$$\frac{dv}{d(1/\lambda)} = \frac{dE}{dp} = \frac{d}{dp} \left(\frac{p^2}{2m} \right) = \frac{p}{m}$$

is physically meaningful.

CHAPTER 12

- 12.1** (a) No different from
 (b) Thomson's model; Rutherford's model
 (c) Rutherford's model
 (d) Thomson's model; Rutherford's model
 (e) Both the models
- 12.2** The nucleus of a hydrogen atom is a proton. The mass of it is 1.67×10^{-27} kg, whereas the mass of an incident α -particle is 6.64×10^{-27} kg. Because the scattering particle is more massive than the target nuclei (proton), the α -particle won't bounce back in even in a head-on collision. It is similar to a football colliding with a tennis ball at rest. Thus, there would be no large-angle scattering.
- 12.3** 820 nm.
- 12.4** 5.6×10^{14} Hz
- 12.5** 13.6 eV; -27.2 eV
- 12.6** 9.7×10^{-8} m; 3.1×10^{15} Hz.
- 12.7** (a) 2.18×10^6 m/s; 1.09×10^6 m/s; 7.27×10^5 m/s
 (b) 1.52×10^{-16} s; 1.22×10^{-15} s; 4.11×10^{-15} s.
- 12.8** 2.12×10^{-10} m; 4.77×10^{-10} m
- 12.9** Lyman series: 103 nm and 122 nm; Balmer series: 656 nm.
- 12.10** 2.6×10^{74}
- 12.11** (a) About the same.
 (b) Much less.
 (c) It suggests that the scattering is predominantly due to a single collision, because the chance of a single collision increases linearly with the number of target atoms, and hence linearly with thickness.
 (d) In Thomson's model, a single collision causes very little deflection. The observed average scattering angle can be explained only by considering multiple scattering. So it is wrong to ignore multiple scattering in Thomson's model. In Rutherford's model, most of the scattering comes through a single collision and multiple scattering effects can be ignored as a first approximation.
- 12.12** The first orbit Bohr's model has a radius a_0 given by $a_0 = \frac{4\pi\epsilon_0(h/2\pi)^2}{m_e e^2}$. If we consider the atom bound by the gravitational force ($Gm_p m_e / r^2$), we should replace ($e^2 / 4\pi\epsilon_0$) by $Gm_p m_e$. That is, the radius of the first Bohr orbit is given by $a_0^G = \frac{(h/2\pi)^2}{Gm_p m_e^2} \cong 1.2 \times 10^{29}$ m.

This is much greater than the estimated size of the whole universe!

$$12.13 \quad v = \frac{me^4}{(4\pi)^3 \epsilon_0^2 (h/2\pi)^3} \left[\frac{1}{(n-1)^2} - \frac{1}{n^2} \right] = \frac{me^4(2n-1)}{(4\pi)^3 \epsilon_0^2 (h/2\pi)^3 n^2 (n-1)^2}$$

For large n , $v \cong \frac{me^4}{32\pi^3 \epsilon_0^2 (h/2\pi)^3 n^3}$

Orbital frequency $\nu_c = (v/2\pi r)$. In Bohr model $v = \frac{n(h/2\pi)}{mr}$, and

$$r = \frac{4\pi\epsilon_0(h/2\pi)^2}{me^2} n^2. \text{ This gives } \nu_c = \frac{n(h/2\pi)}{2\pi mr^2} = \frac{me^4}{32\pi^3 \epsilon_0^2 (h/2\pi)^3 n^3}$$

which is same as ν for large n .

12.14 (a) The quantity $\left(\frac{e^2}{4\pi\epsilon_0 mc^2} \right)$ has the dimensions of length. Its value is $2.82 \times 10^{-15} \text{ m}$ – much smaller than the typical atomic size.

(b) The quantity $\frac{4\pi\epsilon_0(h/2\pi)^2}{me^2}$ has the dimensions of length. Its value is $0.53 \times 10^{-10} \text{ m}$ – of the order of atomic sizes. (Note that the dimensional arguments cannot, of course, tell us that we should use 4π and $h/2\pi$ in place of h to arrive at the right size.)

