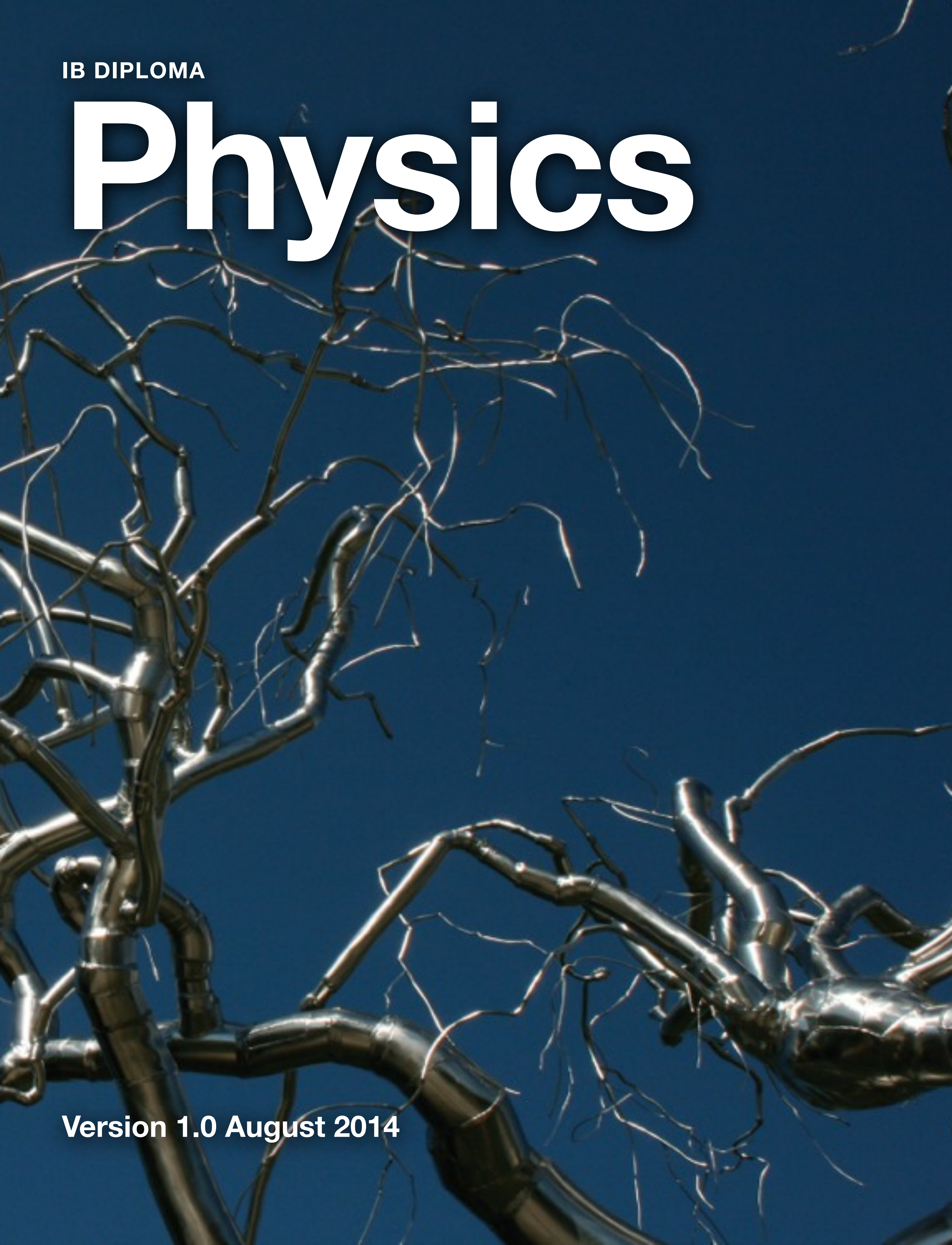
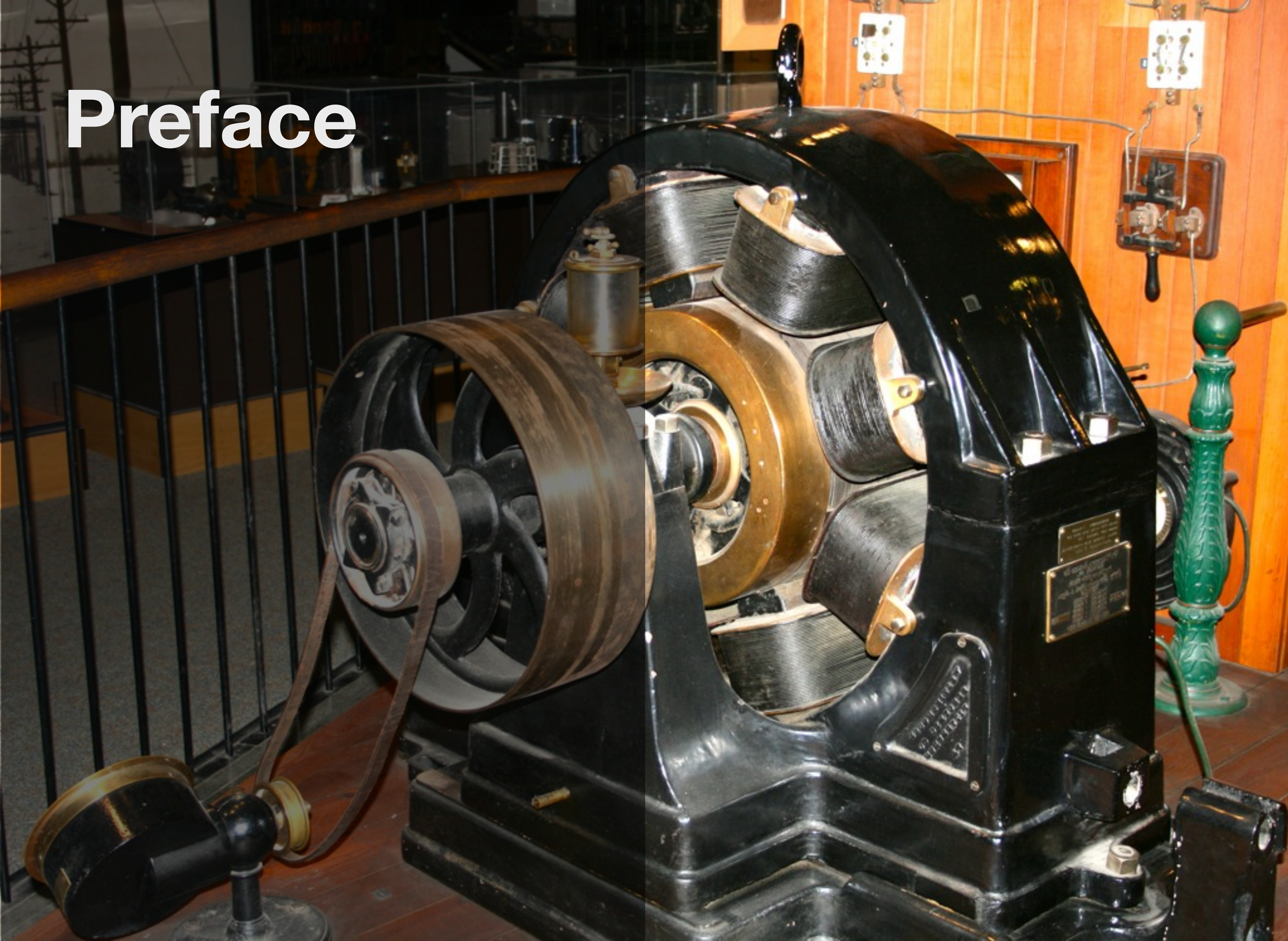
IB DIPLOMA

Physics



Version 1.0 August 2014

Preface



This resource supplements the text:

Phusics 4th Edition by Gregg Kerr.

ISBN: 978 – 1 – 921917 – 21 – 9

published in print form by IBID Press.

It is not intended to be a stand alone resource for the IB Diploma Course.

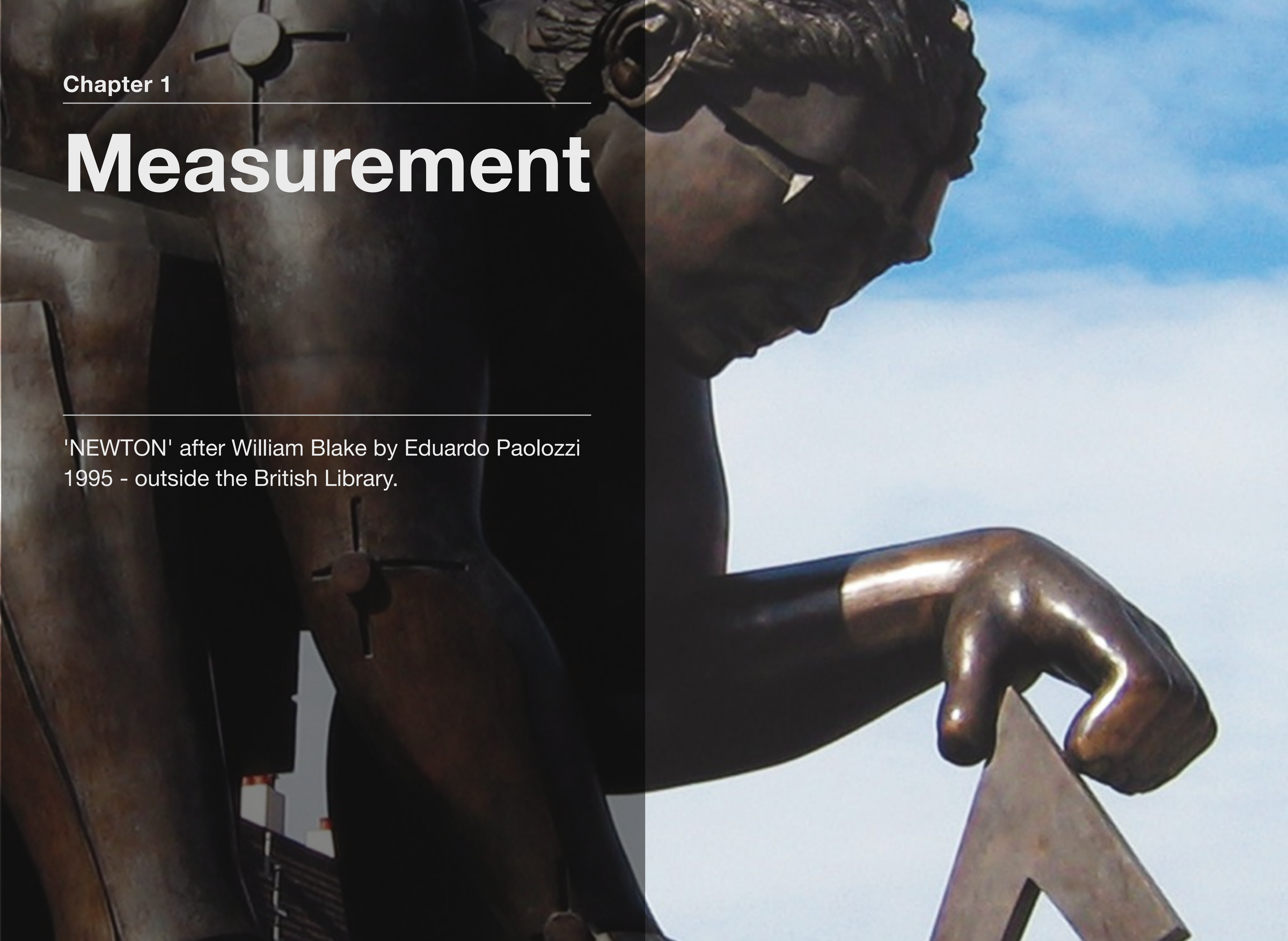
We have produced this resource to provide a few of the things that are difficult to include in print media:

- Video material.
- Additional photographs.
- Enlargements of the more detailed diagrams from the text.
- Internet links.

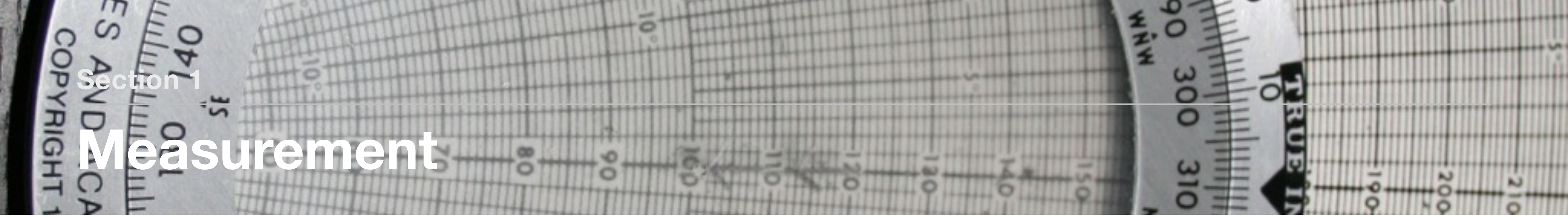
The main intention of this resource is to support the cross-curricular objectives of the IB Diploma courses. Students will be challenged to address the historical aspects of science, the mathematical background of the sciences and the over-arching principle that the pursuit of knowledge is a powerful human drive.

