

APPENDICES

APPENDIX A 1 THE GREEK ALPHABET

Alpha	A	α	Iota	I	ι	Rho	P	ρ
Beta	B	β	Kappa	K	κ	Sigma	Σ	σ
Gamma	Γ	γ	Lambda	Λ	λ	Tau	T	τ
Delta	Δ	δ	Mu	M	μ	Upsilon	Y	υ
Epsilon	E	ε	Nu	N	ν	Phi	Φ	ϕ, φ
Zeta	Z	ζ	Xi	Ξ	ξ	Chi	X	χ
Eta	H	η	Omicron	O	$\omicron$	Psi	Ψ	ψ
Theta	Θ	θ	Pi	Π	π	Omega	Ω	ω

APPENDIX A 2 COMMON SI PREFIXES AND SYMBOLS FOR MULTIPLES AND SUB-MULTIPLES

Multiple			Sub-Multiple		
Factor	Prefix	Symbol	Factor	Prefix	symbol
10^{18}	Exa	E	10^{-18}	atto	a
10^{15}	Peta	P	10^{-15}	femto	f
10^{12}	Tera	T	10^{-12}	pico	p
10^9	Giga	G	10^{-9}	nano	n
10^6	Mega	M	10^{-6}	micro	μ
10^3	kilo	k	10^{-3}	milli	m
10^2	Hecto	h	10^{-2}	centi	c
10^1	Deca	da	10^{-1}	deci	d

APPENDIX A 3 SOME IMPORTANT CONSTANTS

Name	Symbol	Value
Speed of light in vacuum	c	$2.9979 \times 10^8 \text{ m s}^{-1}$
Charge of electron	e	$1.602 \times 10^{-19} \text{ C}$
Gravitational constant	G	$6.673 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Planck constant	h	$6.626 \times 10^{-34} \text{ J s}$
Boltzmann constant	k	$1.381 \times 10^{-23} \text{ J K}^{-1}$
Avogadro number	N_A	$6.022 \times 10^{23} \text{ mol}^{-1}$
Universal gas constant	R	$8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
Mass of electron	m_e	$9.110 \times 10^{-31} \text{ kg}$
Mass of neutron	m_n	$1.675 \times 10^{-27} \text{ kg}$
Mass of proton	m_p	$1.673 \times 10^{-27} \text{ kg}$
Electron-charge to mass ratio	e/m_e	$1.759 \times 10^{11} \text{ C/kg}$
Faraday constant	F	$9.648 \times 10^4 \text{ C/mol}$
Rydberg constant	R	$1.097 \times 10^7 \text{ m}^{-1}$
Bohr radius	a_0	$5.292 \times 10^{-11} \text{ m}$
Stefan-Boltzmann constant	σ	$5.670 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Wien's Constant	b	$2.898 \times 10^{-3} \text{ m K}$
Permittivity of free space	ϵ_0 $1/4\pi \epsilon_0$	$8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ $8.987 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Permeability of free space	μ_0	$4\pi \times 10^{-7} \text{ T m A}^{-1}$ $\cong 1.257 \times 10^{-6} \text{ Wb A}^{-1} \text{ m}^{-1}$

OTHER USEFUL CONSTANTS

Name	Symbol	Value
Mechanical equivalent of heat	J	4.186 J cal^{-1}
Standard atmospheric pressure	1 atm	$1.013 \times 10^5 \text{ Pa}$
Absolute zero	0 K	$-273.15 \text{ }^\circ\text{C}$
Electron volt	1 eV	$1.602 \times 10^{-19} \text{ J}$
Unified Atomic mass unit	1 u	$1.661 \times 10^{-27} \text{ kg}$
Electron rest energy	mc^2	0.511 MeV
Energy equivalent of 1 u	1 u c^2	931.5 MeV
Volume of ideal gas (0 °C and 1atm)	V	22.4 L mol^{-1}
Acceleration due to gravity (sea level, at equator)	g	9.78049 m s^{-2}

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., $r \simeq 38^\circ$.
- 9.5** $r = 0.8 \times \tan i_c$ and $\sin i_c = 1/1.33 \simeq 0.75$, 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** $n \simeq 1.53$ and D_m for prism in water $\simeq 10^\circ$
- 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; $v_o = (15 - 5) \text{ cm} = 10 \text{ cm}$,
 $f_o = u_o = -2.5$ 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** 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.
- 9.19** 21.4 cm
- 9.20** (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);
 $f_2 = -20$ cm which gives $v_2 = -\frac{112 \times 20}{92}$ cm
 Magnitude of magnification due to the second (concave)

$$\text{lens} = 20/92.$$

$$\text{Net magnitude of magnification} = 0.652$$

$$\text{Size of the image} = 0.98 \text{ cm}$$

- 9.21** 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 $(60^\circ - i_c)$.