12.15 In Bohr's model, $mvr = \frac{nh}{2\pi}$ and $\frac{mv^2}{r} = \frac{Ze^2}{4\pi\epsilon_0 r^2}$

which give

$$T = \frac{1}{2}mv^2 = \frac{Ze^2}{8\pi\epsilon_0 r} ; r = \frac{4\pi\epsilon_0 h^2}{Ze^2 m} n^2$$

These relations have nothing to do with the choice of the zero of potential energy. Now, choosing the zero of potential energy at infinity we have $V = -(Ze^2/4\pi\epsilon_0 r)$ which gives $V = -2T$ and $E = T + V = -T$

(a) The quoted value of $E = -3.4 \text{ eV}$ is based on the customary choice of zero of potential energy at infinity. Using $E = -T$, the kinetic energy of the electron in this state is $+3.4 \text{ eV}$.

(b) Using $V = -2T$, potential energy of the electron is $= -6.8 \text{ eV}$

(c) If the zero of potential energy is chosen differently, kinetic energy does not change. Its value is $+3.4 \text{ eV}$ independent of the choice of the zero of potential energy. The potential energy, and the total energy of the state, however, would alter if a different zero of the potential energy is chosen.

12.16 Angular momenta associated with planetary motion are incomparably large relative to h . For example, angular momentum of the earth in its orbital motion is of the order of $10^{70}h$. In terms of the Bohr's quantisation postulate, this corresponds to a very large value of n (of the order of 10^{70}). For such large values of n , the differences in the successive energies and angular momenta of the quantised levels of the Bohr model are so small compared to the energies and angular momenta respectively for the levels that one can, for all practical purposes, consider the levels continuous.

- 12.17** All that is needed is to replace m_e by m_μ in the formulas of the Bohr model. We note that keeping other factors fixed, $r \propto (1/m)$ and $E \propto m$. Therefore,

$$r_\mu = \frac{r_e m_e}{m_\mu} = \frac{0.53 \times 10^{-13}}{207} = 2.56 \times 10^{-13} \text{ m}$$

$$E_\mu = \frac{E_e m_\mu}{m_e} = -(13.6 \times 207) \text{ eV} \cong -2.8 \text{ keV}$$

CHAPTER 13

- 13.1** (a) 6.941 u (b) 19.9%, 80.1%

- 13.2** 20.18 u

- 13.3** 104.7 MeV

- 13.4** 8.79 MeV, 7.84 MeV

- 13.5** 1.584×10^{25} MeV or 2.535×10^{12} J

- 13.6** i) ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\text{He}$ ii) ${}^{242}_{94}\text{Pu} \rightarrow {}^{238}_{92}\text{U} + {}^4_2\text{He}$

- iii) ${}^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + e^- + \bar{\nu}$ iv) ${}^{210}_{83}\text{B} \rightarrow {}^{210}_{84}\text{Po} + e^- + \bar{\nu}$

- v) ${}^{11}_6\text{C} \rightarrow {}^{11}_5\text{B} + e^+ + \nu$ vi) ${}^{97}_{43}\text{Tc} \rightarrow {}^{97}_{42}\text{Mo} + e^+ + \nu$

- vii) ${}^{120}_{54}\text{Xe} + e^- \rightarrow {}^{120}_{53}\text{I} + \nu$

- 13.7** (a) 5 T years (b) 6.65 T years

- 13.8** 4224 years

- 13.9** 7.126×10^{-6} g

- 13.10** 7.877×10^{10} Bq or 2.13 Ci

- 13.11** 1.23

- 13.12** (a) $Q = 4.93 \text{ MeV}$, $E_\alpha = 4.85 \text{ MeV}$ (b) $Q = 6.41 \text{ MeV}$, $E_\alpha = 6.29 \text{ MeV}$

- 13.13** ${}^{11}_6\text{C} \rightarrow {}^{11}_5\text{B} + e^+ + \nu + Q$

$$Q = [m_N({}^{11}_6\text{C}) - m_N({}^{11}_5\text{B}) - m_e]c^2,$$

where the masses used are those of nuclei and not of atoms. If we use atomic masses, we have to add $6m_e$ in case of ${}^{11}_6\text{C}$ and $5m_e$ in case of ${}^{11}_5\text{B}$. Hence

$$Q = [m({}^{11}_6\text{C}) - m({}^{11}_5\text{B}) - 2m_e]c^2 \quad (\text{Note } m_e \text{ has been doubled})$$

Using given masses, $Q = 0.961 \text{ MeV}$.

$$Q = E_d + E_e + E_\nu$$

The daughter nucleus is too heavy compared to e^+ and ν , so it carries negligible energy ($E_d \approx 0$). If the kinetic energy (E_ν) carried by the neutrino is minimum (i.e., zero), the positron carries maximum energy, and this is practically all energy Q ; hence maximum $E_e \approx Q$.