Chapter 1

Measurement



'NEWTON' after William Blake by Eduardo Paolozzi
1995 - outside the British Library.



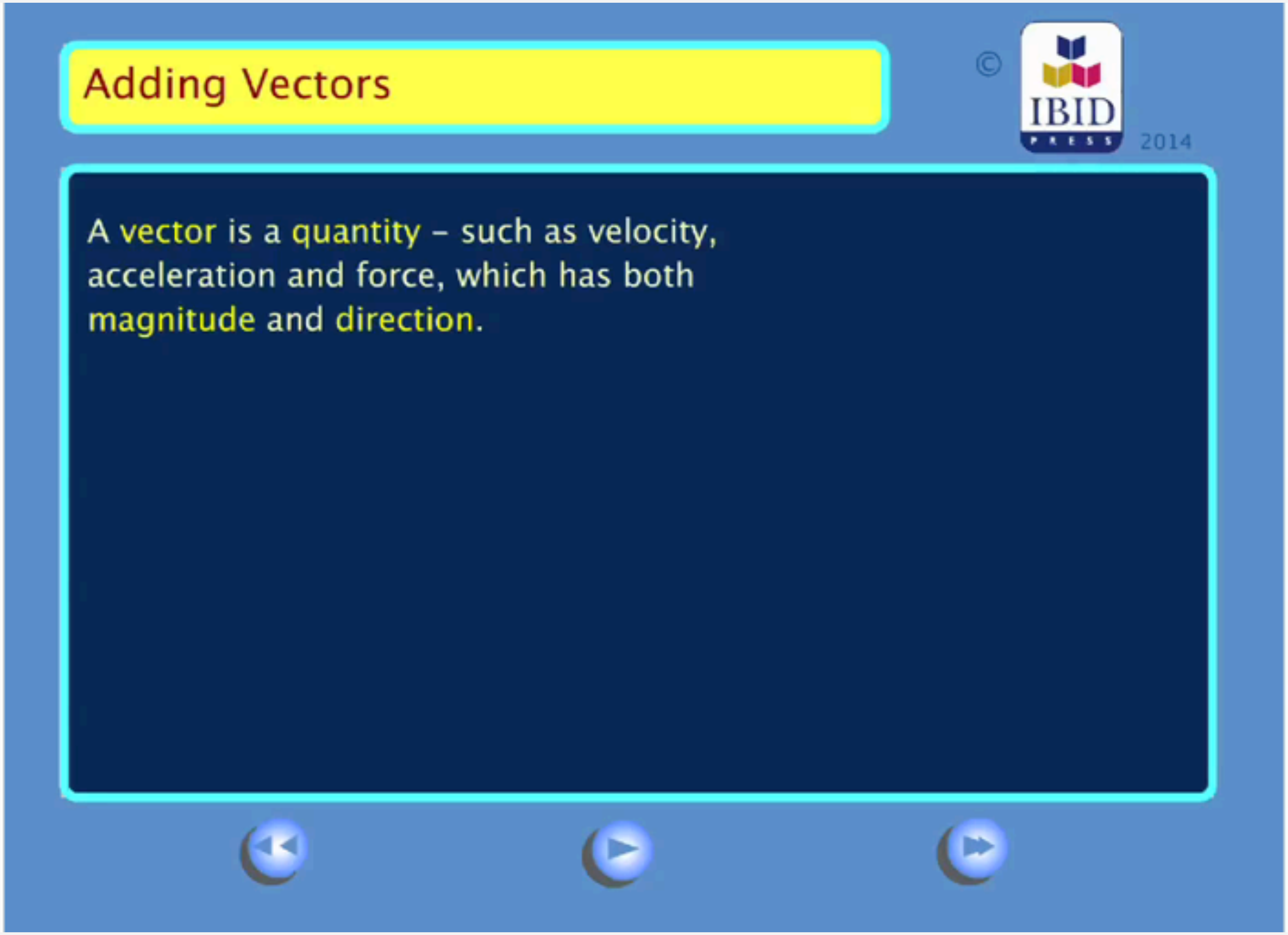
Section 1

Measurement

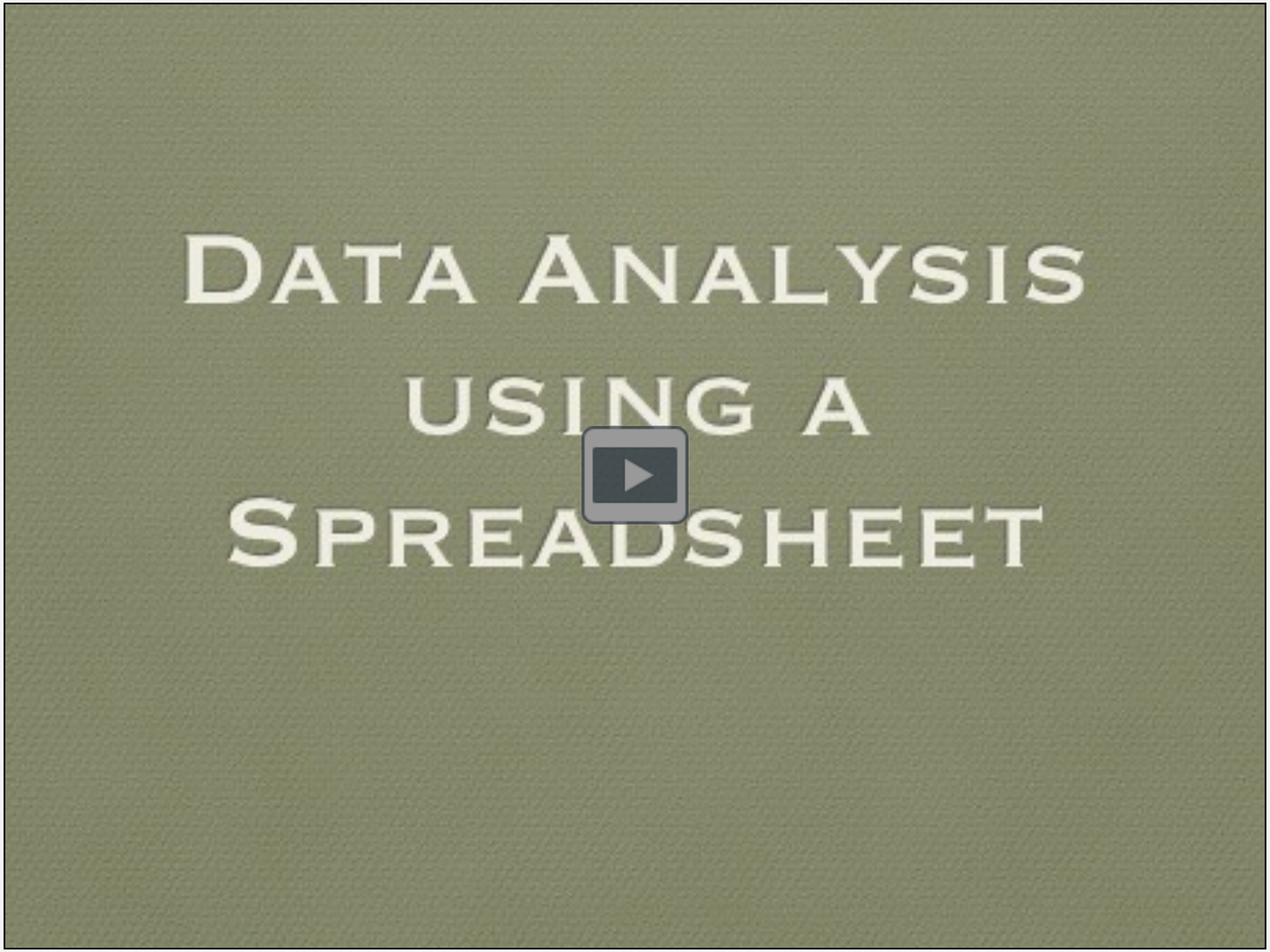
CONTENTS

Additional material

Movie 1.1 Vectors

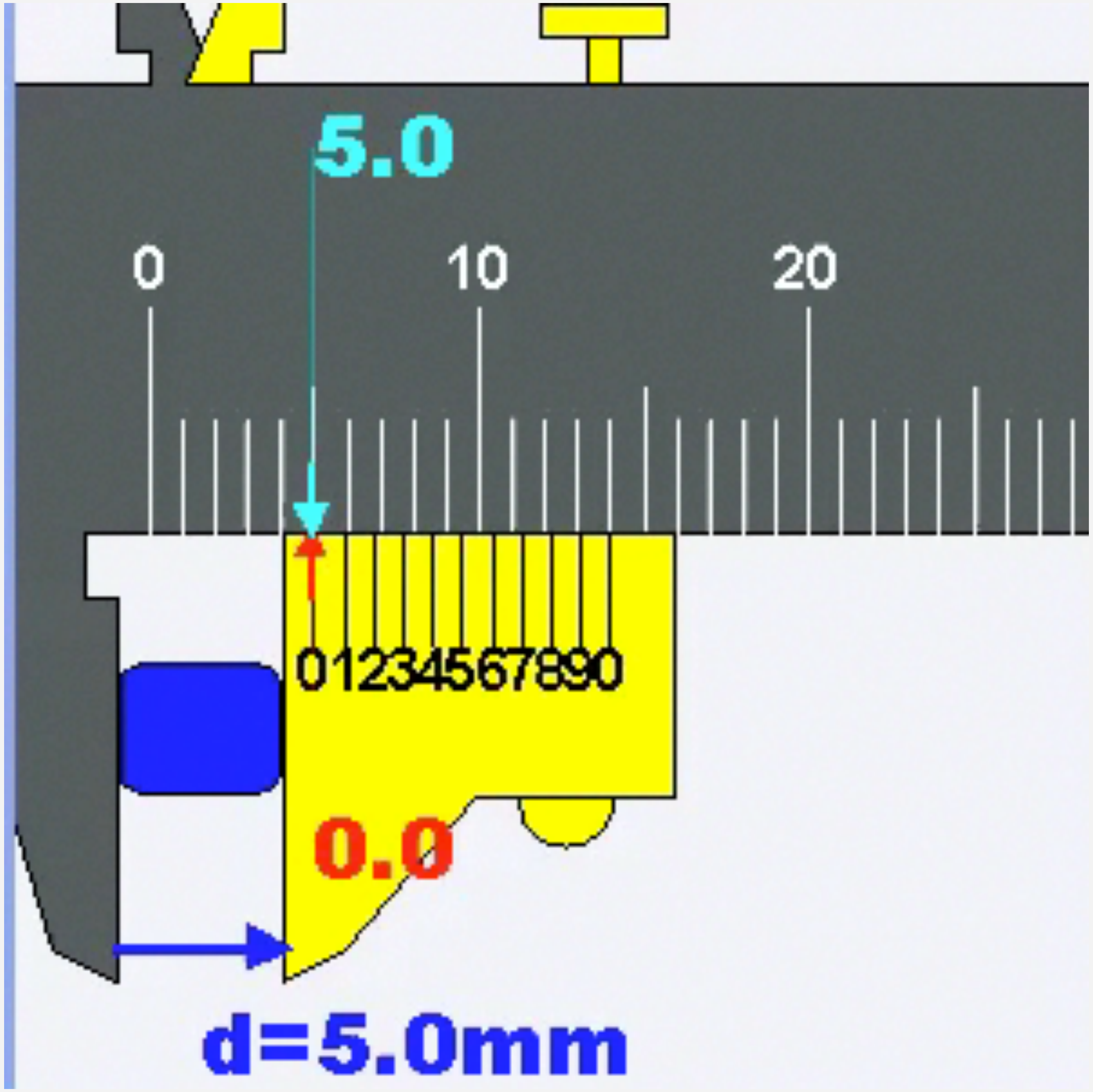


Interactive 1.1 A simple data analysis using a spreadsheet.



There are many more options to investigate!

Movie 1.2 The vernier scale



A short explanation of the Vernier (Wikipedia GNU License)

Interactive 1.2 Cross-wind landing.

Landing an aeroplane in a cross-wind is a vector problem.