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

$$\text{Therefore, } r = 19^\circ$$

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

9.22 (a) $\frac{1}{v} + \frac{1}{9} = \frac{1}{10}$

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

$$\text{Magnitude of magnification} = 90/9 = 10.$$

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

(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 $|v| = 25 \text{ cm}$, are the two quantities equal.

- 9.23** (a) Maximum magnifying power is obtained when the image is at the near point (25 cm)

$$u = -7.14 \text{ cm.}$$

(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.

9.24 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.

- 9.25** (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.

- 9.26** 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.

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

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

- 9.28** (a) $f_o + f_e = 145 \text{ cm}$
 (b) Angle subtended by the tower $= (100/3000) = (1/30) \text{ rad}$.
 Angle subtended by the image produced by the objective

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

 Equating the two, $h = 4.7 \text{ cm}$.
 (c) Magnification (magnitude) of the eye-piece $= 6$. Height of the final image (magnitude) $= 28 \text{ cm}$.
- 9.29** 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 $= (110 - 20) = 90 \text{ mm}$. The focal length of smaller mirror is 70 mm . Using the mirror formula, image is formed at 315 mm from the smaller mirror.
- 9.30** The reflected rays get deflected by twice the angle of rotation of the mirror. Therefore, $d/1.5 = \tan 7^\circ$. Hence $d = 18.4 \text{ cm}$.
- 9.31** $n = 1.33$

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)
 $\nu = 5.09 \times 10^{14} \text{ Hz}$
 $\nu = (c/n) = 2.26 \times 10^8 \text{ m s}^{-1}$, $\lambda = (\nu/\nu) = 444 \text{ nm}$
- 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°

10.10 40m

CHAPTER 11

11.1 (a) $7.24 \times 10^{18} \text{ Hz}$ (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) $3 \times 10^{16} \text{ photons/s}$
(c) 0.63 m/s

11.5 $6.59 \times 10^{-34} \text{ Js}$

11.6 2.0 V

11.7 No, because $v < v_0$

11.8 $4.73 \times 10^{14} \text{ Hz}$

11.9 $2.16 \text{ eV} = 3.46 \times 10^{-19} \text{ J}$

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

11.11 $\lambda = h/p = h/(hv/c) = c/v$

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 $1.67 \times 10^{-27} \text{ kg}$, whereas the mass of an incident α -particle is $6.64 \times 10^{-27} \text{ kg}$. 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 $5.6 \times 10^{14} \text{ Hz}$

12.4 13.6 eV; -27.2 eV

12.5 $9.7 \times 10^{-8} \text{ m}$; $3.1 \times 10^{15} \text{ Hz}$.

12.6 (a) $2.18 \times 10^6 \text{ m/s}$; $1.09 \times 10^6 \text{ m/s}$; $7.27 \times 10^5 \text{ m/s}$
(b) $1.52 \times 10^{-16} \text{ s}$; $1.22 \times 10^{-15} \text{ s}$; $4.11 \times 10^{-15} \text{ s}$.

12.7 $2.12 \times 10^{-10} \text{ m}$; $4.77 \times 10^{-10} \text{ m}$

12.8 Lyman series: 103 nm and 122 nm; Balmer series: 656 nm.

12.9 2.6×10^{74}

CHAPTER 13

13.1 104.7 MeV

13.2 8.79 MeV, 7.84 MeV

13.3 $1.584 \times 10^{25} \text{ MeV}$ or $2.535 \times 10^{12} \text{ J}$

13.4 1.23

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

(ii) $Q = 4.62$ MeV; exothermic

13.6 $Q = m(^{56}_{26}\text{Fe}) - 2m(^{28}_{13}\text{Al}) = 26.90$ MeV; not possible.

13.7 4.536×10^{26} MeV

13.8 About 4.9×10^4 y

13.9 360 KeV

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

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.

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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.

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