- 13.14** ${}^{23}_{10}\text{Ne} \rightarrow {}^{23}_{11}\text{Na} + e^- + \bar{\nu} + Q$; $Q = [m_N({}^{23}_{10}\text{Ne}) - m_N({}^{23}_{11}\text{Na}) - m_e]c^2$, where the masses used are masses of nuclei and not of atoms as in Exercise

13.13. Using atomic masses $Q = [m({}^{23}_{10}\text{Ne}) - m({}^{23}_{11}\text{Na})]c^2$. Note m_e has

been cancelled. Using given masses, $Q = 4.37$ MeV. As in Exercise 13.13, maximum kinetic energy of the electron ($\max E_e$) = $Q = 4.37$ MeV.

13.15 (i) $Q = -4.03$ MeV; endothermic

(ii) $Q = 4.62$ MeV; exothermic

13.16 $Q = m(^{56}_{26}\text{Fe}) - 2m(^{28}_{13}\text{Al}) = 26.90$ MeV; not possible.

13.17 4.536×10^{26} MeV

13.18 Energy generated per gram of $^{235}_{92}\text{U} = \frac{6 \times 10^{23} \times 200 \times 1.6 \times 10^{-13}}{235} \text{ J g}^{-1}$

The amount of $^{235}_{92}\text{U}$ consumed in 5y with 80% on-time

$$= \frac{5 \times 0.8 \times 3.154 \times 10^{16} \times 235}{1.2 \times 1.6 \times 10^{13}} \text{ g} = 1544 \text{ kg}$$

The initial amount of $^{235}_{92}\text{U} = 3088$ kg.

13.19 About 4.9×10^4 y

13.20 360 KeV

13.22 Consider the competing processes:



$$\begin{aligned} Q_1 &= [m_N(^A_Z\text{X}) - m_N(^A_{Z-1}\text{Y}) - m_e]c^2 \\ &= [m(^A_Z\text{X}) - Zm_e - m(^A_{Z-1}\text{Y}) - (Z-1)m_e - m_e]c^2 \\ &= [m(^A_Z\text{X}) - m(^A_{Z-1}\text{Y}) - 2m_e]c^2 \end{aligned}$$

$$Q_2 = [m_N(^A_Z\text{X}) + m_e - m_N(^A_{Z-1}\text{Y})]c^2 = [m(^A_Z\text{X}) - m(^A_{Z-1}\text{Y})]c^2$$

This means $Q_1 > 0$ implies $Q_2 > 0$ but $Q_2 > 0$ does not necessarily mean $Q_1 > 0$. Hence the result.

13.23 $^{25}_{12}\text{Mg} : 9.3\%$, $^{26}_{12}\text{Mg} : 11.7\%$

13.24 Neutron separation energy S_n of a nucleus ^A_ZX is

$$S_n = [m_N(^{A-1}_Z\text{X}) + m_n - m_N(^A_Z\text{X})]c^2$$

From given data, $S_n(^{41}_{20}\text{Ca}) = 8.36$ MeV, $S_n(^{27}_{13}\text{Al}) = 13.06$ MeV

13.25 209 d

13.26 For $^{14}_6\text{C}$ emission

$$\begin{aligned} Q &= [m_N(^{223}_{88}\text{Ra}) - m_N(^{209}_{82}\text{Pb}) - m(^{14}_6\text{C})]c^2 \\ &= [m(^{223}_{88}\text{Ra}) - m(^{209}_{82}\text{Pb}) - m(^{14}_6\text{C})]c^2 = 31.85 \text{ MeV} \end{aligned}$$

For ^4_2He emission, $Q = [m(^{223}_{88}\text{Ra}) - m(^{219}_{86}\text{Rn}) - m(^4_2\text{He})]c^2 = 5.98$ MeV

13.27 $Q = [m(^{238}_{92}\text{U}) + m_n - m(^{140}_{58}\text{Ce}) - m(^{99}_{44}\text{Ru})]c^2 = 231.1$ MeV