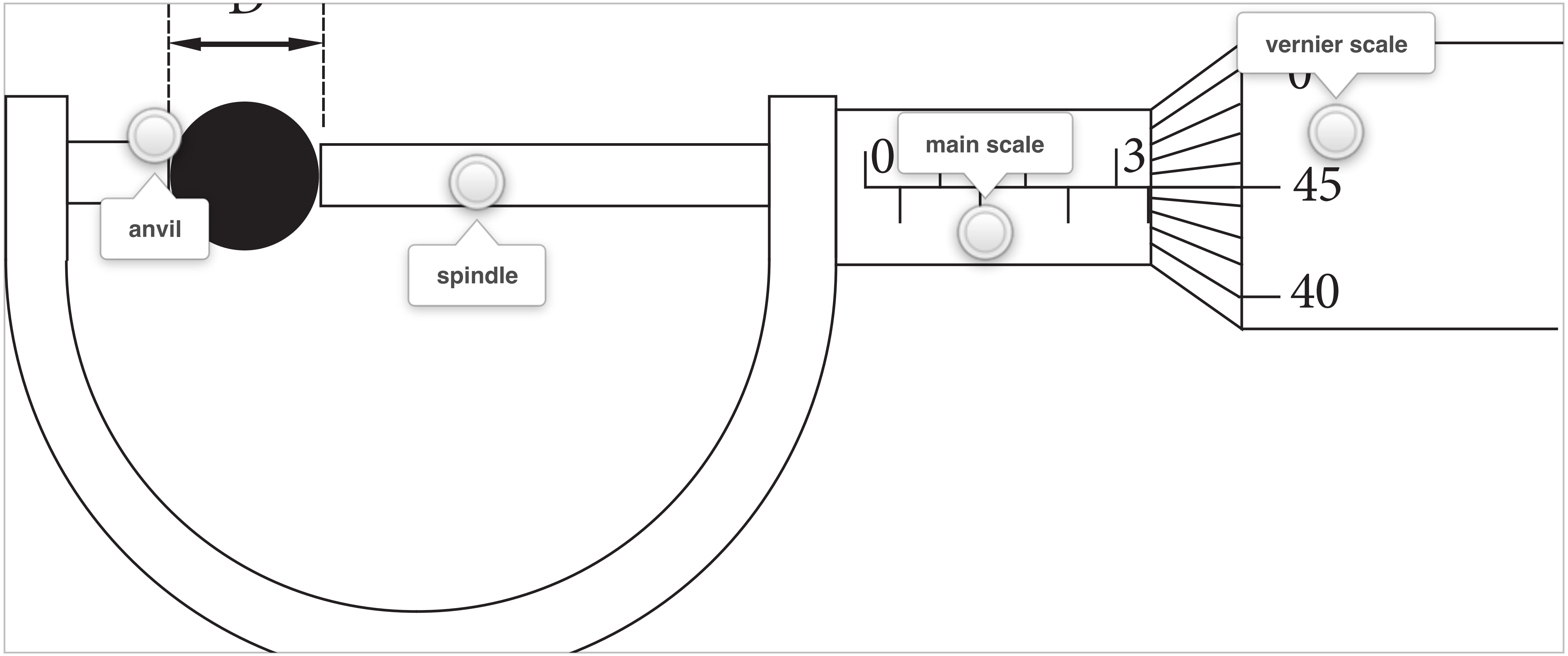
Gallery 1.1 The ultrasonic ruler

Where is the zero of this ultrasonic ruler? How accurate is it?

Labelling exercise

Review 1.1 Drag the labels to the correct locations.

Micrometer



anvil | spindle | main scale | vernier scale

Check Answer

Answers to exercises

Exercise 1.1

1. C

2. C

3. A

4. C

5. D

6. (a) 5.6×10^{-3} kg

(b) 3.5×10^{-6} A

(c) 3.2×10^{-2} m

(d) 6.3×10^{-9} m

(e) 2.25×10^{3} kg

(f) 440 s^{-1}

7. (a) 2.24×10^{6} J

(b) 2.50×10^{3} N m^{-2}

(c) 7.5×10^{-1} m s^{-1}

(d) 2.5×10^{-6} m^{2}

(e) 2.4×10^{-3} m^{3}

(f) 3.6×10^{-6} m^{3}

(g) 2.301×10^{5} m^{3}

(h) 3.62×10^{-9} m^{3}

8. (a) 10^{0} (b) 10^{5} (c) 10^{-5} (d) 10^{9} s

9. 400 m

10. N m^{2} kg^{-2}

11. N s m^{-2}

Exercise 1.2

Please note that questions 7, 8 and 9 all appear in the wrong position. Q12 should be labeled q10. The answers do not match the question numbers, they correspond to the order in which they have actually been displayed. Hence,question 9 uses the question 7 answer, 7 uses the answers for question 8, and question 8 uses the answers for question 9.

1. A

2. (a) 4 (b) 4 (c) 2 (d) 3 (e) 3 (f) 2 (g) 3 (h) 3 (i) 2 (j) 2 (k) 3 (l) 2

3. (a) 1.2 x 10

4. ^{17} (b) 3.0007×10^{4} (c) 2.510×10^{1} (d) 4×10^{6}

(e) 12.0 nmsq to msq

4. 1.0×10^{1} m^2

5. 21.8435 = 21.8 ~ 22 m

There are errors in the numbering of this exercise.

6. 490 cm^3

7. 200 g cm^{-3}

8. (a) 91 (b) 99 (c) 2.00×10^{3} (d) 2130 (e) 6.56

9. (a) 89.8 (b) 98.5

10. 3.7×10^{-5} cm

Exercise 1.3

1. D

2. (a) 10^{5} (b) 10^{4} (c) 10^{18} (d) 10^{16} (e) 1^{-24} (f) 10^{-29}

3. (a) 10^{7} (b) 10^{-3} (c) 10^{28} (d) 10^{10} (e) 10^{-6}

4. C

5. (a) 10^{8} (b) 10^{7}

6. (a) 10^{7} (b) 10^{13}

Exercise 1.4

1. B

2. (a) 25 cm × 10 cm × 5 cm (b) 150 g (c) 1 sec (d) 20°C

3. (a) 3×10^{14} (b) 1×10^{-2} (c) 4×10^{-12}

4. 2×10^{10} yrs

5. (a) 10^{0} (b) 10^{6} (c) 10^{4} (d) 10^{-4} (e) 10^{5} (f) 10^{9} (China)

Exercise 1.5

1. D

2. C

3. D

4. B

5. C

6. B

7. 0.932 ± 0.0005 μm

8. (a) 2.35 ± 0.005 mm (b) random error

9 (a) Yes. Random error evident for the 1.2 A reading.

(b) Average = 8.28 greatest residual from the average is 0.13 So answer is 0.8±0.1 A

10. 9.0 ± 0.1 N

11. 1.47 ± 0.03 m

12. 27.0 ± 0.3 cm^3

13. (1.2 ± 0.3) x 10^{-3} g cm^{-3}

14. 0.488 ± 0.003

15. mean sin 6° = 0.104. max sin 11° = 0.191. min sin 1° = 0.017

Answer = 0.10 ± 0.09

Exercise 1.6

1. D

2. B

3. R_0 = 22 ± 1 W, μ = 0.0046 ± 0.0005 W q^{-1}

4. 10 m s^{-2}

5. C

6. (a) $\log_{10} F$ versus $\log_{10} d$

(b) By determining the *Y* offset (*k*) and gradient(*n*) of the above graph

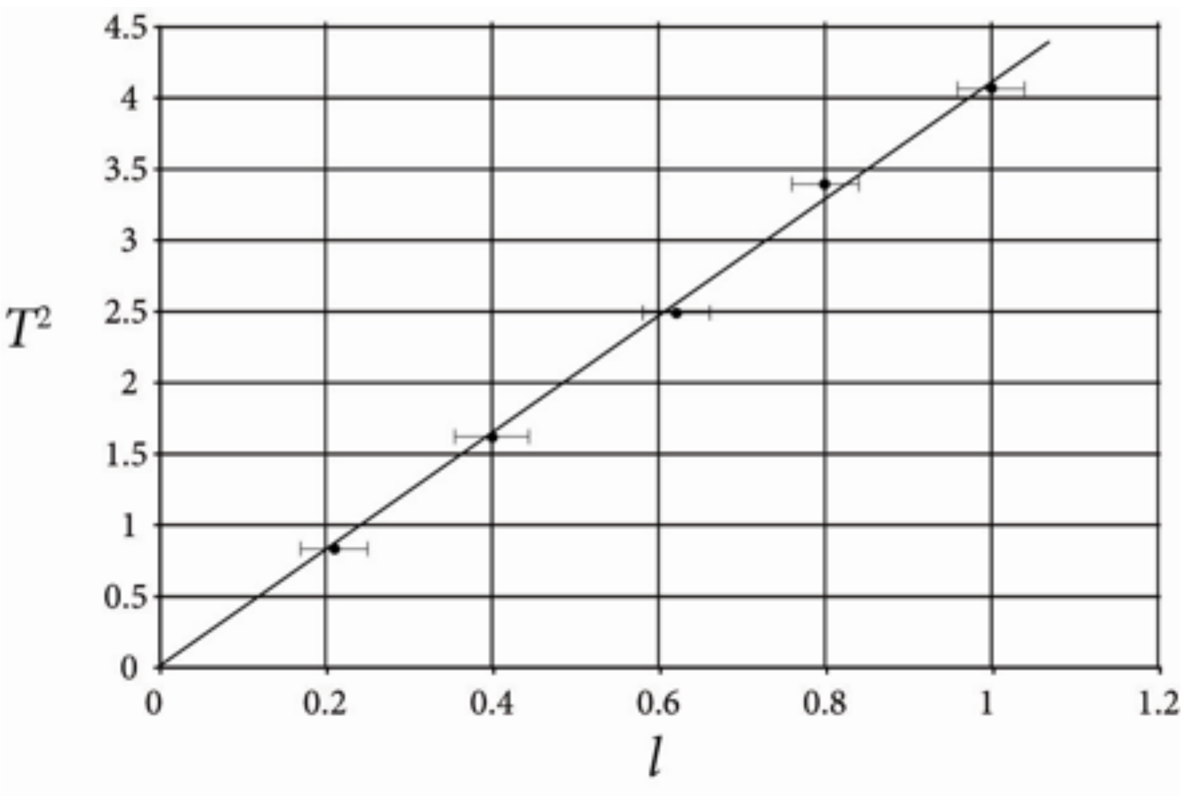
7. ln *I* versus *x*.

Exercise 1.7

1. (a), (b) and (c)

Period T ± 0. 1 s	T^2 s^2	Absolute error of T^2
0.905	0.819	0.02
1.28	1.64	0.03
1.58	2.48	0.03
1.84	3.39	0.04

(d)



(e) T^2 is directly proportional to l as seen from the straight line graph

(f) The value for l = 0.8 m falls outside the line of best fit

(g) gradient = $4\pi^2/ g = 4.1$, so g = 9.6 m s^{-2}

Exercise 1.8

1. A

2. C

3. D

4. C

5. C

6. (a) 4 m north (b) 13 m west 23° north

(c) 8.5 N north–west (d) 5.0 m.s^{-1} east 37° north

7. (a) 3 m east (b) 13 m.s^{-2} south

(c) 5.0 N east 54° south (d) 6.0 T south 32° west

8. (a) 60 ms^{-1} north (b) 60 N north 12° east

9. 20 ms^{-1} W

10. 9.1 m north 22°east

Exercise 1.9

1. B

2. 4.2 N

3. vertical = 22.7 m s^{-1}, horizontal = 10.6 m s^{-1}

4. 11 N

5. 13 N east 23° north

6. 2.8 N south

7. a = g × sin 30 = 4.90 ms^{-2}

8. Horizontal = 12 cos 45 – 8 cos 25 = 1.235 N west.

Vertical = 15 – (12 sin 45 + 8 sin 25 = 3.13 N south.

Resultant = √ (3.132 + 1.2352) = 3.4 N. tan θ = 1.235 ÷ 3.13 = 21.5.

Answer = 3.4 N south 220 west.

8. (a) 3 (b) –2

9. (a) 5.03 cm (b) 2.01 cm2

10. V = 5.1 °— 10 –5 m3 SA = 6.6 °— 10–3 m2

11. (a) 4.7 rad (b) 0.79 rad

12. 45°

Exercise 1.10

1. 0.76 76%

2. 46.7 2.08

3. y = 1/2 x + 3

4. $v = \sqrt{\frac{Fr}{m}}$

5. $\frac{4\pi^2}{T^2}$

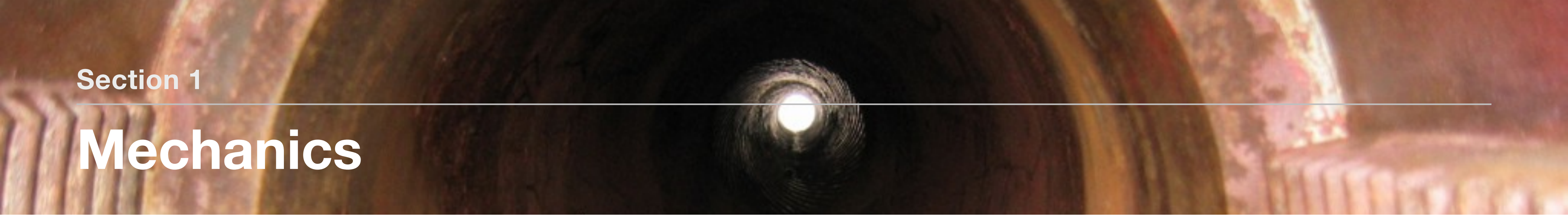
6. x = 7/3, y = 10/3

7. (a) 4352 (b) 125 (c) 4 (d) 0.33

Chapter 2

Mechanics

Early wind power - The Netherlands.