- 13.28** (a) $Q = [m({}_1^2\text{H}) + m({}_1^3\text{H}) - m({}_2^4\text{He}) - m_n]c^2 = 17.59 \text{ MeV}$
 (b) K.E. required to overcome Coulomb repulsion = 480.0 keV
 $480.0 \text{ KeV} = 7.68 \times 10^{-14} \text{ J} = 3kT$
 $\therefore T = \frac{7.68 \times 10^{-14}}{3 \times 1.381 \times 10^{-23}} \quad (\text{as } k = 1.381 \times 10^{-23} \text{ J K}^{-1})$
 $= 1.85 \times 10^9 \text{ K (required temperature)}$
- 13.29** $K_{\max}(\beta_1^-) = 0.284 \text{ MeV}$, $K_{\max}(\beta_2^-) = 0.960 \text{ MeV}$
 $\nu(\gamma_1) = 2.627 \times 10^{20} \text{ Hz}$, $\nu(\gamma_2) = 0.995 \times 10^{20} \text{ Hz}$, $\nu(\gamma_3) = 1.632 \times 10^{20} \text{ Hz}$
- 13.30** (a) Note that in the interior of Sun, four ${}_1^1\text{H}$ nuclei combine to form one ${}_2^4\text{He}$ nucleus releasing about 26 MeV of energy per event.
 Energy released in fusion of 1kg of hydrogen = $39 \times 10^{26} \text{ MeV}$
 (b) Energy released in fission of 1kg of ${}_{92}^{235}\text{U} = 5.1 \times 10^{26} \text{ MeV}$
 The energy released in fusion of 1 kg of hydrogen is about 8 times that of the energy released in the fission of 1 kg of uranium.
- 13.31** $3.076 \times 10^4 \text{ kg}$

CHAPTER 14

- 14.1** (c)
14.2 (d)
14.3 (c)
14.4 (c)
14.5 (c)
14.6 50 Hz for half-wave, 100 Hz for full-wave
14.7 No ($h\nu$ has to be greater than E_g).
14.8 $n_e \approx 4.95 \times 10^{22}$; $n_h = 4.75 \times 10^9$; n-type since $n_e \gg n_h$
 For charge neutrality $N_D - N_A = n_e - n_h$; $n_e \cdot n_h = n_i^2$
 Solving these equations, $n_e = \frac{1}{2} \left[(N_D - N_A) + \sqrt{(N_D - N_A)^2 + 4n_i^2} \right]$
- 14.9** About 1×10^5
14.10 (a) 0.0629 A, (b) 2.97 A, (c) 0.336 Ω
 (d) For both the voltages, the current I will be almost equal to I_0 , showing almost infinite dynamic resistance in the reverse bias.
- 14.12** NOT ; A Y
 0 1
 1 0
- 14.13** (a) AND (b) OR
14.14 OR gate
14.15 (a) NOT, (b) AND

BIBLIOGRAPHY

TEXTBOOKS

For additional reading on the topics covered in this book, you may like to consult one or more of the following books. Some of these books however are more advanced and contain many more topics than this book.

- 1 **Ordinary Level Physics**, A.F. Abbott, Arnold-Heinemann (1984).
- 2 **Advanced Level Physics**, M. Nelkon and P. Parker, 6th Edition, Arnold-Heinemann (1987).
- 3 **Advanced Physics**, Tom Duncan, John Murray (2000).
- 4 **Fundamentals of Physics**, David Halliday, Robert Resnick and Jearl Walker, 7th Edition John Wiley (2004).
- 5 **University Physics** (Sears and Zemansky's), H.D. Young and R.A. Freedman, 11th Edition, Addison—Wesley (2004).
- 6 **Problems in Elementary Physics**, B. Bukhovtsova, V. Krivchenkov, G. Myakishev and V. Shalnov, MIR Publishers, (1971).
- 7 **Lectures on Physics** (3 volumes), R.P. Feynman, Addison – Wesley (1965).
- 8 **Berkeley Physics Course** (5 volumes) McGraw Hill (1965).
 - a. Vol. 1 – Mechanics: (Kittel, Knight and Ruderman)
 - b. Vol. 2 – Electricity and Magnetism (E.M. Purcell)
 - c. Vol. 3 – Waves and Oscillations (Frank S. Crawford)
 - d. Vol. 4 – Quantum Physics (Wichmann)
 - e. Vol. 5 – Statistical Physics (F. Reif)
- 9 **Fundamental University Physics**, M. Alonso and E. J. Finn, Addison – Wesley (1967).
- 10 **College Physics**, R.L. Weber, K.V. Manning, M.W. White and G.A. Weygand, Tata McGraw Hill (1977).
- 11 **Physics: Foundations and Frontiers**, G. Gamow and J.M. Cleveland, Tata McGraw Hill (1978).
- 12 **Physics for the Inquiring Mind**, E.M. Rogers, Princeton University Press (1960).
- 13 **PSSC Physics Course**, DC Heath and Co. (1965) Indian Edition, NCERT (1967).
- 14 **Physics Advanced Level**, Jim Breithampt, Stanley Thornes Publishers (2000).
- 15 **Physics**, Patrick Fullick, Heinemann (2000).
- 16 **Conceptual Physics**, Paul G. Hewitt, Addison—Wesley (1998).
- 17 **College Physics**, Raymond A. Serway and Jerry S. Faughn, Harcourt Brace and Co. (1999).
- 18 **University Physics**, Harris Benson, John Wiley (1996).
- 19 **University Physics**, William P. Crummet and Arthur B. Western, Wm.C. Brown (1994).
- 20 **General Physics**, Morton M. Sternheim and Joseph W. Kane, John Wiley (1988).
- 21 **Physics**, Hans C. Ohanian, W.W. Norton (1989).