Section 1

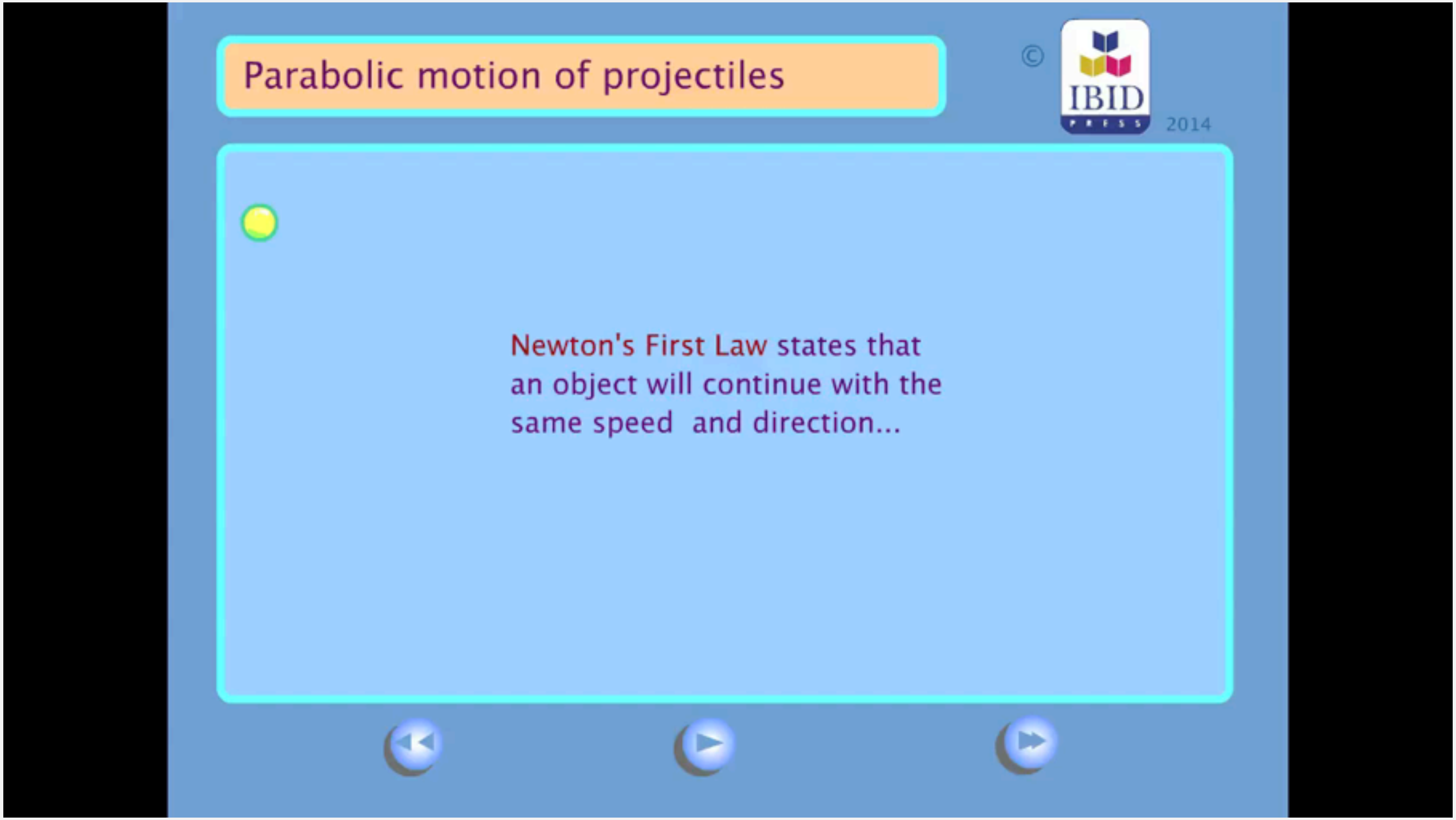
Mechanics

CONTENTS

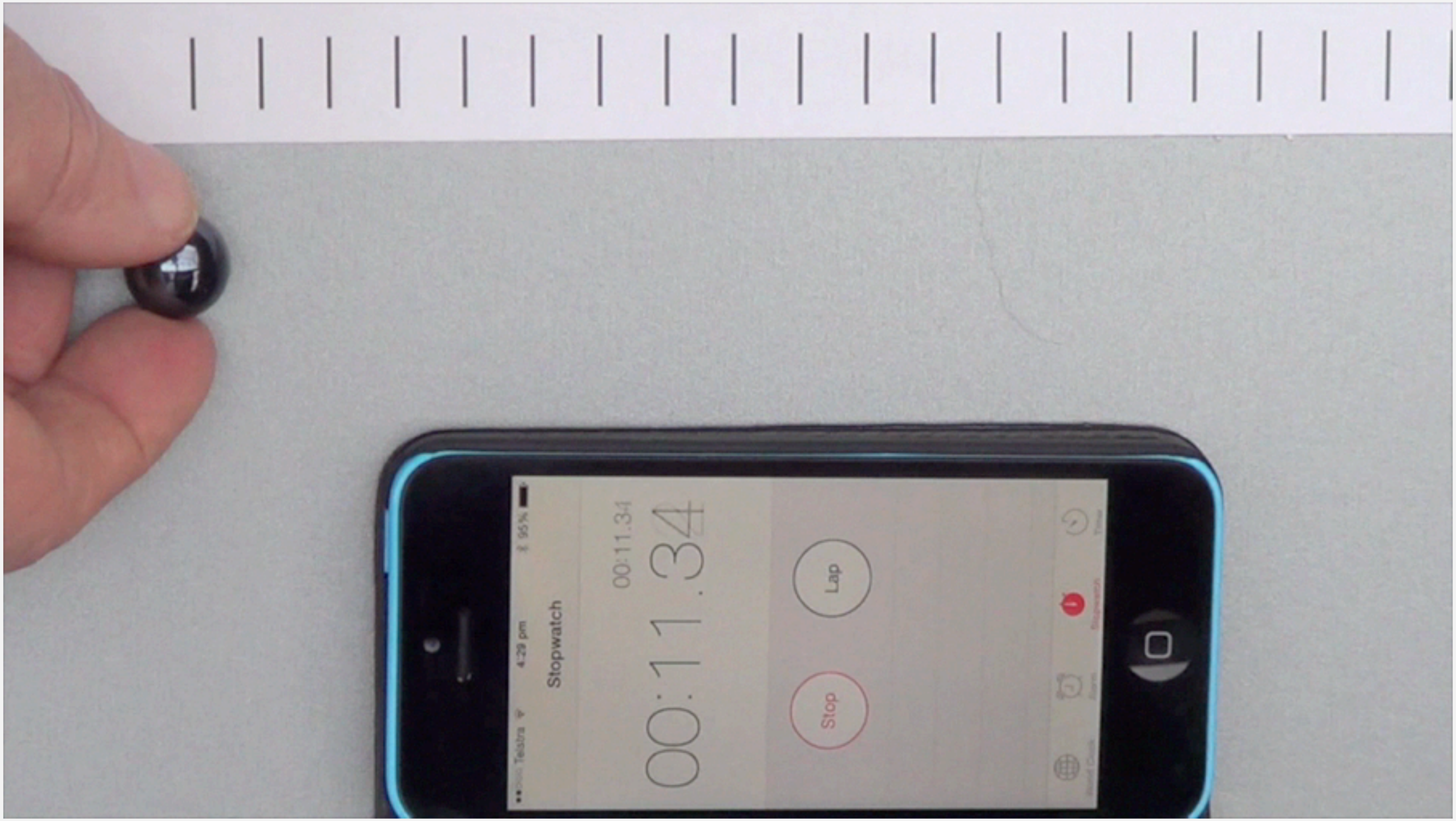
Muzzle-loading canon. HMS Warrior, Portsmouth, UK

Additional material

Movie 2.1 Projectile Motion

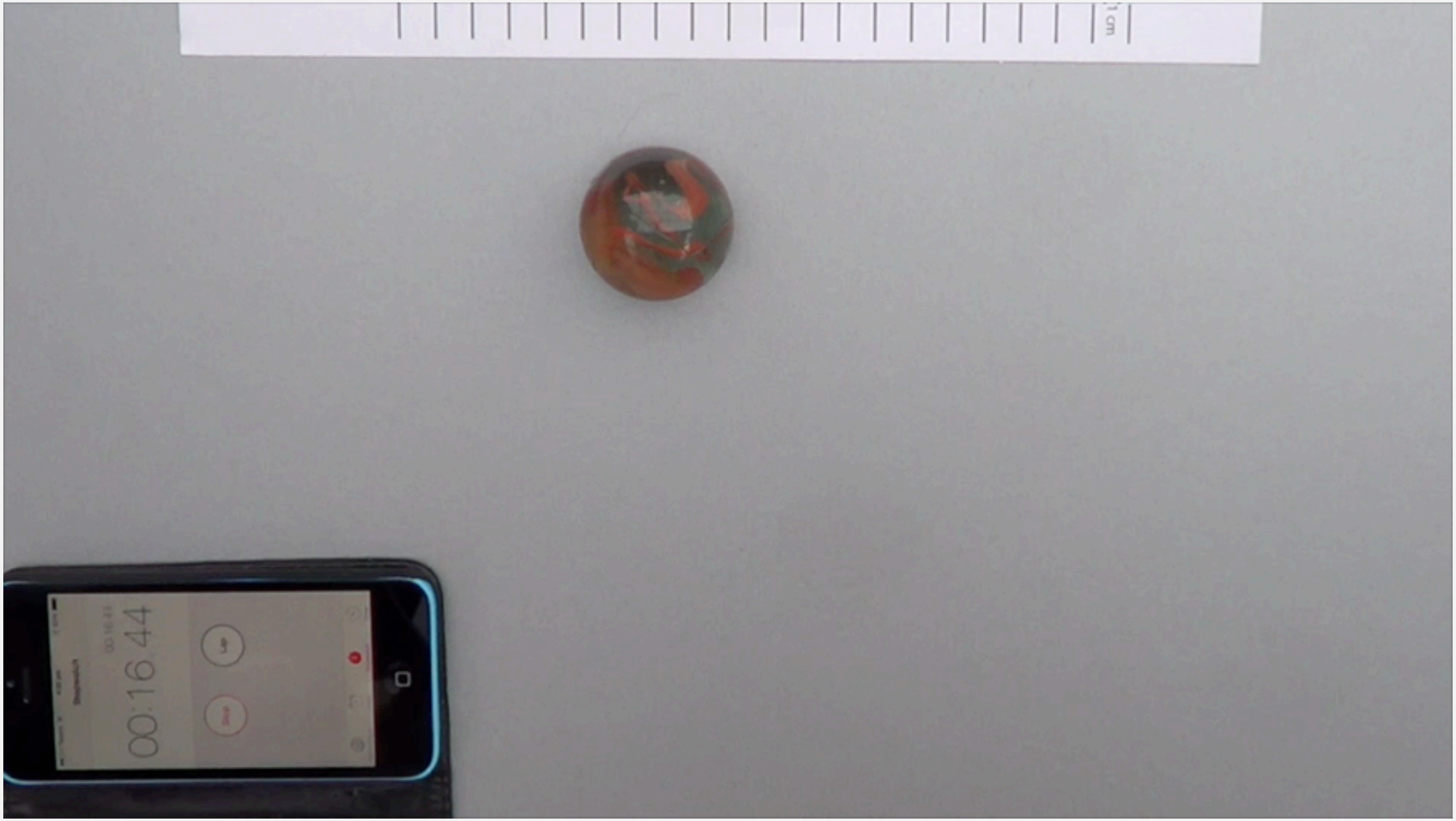


Movie 2.2 Ball on a Slope



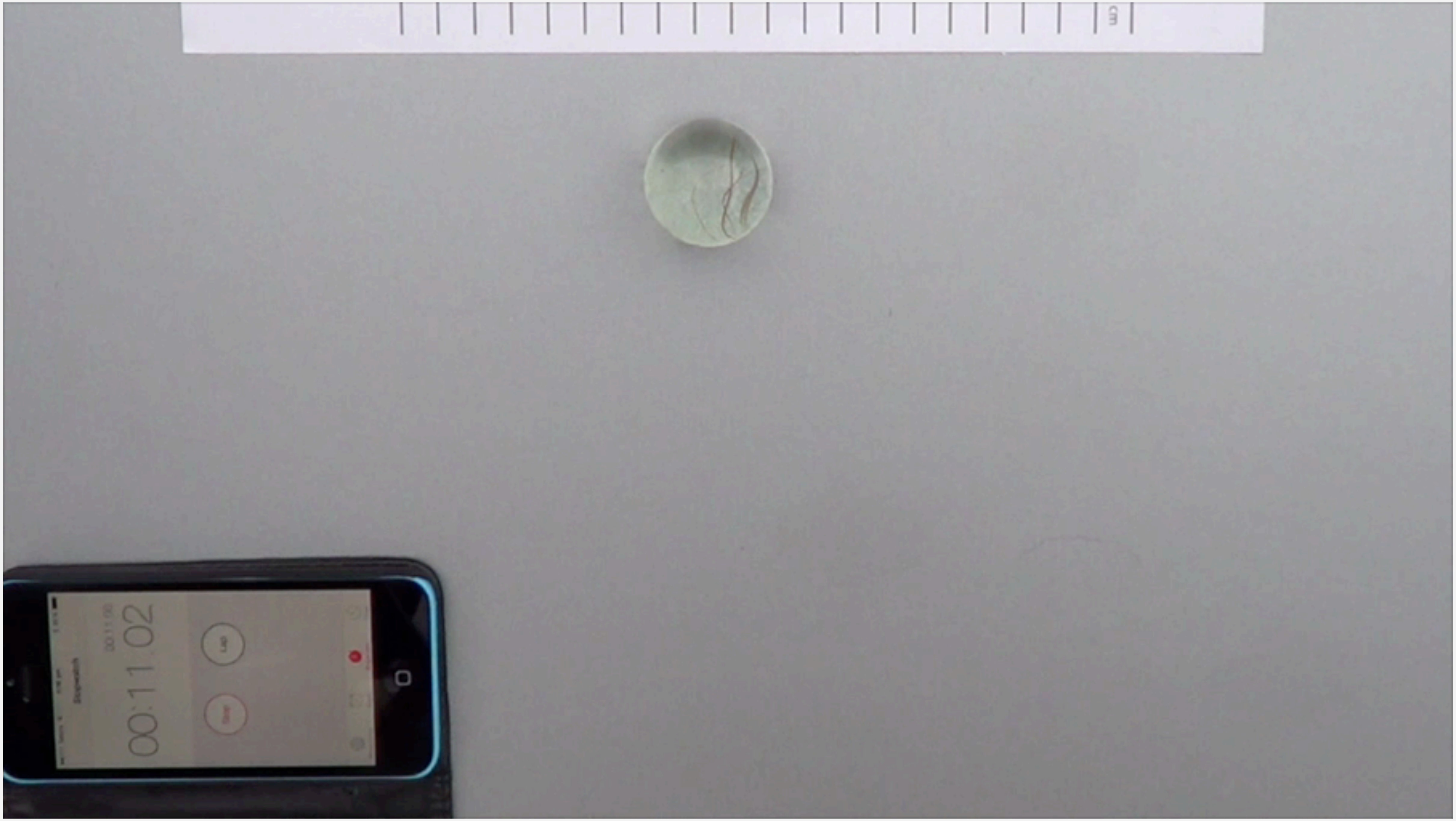
What is the angle of the slope? The clip is in slow motion and the grid lines are at 1cm. You should use the pause control!