- 22 Advanced Physics**, Keith Gibbs, Cambridge University Press (1996).
- 23 Understanding Basic Mechanics**, F. Reif, John Wiley (1995).
- 24 College Physics**, Jerry D. Wilson and Anthony J. Buffa, Prentice Hall (1997).
- 25 Senior Physics, Part – I**, I.K. Kikoin and A.K. Kikoin, MIR Publishers (1987).
- 26 Senior Physics, Part – II**, B. Bekhovtsev, MIR Publishers (1988).
- 27 Understanding Physics**, K. Cummings, Patrick J. Cooney, Priscilla W. Laws and Edward F. Redish, John Wiley (2005).
- 28 Essentials of Physics**, John D. Cutnell and Kenneth W. Johnson, John Wiley (2005).

GENERAL BOOKS

For instructive and entertaining general reading on science, you may like to read some of the following books. Remember however, that many of these books are written at a level far beyond the level of the present book.

- 1 Mr. Tompkins** in paperback, G. Gamow, Cambridge University Press (1967).
- 2 The Universe and Dr. Einstein**, C. Barnett, Time Inc. New York (1962).
- 3 Thirty years that Shook Physics**, G. Gamow, Double Day, New York (1966).
- 4 Surely You're Joking, Mr. Feynman**, R.P. Feynman, Bantam books (1986).
- 5 One, Two, Three... Infinity**, G. Gamow, Viking Inc. (1961).
- 6 The Meaning of Relativity**, A. Einstein, (Indian Edition) Oxford and IBH Pub. Co. (1965).
- 7 Atomic Theory and the Description of Nature**, Niels Bohr, Cambridge (1934).
- 8 The Physical Principles of Quantum Theory**, W. Heisenberg, University of Chicago Press (1930).
- 9 The Physics—Astronomy Frontier**, F. Hoyle and J.V. Narlikar, W.H. Freeman (1980).
- 10 The Flying Circus of Physics with Answer**, J. Walker, John Wiley and Sons (1977).
- 11 Physics for Everyone** (series), L.D. Landau and A.I. Kitaigorodski, MIR Publisher (1978).
 - Book 1: Physical Bodies
 - Book 2: Molecules
 - Book 3: Electrons
 - Book 4: Photons and Nuclei.
- 12 Physics can be Fun**, Y. Perelman, MIR Publishers (1986).
- 13 Power of Ten**, Philip Morrison and Eames, W.H. Freeman (1985).
- 14 Physics in your Kitchen Lab.**, I.K. Kikoin, MIR Publishers (1985).
- 15 How Things Work: The Physics of Everyday Life**, Louis A. Bloomfield, John Wiley (2005).
- 16 Physics Matters: An Introduction to Conceptual Physics**, James Trefil and Robert M. Hazen, John Wiley (2004).