Movie 2.3 Collisions (1)



What is the ratio of masses of these two balls?

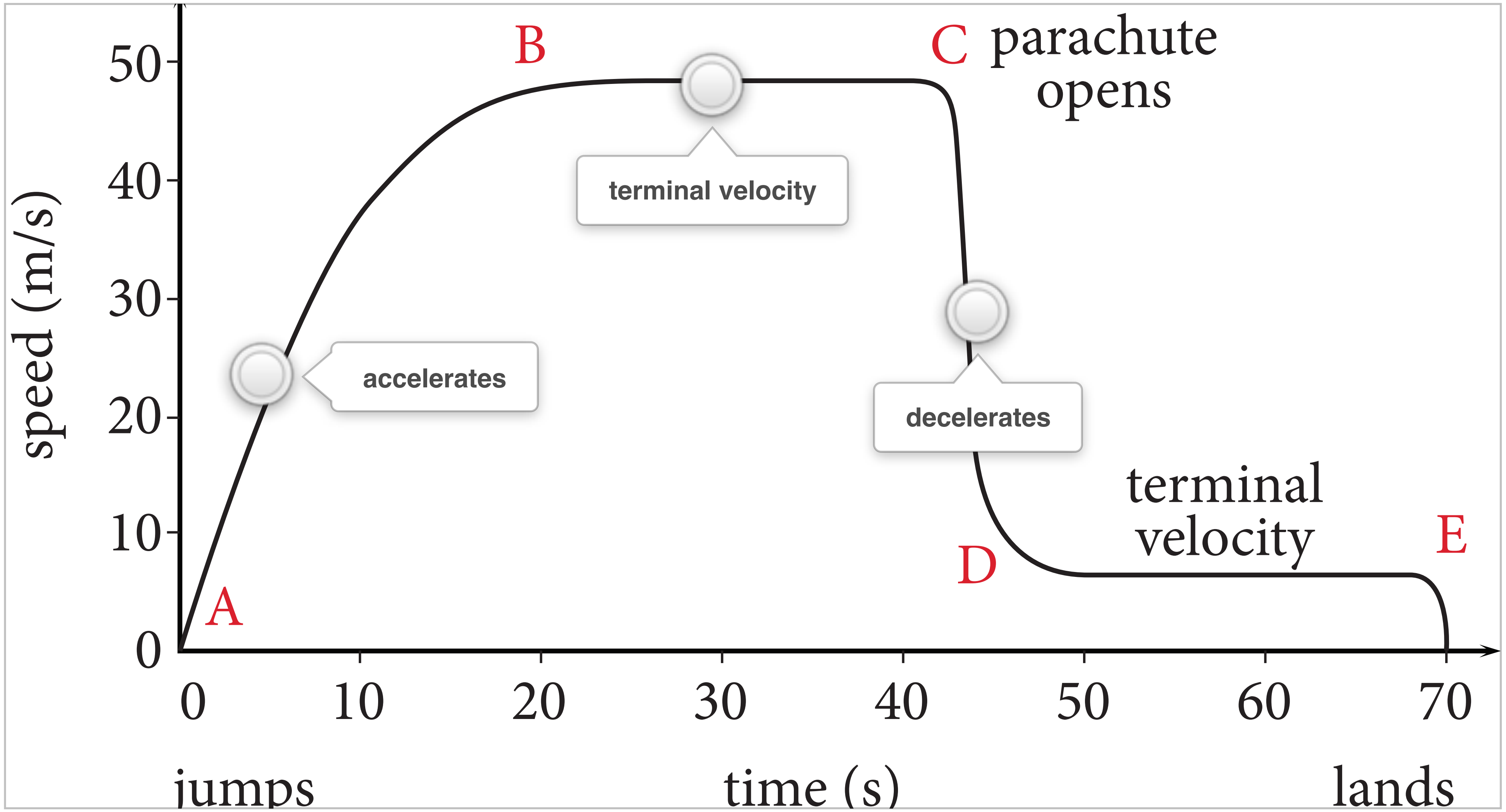
Movie 2.4 Collisions (2)



What is the ratio of masses of these two balls?

Review 2.1 Drag the labels to their correct places.

Parachuting



accelerates | terminal velocity | decelerates

Check Answer

Answers to exercises

Answers

Movies 2,4 & 2.5.

The balls weigh 5, 15 & 55 gms (in order of size).

Gallery 1.1

The device measures from its base. Its advertised accuracy is 0.5% - which it is struggling to make!

Text Exercises

Exercise 2.1

1. D

2. C

3. 7.0 x 103 s

4. A person runs 16 m south in 2.0 s and then 12 m east in 3.0s.

(a) 28 m

(b) 2.0 x 101 m south 370 east

(c) 5.6 ms^{-1}

(d) 0.139 ms^{-2}

5. 0.139 ms^{-2} (0.0556 km h^{-1} s^{-1})

6. (a) 9.80 ms^{-2}

(b) 36.90 ms^{-1}

(c) 278 m

7. (a) various answers

(b) 35 m

8. (a) D

(b) B

(c) A

(d) C

9. The graph below shows the idealised velocity-time graph for a car pulling away from one set of traffic lights until it is stopped by the next set.

i. 1.3 m s-2 and – 2.5 m s-2

ii. 130 m

iii. 2.9 km

10. various answers

Exercise 2.2

1. 29 m (assume 'g' = 10 m s^{-2} and neglect the speed of sound)

2. i. (25 + 11.25) = 36 m (above sea level)

ii. 1.5 s

iii. 27 m s^{-1}

iv 4.2 s;

3. 40 m

4. g = 10 m s^{-2}
20 m neglecting the speed of sound

5. (a) 5 m s^{-2} west

(b) zero

6. (i) 11.3 m

(ii) (g = 10 m s^{-2}) (3.0 s)

7. (a) 39 = 3u + ½ a 32 and 11 = 1<u>u</u> + ½ a 12. Eliminate for a and find u = 10 m s $^{-1}$

(b) 2 m s^{-2}

(c) 2 s

8. (a) 01:20 am

(b) 333.3 km south

9. (a) 4.5 x 104 m s^{-2}

(b) 6.7 x 10^{-3} s

10. (a) 212 m

(b) 7.06 s

Exercise 2.3

1. (c) (100 + 11.25) = 110 m (2sd), 160 m

2. (a) 20 ms^{-1}

(b) 2 s

(c) 10 m

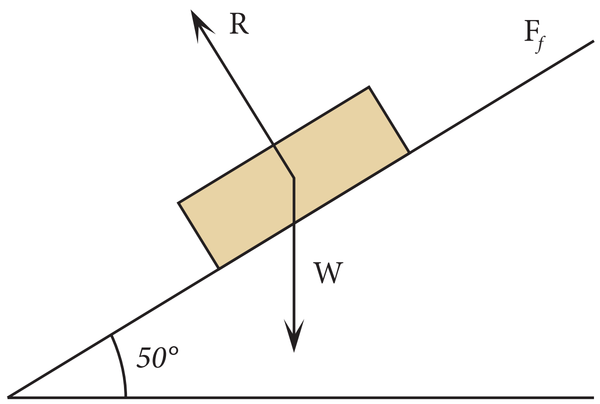
3. (a) 50 m s^{-1} and 9.8 m s^{-1} down, 50 m s^{-1} and 49 m s^{-1}

(b) 51 m s^{-1} 110 below the horizontal, 70 m s^{-1} 440 below the horizontal

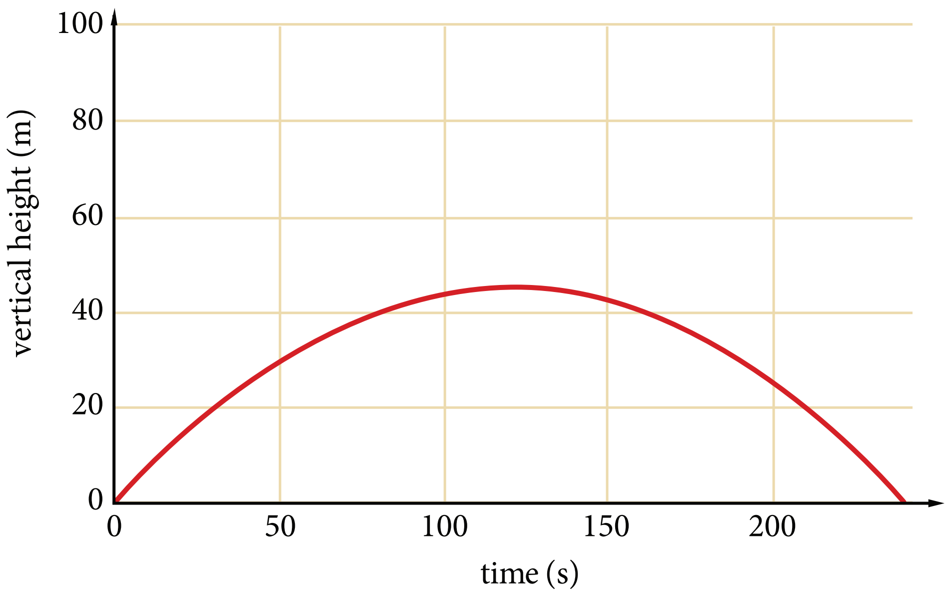
4. (a) 6 s

(b) 240 m

(c)



(d)



(e) 300 m from cliff

5. (a) 1.0 x 101 m

(b) 2.9 s

(c) 49 m

6. (a) 241 m

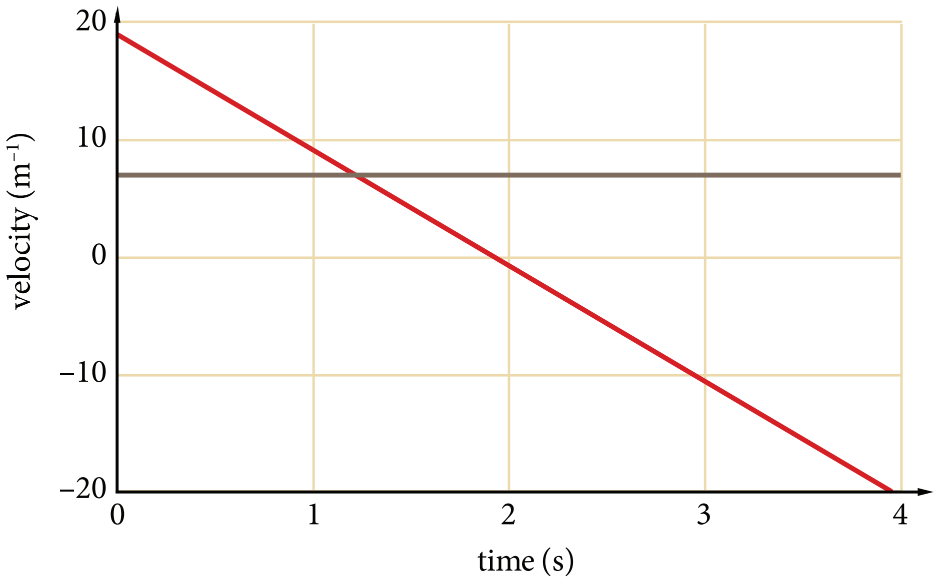
(b) 305 m

7. 4.2 s

8. (a) 18.8 m s^{-1} and 6.84 m s^{-1}

(b) 3.84 s

(c)



(d) Height is the area of the triangle 18.0 and the range is the area of the rectangle 26.2 m