INDEX

Absorption spectra	421	Biot-Savart law	143
AC current	233	Bohr magneton	163
AC Generator	224	Bohr radius	425
AC voltage	233	Bohr's model of atom	422
applied to a capacitor	241	Bohr's postulates	424
applied to a resistor	234	Brewster's angle	380
applied to an inductor	237	Brewster's law	381
applied to a series LCR circuit	244	C.A. Volta	53
Accelerators in India	142	Capacitance	73
Activity of radioactive substances	447	Capacitive reactance	241
Additivity of charges	8	Capacitive circuit	252
Alpha decay	449	Capacitor	
Alpha particle scattering	415	parallel plate	74
Ammeter	165	in parallel	79
Ampere	155	in series	78
Amperes circuital law	147	Cartesian sign convention	311
Analog signal	491	Cassegrain telescope	341
AND gate	492	Cells	110
Andre, Ampere	148	in parallel	114
Angle		in series	113
of deviation	330	Chain reaction	453
of incidence	355	Charging by induction	6
of reflection	357	Charles August de Coulomb	11
of refraction	355	Chromatic aberration	332
Angular magnification	339	Coercivity	195
Apparent depth	318	Coherent source	360
Area element vector	26	Colour code of resistors	103
Atomic		Combination of lenses	328
mass unit	439	Combination of resistors	
number	440	series	107
spectra	420	parallel	108
Aurora Borealis	139	Composition of nucleus	438
Band gap	471	Concave mirror	312
Bar magnet	174	Conduction band	469
as solenoid	176	Conductivity	97, 468
Barrier potential	479	Conductors	5
Becquerel	448	Conservation of charge	8
Beta decay	450	Conservative force	51
Binding energy per nucleon	444	Continuous charge distribution	32

Index

Control rods	454	susceptibility	72
Convex mirror	312	Electrical energy	105
Coulomb	11	Electromagnetic	
Coulomb's law	10	waves, sources	274
Critical angle	320	waves, nature	275
Curie temperature	194	damping	218
Curie	448	spectrum	280
Current	94	Electron emission	387
density	97	Electrostatic	
loop as a magnetic dipole	160	analog	180
sensitivity of galvanometer	165	potential	53
Cut-off voltage/Stopping potential	391	shielding	69
Cyclotron	140	Electrostatics	1
frequency	141	of conductors	67
Davisson & Germer Experiment	403	Electromotive force (emf)	110
de Broglie		Emission spectra	421
relation	398	Energy	
wavelength	398	bands	469
explanation	430	generation in stars	455
Decay constant	446	levels	427
Diamagnetism	192	stored in a capacitor	80
Dielectrics	71	Equipotential surfaces	60
Dielectric		Excited state	427
constant	76	Experiments of Faraday & Henry	205
strength	74	Extrinsic semiconductor	474
Diffraction	367	Farad	74
single slit	368	Faraday's law of Induction	207
Digital		Fast breeder reactor	453
electronics	491	Ferromagnetism	193
signal	491	Field	
Diopetre	328	due to infinite plane sheet	38
Dipole		due to uniformly charged thin spherical shell	39
moment	28	Field emission	388
moment vector	28	Flux leakage	261
in uniform electric field	31	Focal length	311
physical significance	29	Force between two parallel currents	154
Displacement current	270	Forward bias	479
Doppler effect	358	Franck-Hertz experiment	428
Drift velocity	98	Fringe width	364
Earth's magnetism	185	Full-wave rectifier	483
Earthing	5	G.S. Ohm	95
Eddy currents	218	Gamma	
Einstein's photoelectric equation	394	rays	283
Electric		decay	451
charge	1	Gauss's law	33
current	93	its applications	37
dipole	27	in magnetism	181
displacement	77	Gaussian surface	35
field	18	Geographic meridian	186
field, physical significance	20	Gold leaf electroscope	4
field due to a system of charges	19	Ground state	427
field lines	23	H.A. Lorentz	134
flux	25		