Exercise 2.4

1. (a) less

(b) same

(c) same

(d) less pain

(e) same pain

(f) use lighter duty materials

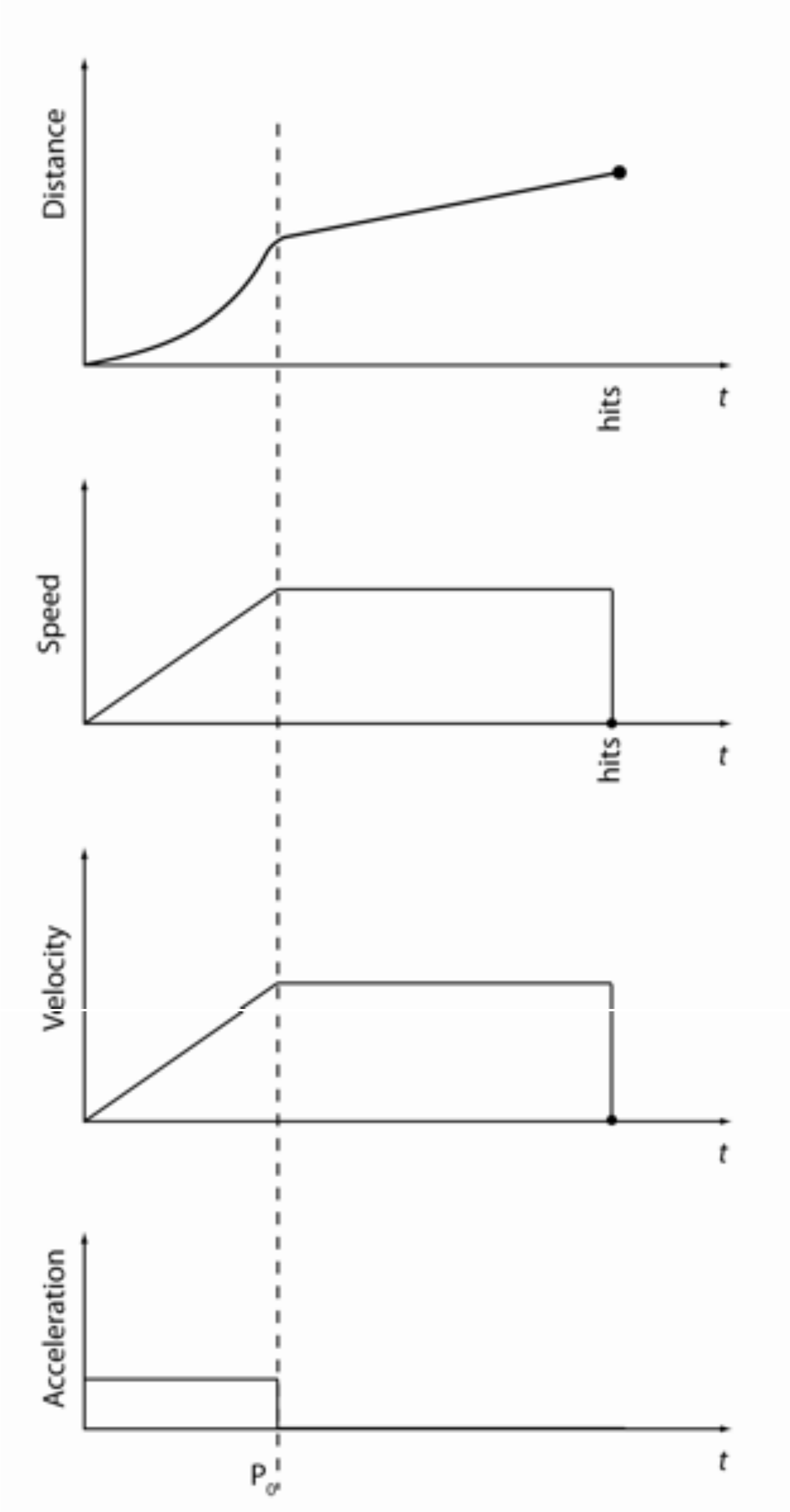
2. (i) 20 cm

(ii) 90 N m^{-1}

3. 680 N ->1.3 m s^{-2} , 600 N ->0 , 500 N ->1.7 m s^{-2}' 600 N ->0.

4. 0

5.



6. weight

7. 29 N

8. 72 kg

9. 3.3 $m\ s^{-2}$

10. A and B

11. C

12. C

13. D

14. B

15. B

17. A

18. D

19. (a) $= 0.3 \times mg\cos\theta$
$= 0.3 \times 3 \times 9.8 \times 0.906$
$= 7.994 = 8.0$ N

(b) $F_{net} = -(F_f + mg\sin\theta)$
$= -20.4$ N

$F = ma \qquad a = -20.4 / 3 = -6.8\ ms^{-2}$

$v^2 = u^2 + 2as \qquad 0 = u^2 + 2 \times -6.8 \times 3 \quad u = 6.4\ ms^{-1}$

20. (a) 4 ms^{-2}

(b) 8 N

(c) 8 N

Exercise 2.5

1. B

2. B

3. D

4.

5. C

6. D

7. (a) 2000 J (b) 2500 J

8. 46 %

9. 3.6×10^4 N (both cases)

10. (i) 1000 J (ii) 1000 J (iii) 50% (iv) 500 W

11. . (i) 5.0×10^{-3} litre s^{-1} (ii) 2.5×104 J s^{-1}

12. Reasoning: The motor has done work on the aircraft in accelerating it to 80ms-1 and providing the lift to get it to an altitude of 300m. The work done is the sum of the KE and PE after 4 minutes.

$W = mgh + 1/2mv^2$ = 800 x 9.8 x 300 + (800 x 80 x 80)/2 = 2 352 000 + 2 560 000

= 4 912 000 = 4.9 x 106 J = 4.9 MJ.

13. Reasoning: The law of conservation of energy states that the KE + PE = constant.

$1/2mv^2 + mgh_1 = mgh_2$

$h^2 = (1/2v^2 + gh_1) / g$ = 1.2286 m = 1.23 m.

14. Reasoning: The final velocity at maximum height will momentarily be zero. The net force on the gymnast is only due to the gravitational force. The work done due to this force can be determined by the change in potential energy. Because the kinetic energy at the top is zero, then the work due to gravity will be equal to the initial kinetic energy.

$Wg = mg\Delta h$ and $Wg = 0 – 1/2mv_0^2$

$m \times 9.8 \times (1.25 – 5.10) = -1/2mv_0^2$

$-v_0 = \sqrt{}\, 2 \times 9.8 \times -3.85 = 8.687 = 8.69\ ms^{-1}$.

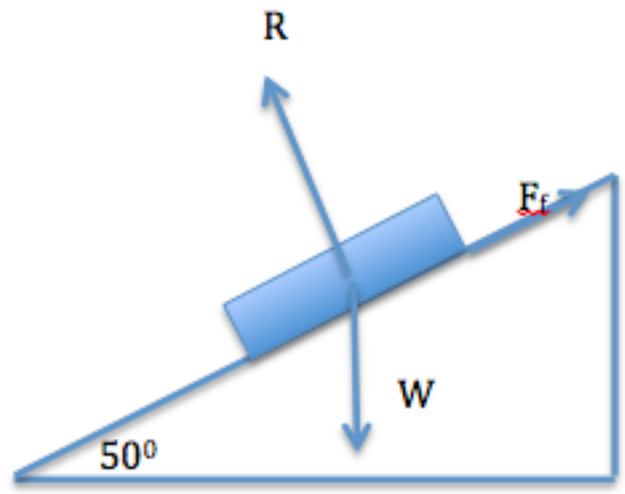
15. (a) v = u + at = 12 + 2 x 45 = $10^2 ms^{-1}$

The work done by the force will be equal to the change in kinetic energy.

W = ½ x 5 x 10^{22} – ½ x 5 x 122 = 26010 – 360 = 25650 = 2.6 x 104 J.

(b) P = W/t = 25650 / 45 = 570 W.

16. (a)



(b) (i) 2.47 ms^{-2} (ii) 7.51M N

(c) 6.30 µkM

(d) µk = 1.19

17. 1.96 x 10^4 J

18. (a) 5.0 x 10^2 J (b) 2.3 ms^{-1} (c) 3.3 x 10^2 J

19. Estimates

mass of grasshopper = 2.0×10^{-3} kg

height to which it jumps 0.50 m

time it takes to develop take-off power = 200 ms

Calculation

energy needed to reach 0.50 m = mgh

= $2.0 \times 10\text{-}^{3} \times 10 \times 0.50 = 10^{-2}$ J

= 0.05 W

20.

Exercise 2.6

1. A

2. C

3. D

4. B

5. C

6. . 4.0 m s^{-1}

7. 40 kg

8. HINT: consider F = Δ p / Δ t. The raindrops and hailstones fall with the same terminal velocity and mass rate. However, the raindrops come to rest upon striking you whereas the hailstones bounce upwards after hitting you. Therefore they have a greater change in velocity. Therefore, the change in momentum is greater for the hailstone. Since the same mass falls in a certain time for both, the impulse is greater for the hailstones and your body will have to exert a greater force on the hailstones.

9. (a) 3.5 Ns (b) 14 N

10.1. 10.(i) 4.0 m s^{-1} (ii) 8000 J

11. 46 %

12. 1800 N

13. 7.0×10^3 N (average is 3.5×10^3 N, minimum is 0)

14. (i) 6.3 m s^{-1} (ii) 5.5 m s^{-1} (iii) 1.2 kg m s^{-1} (iv) 1.2 N s (v) 24 N

15. 600 m s^{-1}

16. v = 4.9 m s^{-1} F = 250 N

17. (a)

(b) The change in momentum for ball B = m vB .

Hence:

FAB Δ t = m vB.

The change in momentum for ball A = m(vA –v).

Hence from Newton's second law:

FBA Δ t = m(vA – v).

Therefore: -m (vA –v) = m vB

Therefore: m v = m vB + m vA.

That is, the momentum before the collision equals the momentum after the collision, so the net change in momentum is zero (unchanged).

(c) From the law of conservation of momentum: v = vB + vA

From the law of conservation of energy:

½ m v2 = ½ m vB2 + ½ m vA2 OR v2 = vB2 + vA2

If vA = 0 , then vB = v .

18. 2.04×10^6 N s

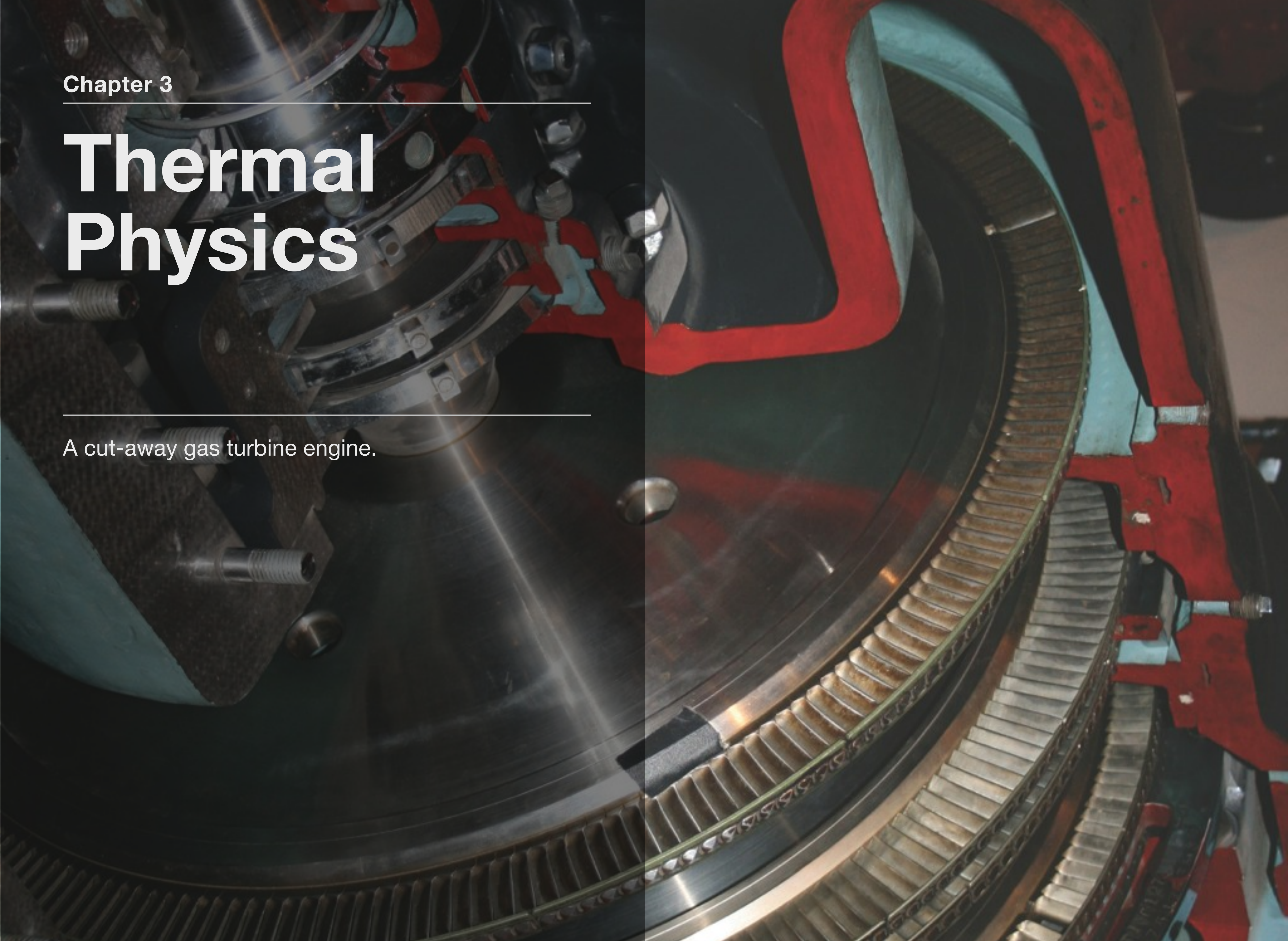
19. 7.66×10^2 m s^{-1}

20.(a) 3.6×10^{-3} kg m s^{-1}

(b) 530 to the initial direction of the first ball

Chapter 3

Thermal Physics



A cut-away gas turbine engine.