Physics

Half life	448	field on the axis of a circular current loop	145
Half-wave rectifier	483	flux	182, 206
Hallwachs' and Lenard's observations	388	force on a current carrying conductor	135
Henry	220	force	133
Hertz Experiment	274	hysteresis	195
Holes	472	inclination	187
Horizontal component of earth's magnetic field	187	intensity	190
Huygen's Principle	353	meridian	186
Impact parameter	418	moment of a current loop	158
Impedance diagram	246	moment	178
Inductance	219	permeability	190
mutual	220	potential energy	178
self	222	susceptibility	190
Induction	6	torque	178
of charge	6	Magnetisation	189
Inductive		Majority carriers	476
circuit	252	Mass	
reactance	238	defect	443
Insulators	5	number	440
Interference		energy relation	442
constructive	361	Maxwell's equations	273
destructive	361	Mean life	448
fringes	363	Meter bridge	120
Internal resistance	110	Michael Faraday	208
Intrinsic semiconductor	472	Microscope	335
Ionisation energy	427	compound	337
Isobars	441	Microwaves	281
Isotones	441	Minority carriers	476
Isotopes	439	Mirage	321
J.C. Maxwell	270	Mirror equation	314
K.F. Gauss	182	Mobility	100
Kirchhoff's rules	115	Moderator	454
Lateral shift	317	Motion in a magnetic field	137
Law		Motional emf	212
of radioactive decay	447	Moving coil galvanometer	163
of reflection	357	Multiplication factor (fission)	454
of refraction	356	NAND gate	504
LC oscillations	255	Neutrons	440
Lenz's law	210	Non-polar molecules	72
Lens maker's formula	326	NOR gate	505
Light emitting diode	488	North pole	174
Limitations of Ohm's law	101	NOT gate	491
Linear		n-type semi conductor	475
charge density	32	Nuclear	
magnification/Magnifying power	336	binding energy	442
Logic gates	491	density	442
Lorentz force	134	energy	451
Magnetic		fission	452
declination	186	force	445
dipole	177	fusion	455
dipole moment of a revolving electron	162	holocaust	457
field	132	reactor	452
field lines	175	size	441
		winter	457

Index

Numerical aperture	375	Radio waves	281
Ohm	95	Radioactivity	446
Ohm's law	95	Rainbow	333
Optical fibres	321	Ray optics, validity of	375
OR gate	491	Rayleigh scattering	334
Orbital magnetic moment	163	Rectifier	483
Paramagnetism	192	Red shift	358
Permanent magnets	195	Reflection of light	310
Permeability of free space	143	Refraction	318
Permittivity		of a plane wave	355
of free space	11, 76	Refractive index	317, 356
of medium	76	Relation between field and potential	61
Phasors	237	Relaxation time	98
diagram	237	Rententivity	195
Photodiode	487	Resistance	95
Photoelectric effect	388	Resistivity	96, 468
Photocell	399	of some materials	102
Photoelectric emission	388	Resolving power	373
Photoelectrons	389	of eye	374
Photon	395	Resonance	248
Pith ball	2	Sharpness	249
Plane polarised wave	377	Resonant frequency	248
p-n-p junction	478	Reverse bias	480
Point charge	10	Right hand rule	149
Polar molecules	72	Root mean square (rms) or effective	
Polarisation	71, 376	current	235
by reflection	380	voltage	236
by scattering	379	Roget's spiral	156
Polarity of charge	2	Rutherford's model of atom	415
Polaroid	378	Saturation current	390
Potential	53	Scattering of light	334
due to an electric dipole	55	Secondary wavelet	354
due to a point charge	54	Semiconductors	469
due to a system of charges	57	diode	479
energy difference	53	elemental	468
energy for a system of charges	61	compound	468
energy of a dipole	66	Shunt resistance	164
energy of a single charge	64	Snell's law	317, 356
energy of a system of two charges	65	Solar cell	489
energy	52	Solenoid	151
Potentiometer	122	South pole	174
Power (electrical)	106	Spectral series	421
factor	252	Brackett	422
in ac circuit	252	Fund	422
of lens	327	Lyman	422
Pressurised heavy water reactors	453	Paschen	422
Primary coil		Spherical mirror	310, 311
Principal focus	311	Spin magnetic moment	163
Principle of superposition	15	Surface charge density	32
Principle quantum number	425	Telescope	339
Properties of electric charge	8	Temperature dependence of	
p-type semi conductor	476	resistivity	103
Q factor/quality factor	250	Tesla	135
Quanta of energy	393	Thermionic emission	388
Quantisation of charge	8		

Physics

Thermonuclear fusion	456	Velocity selector	140
Thin lens formula	326	Visible rays	282
Threshold frequency	392	Voltage Regulator	486
Tokamak	153	Voltage sensitivity of a galvanometer	165
Toroid	152	Voltmeter	165
Torque		Volume charge density	32
on a current loop	157	Wattless current	252
on a dipole	31	Wavefront	353
Total internal reflection	319	plane	354
Transformer	259	spherical	354
Step-down	261	Wheatstone bridge	118
Step-up	261	Work function	394
Truth table	491	X rays	283
Uncertainty Principle	400	Young's experiment	362
Unpolarised wave	377	Zener	
Ultraviolet rays	282	diode	485
Valence band	469	breakdown	485