Section 1

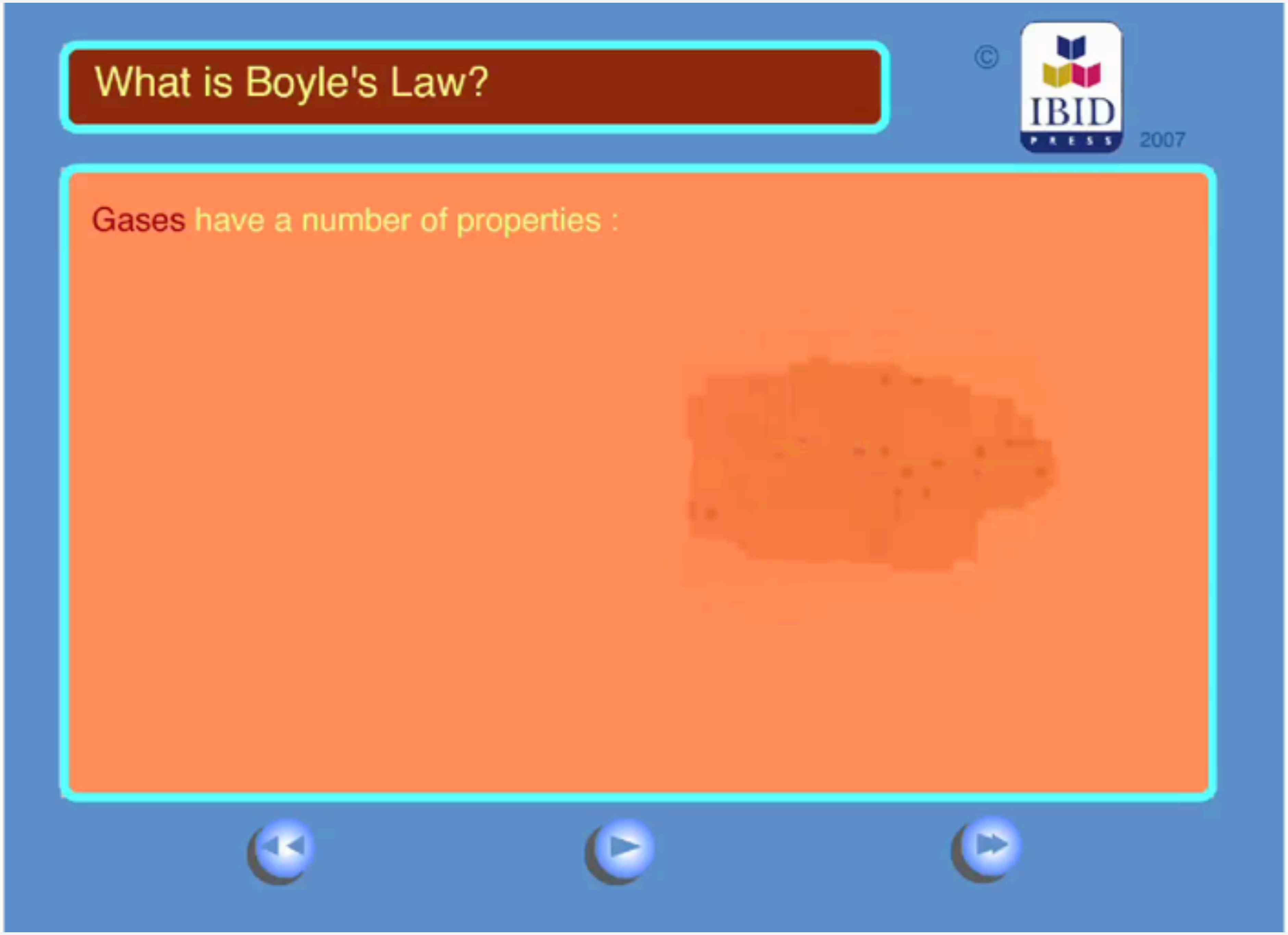
Thermal Physics

CONTENTS

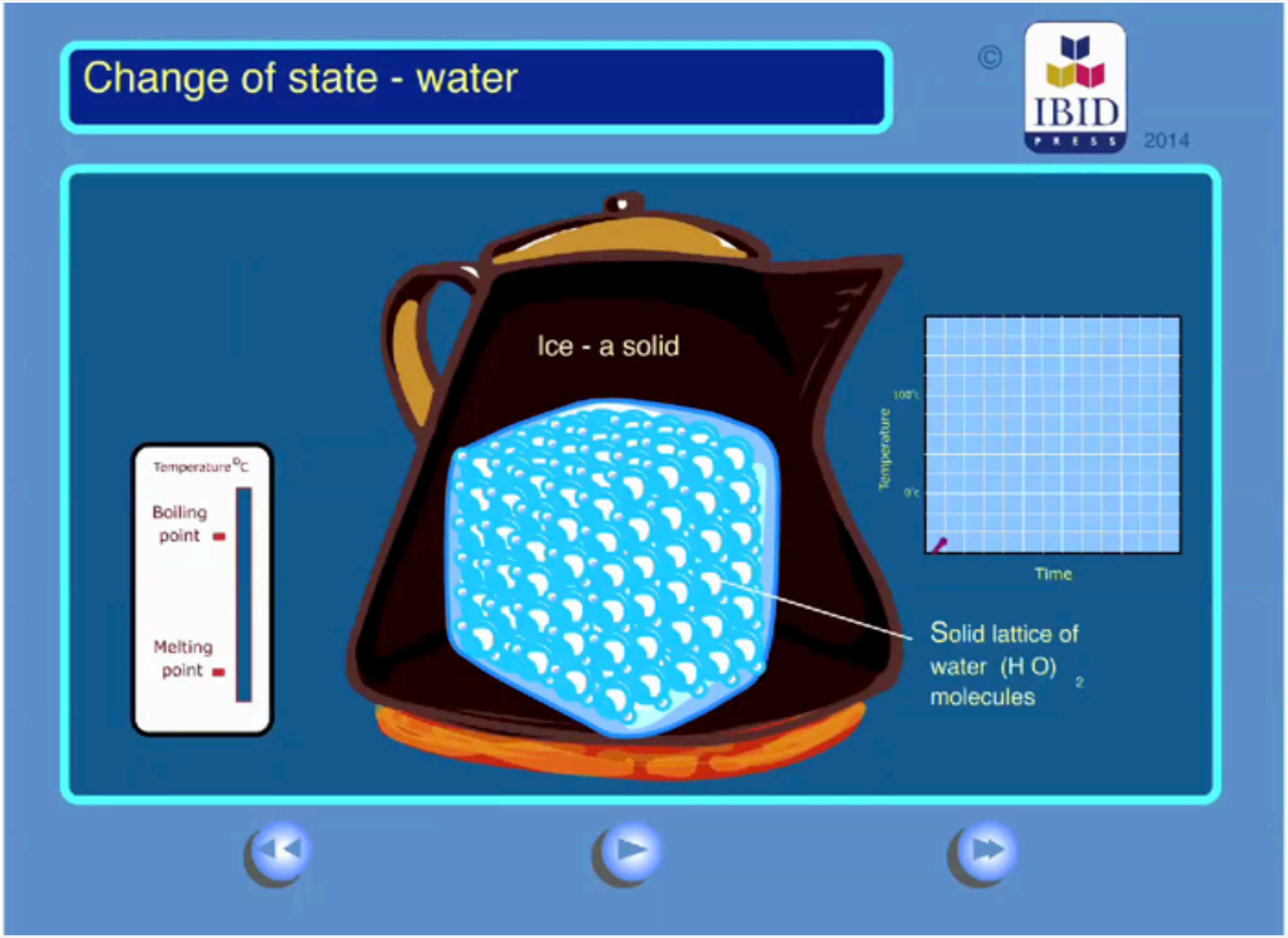
A triple expansion steam engine. The engine is fully functional and powers *TSS Earnslaw* across Lake Wakatipu in New Zealand. The *Earnslaw* was built in 1912, around the time of the *Titanic*.

Additional material

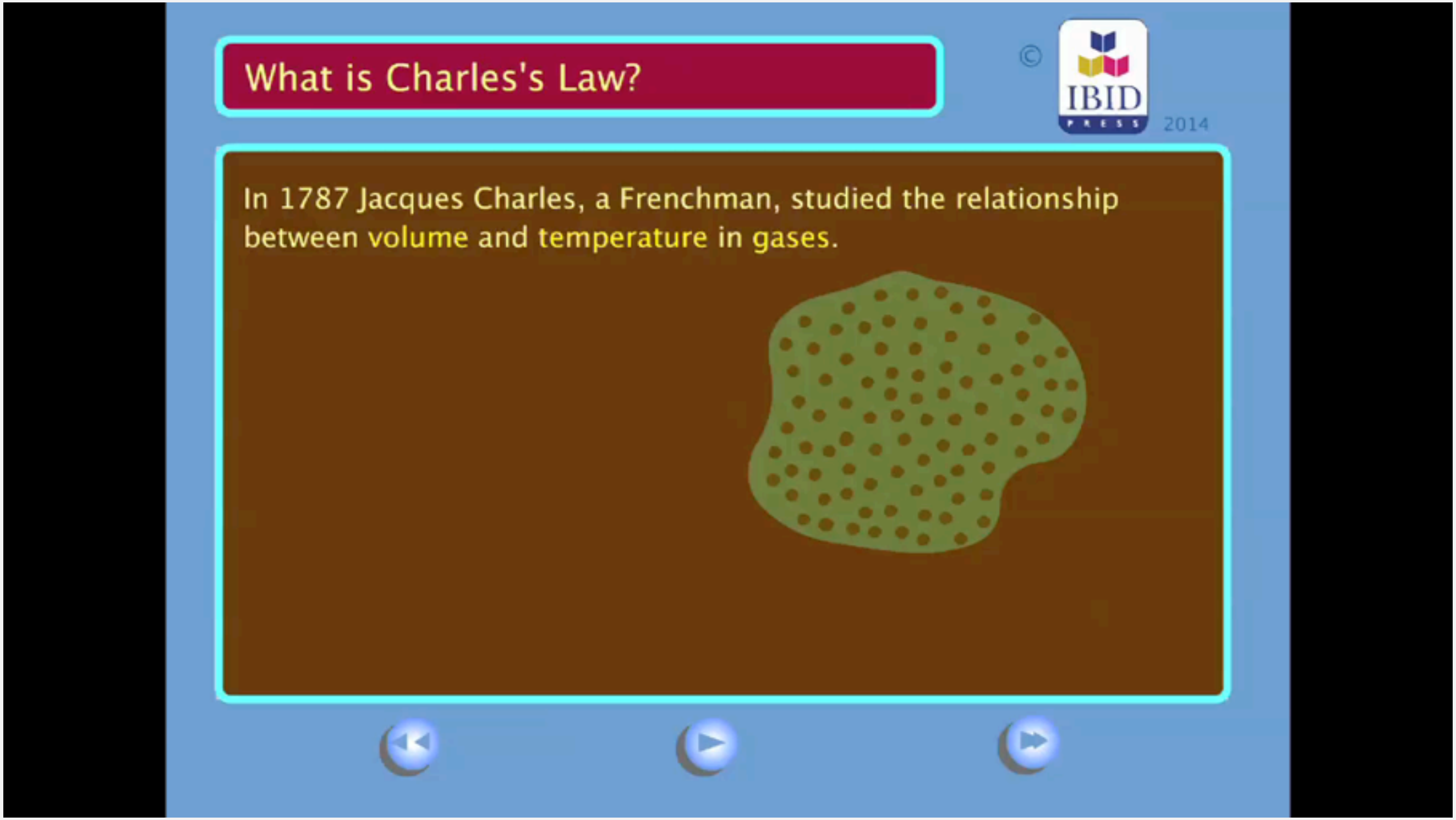
Movie 3.1 Boyle's Law



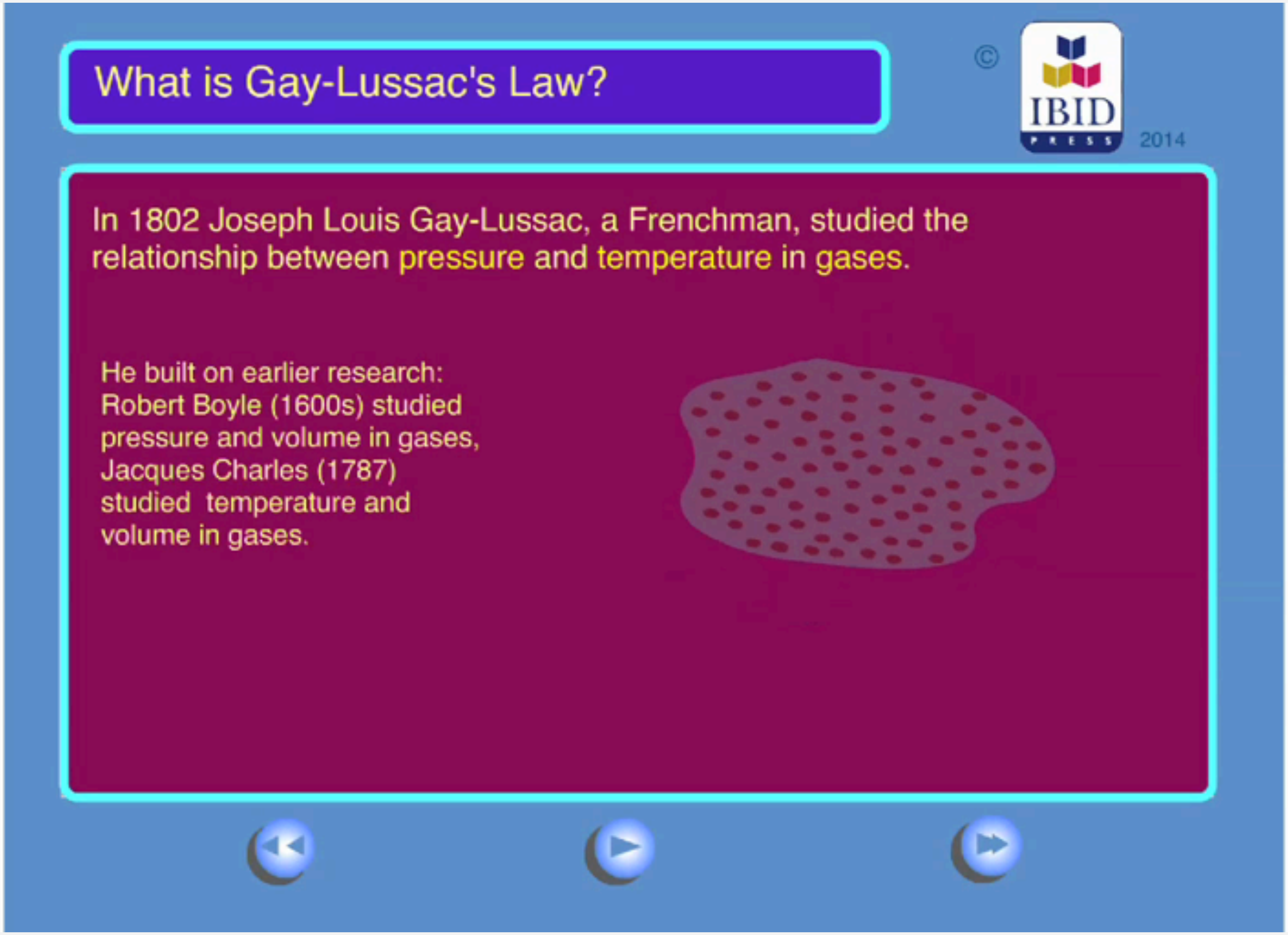
Movie 3.2 Change of State



Movie 3.3 Charles's Law



Movie 3.4 Gay Lussac’s Law



Gallery 3.1 Images of Heat Transfer

This iceberg absorbs the latent heat of melting as it melts.

The Gas Laws determine much of what a scuba diver can do.

The deeper they go, the more rapidly they use air and the more rapidly nitrogen dissolves in their tissues, increasing the risk of ‘the bends’ - decompression sickness.

Gallery 3.2 Some Classic Heat Engines

Replica of ‘Locomotion’

Answers to exercises

Exercise 3.1

1. B .

2. Heat is the thermal energy that is absorbed, given up or transferred from one object to indication of the degree of hotness or coldness of a body. Alternatively, temperature is a microscopic property that measures the average kinetic energy of particles on a defined scale such as the Celsius or Kelvin scales. The chosen scale determines the direction of thermal energy transfer between two bodies in contact from the body at higher temperature to that of lower temperature.

3. Alcohol thermometer, because mercury freezes at low temperatures.

4. i) It is portable and direct reading. Small and not very accurate.

ii) Sensitive, accurate and wide range. Cumbersome, slow and inconvenient

5. 0 °C

6. Ice point is 273 K. Steam point is 373 K.

7. Absolute zero is that temperature at which the kinetic energy of the molecules is a minimum value but not zero.

8. 310 K

Exercise 3.2

1. B

2. C

3. 5.4 Å~ 106 J / (28 kg Å~ 428 K) = 450.6 = 450 $Jkg^{-1}K^{-1}$

4. Molten sodium has a higher thermal conductivity than water.

   This allows for rapid conduction of heat from the reactor.

5. 8.7 x 106 J = 600 kg x 8.40 x 10^2 $Jkg^{-1}K^{-1}$ x (95 – Tf)

   = 4.788 x 10^7 – 5.04 x 10^6 Tf.

   Final temperature = 77.7°C.

6. Wood has a higher heat capacity than metal

7. 3.0 J s^{-1}

8. 1.07 x 10^5 J

9. 8.3 kg

10. 3.0 x~ 10^2 J kg^{-1} K^1

11. 19 °C

12. 40 °C

13. Put it in boiling water for a long period of time, so that temp ~ 100 °C, remove from boiling water and place in a fixed quantity of water in a calorimeter. Then apply equations for conservation of heat energy. The main source of error is loss of heat to the surroundings. This can be minimised by insulating the calorimeter. The value obtained is likely to be higher because of the heat lost to the surroundings.

14. $Q = mc\Delta T$ = 250 kg x 4180 $\text{Jkg}^{-1}\ ^\circ\text{C}^{-1}$ x (71 – 15)°C

= 5.852 x 10^7 J.

If 65% efficient, some heat was lost to the surroundings. Therefore, the heat supplied is 5.852 x 10^7 J / 0.65 = 9.0 x 10^7 J. The fluid releases 4.2 x 10^7 J for 1 kg.

For 9.0 Å~ 107 J it would require 9.0 Å~ 107 / 4.2 x 10^7 = 2.1 kg.

15. 0.30 K

16. 627 m

17. 4.4 K

18. 7.5 kJ.

Exercise 3.3

1. B

2. C

3. C

4. D

5. C

6. A

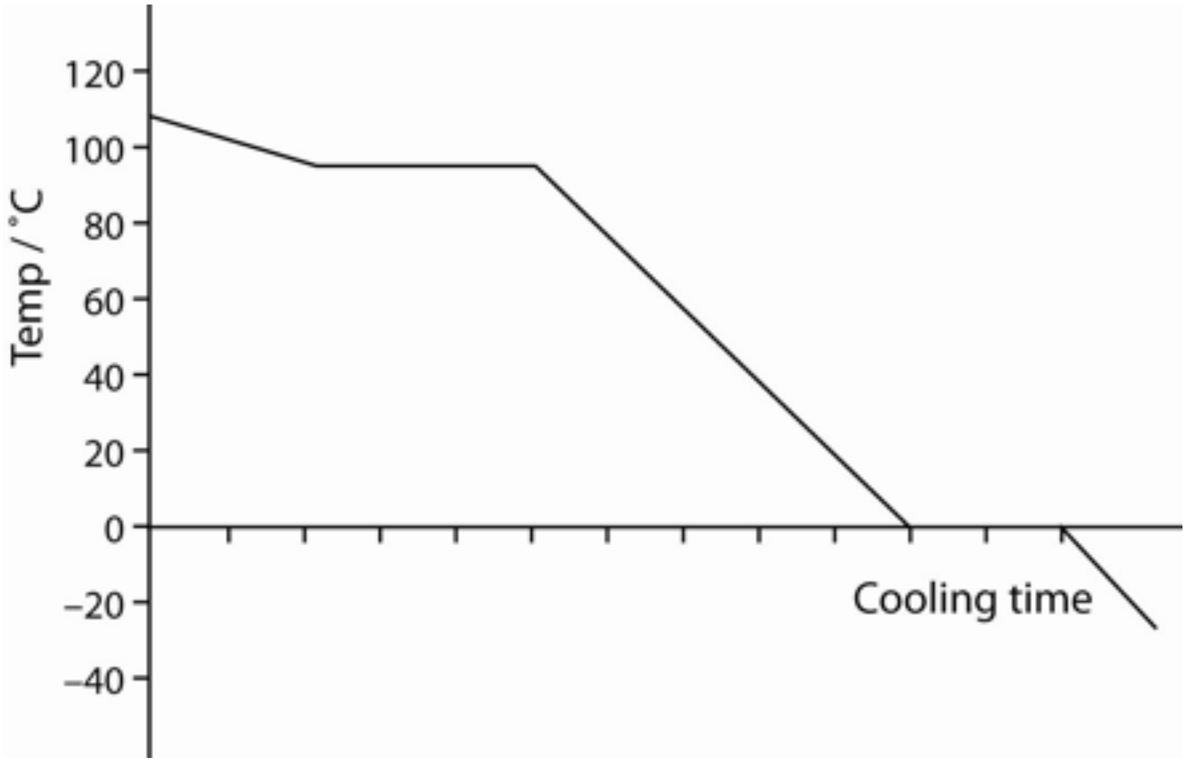
7. Macroscopic – highly compressed, low density, fast diffusion, large pressure

8. (a) kinetic energy only (b) potential energy due to intermolecular forces kinetic energy vibrational and rotational (c) potential energy increases during phase change kinetic energy remains constant

9. Heat is the thermal energy that is absorbed, given up or transferred from one object to another.Temperature is a scalar quantity that gives an indication of the degree of hotness or coldness of a body. Alternatively, temperature is a microscopic property that measures the average kinetic energy of particles on a defined scale such as the Celsius or Kelvin scales. The chosen scale determines the direction of thermal energy transfer between two bodies in contact from the body at higher temperature to that of lower temperature. Heat– transfer of kinetic energy due to a change in temperature (average kinetic energy). Thermal energy– the internal energy of a body of particles.

10. Yes. Ice particles held firmly in a lattice structure by strong forces. High potential energy and some vibrational kinetic energy

11.



12. (a) 336 K (b) –221 °C

13. Air and water have different specific heat values.

14. No. Boiling is a constant temperature process

15. Wrap a towel around it. The water in the wet towel will evaporate and lose thermal energy. To compensate, thermal energy will be taken from the liquid in the bottle and it will become cooler. Evaporation produces cooling.

16. Evaporation of the perspiration results in a loss of thermal energy from the body so that body temperature can be maintained. By standing in a draught your body temperature can be lowered to an unhealthy level due to the increased amount of surface liquid due to the exercise and this can make you susceptible to infections such as the common cold.

17. A small number of particles in a liquid have kinetic energies greater than the average kinetic energy. If these particles are near the surface, they will have enough kinetic energy to overcome the attractive forces of neighbouring particles and to escape the liquid as a gas. Now that the more energetic particles have escaped, the average kinetic energy of the remaining particles will be lower. The temperature of the liquid falls as evaporative cooling takes place.

Exercise 3.4

1. C

2. A

3. D

4. 1.2×10^7 J

5. 0.48 kg

6. Steam has more internal energy as it absorbed latent heat to change phase.

7. Energy required = $mc\Delta T + mL_v$

$=[1.25 \times 10^{-1}$ kg x 4180 J kg^{-1}K^{-1} x (100 – 21 ˚C)]

$+[1.25 \times 10^{-1}$ kg x 2.25×10^{6} J kg^{-1}]

$= 4.13 \times 10^{4}$ J + 2.81×10^{5} J = 3.23×10^{5} J.

Time required = $3.23 \times 10^{5}/5.2 \times 10^{2} = 6.2 \times 10^{2}$ s

8. 4.0×10^{3} J kg^{-1}K^{-1}

9. 0.25 kg

10. 27×10^{2} J s^{-1}

11. You could use an electrical method or the method of mixtures in order to find the page 86.

12. $Q = mL_v = 1.2$ kg . 2.25×10^{6} J kg^{-1} = 2.7×10^{6} J.

13. $Q = mL_V + mc\Delta T_{WATER} + mL_f + mc\Delta T_{ICE}$

$= m [L_V + c\Delta T_{WATER} + L_f + c\Delta T_{ICE}]$

$= 1.5 [22.5 \times 10^{5} + (4180 \times 100) + 3.34 \times 10^{5} + (2100 \times 7)]$

$= 4.425 \times 10^{6}$ J. The energy released is 4.4×10^{6} J or 4.4 MJ.

14. The latent heat of vaporisation can be found using a self–jacketing vaporiser. The liquid to be vaporised is heated electrically so that it boils at a steady rate. The vapour that is produced passes to the condenser through holes in the neck of the inner flask. Condensation occurs in the outer flask and the condenser.

Eventually, the temperature of all the parts of the apparatus becomes steady. When this steady state is reached, a container of known mass is placed under the condense outlet for a measured time t, and the measured mass of the condensed vapour m is determined. The heater current I is measured with the ammeter A and potential difference V is measured with a voltmeter V. They are closely monitored and kept constant with a rheostat.

Exercise 3.5

1. B

2. C

3. B

4. B

5. A

6. C

7. (a) 71 g mol^{-1} (b) 36.5 g mol^{-1} (c) 159.6 g mol^{-1} (d) 106 g mol^{-1} (e) 16 g mol^{-1}

8. (a) 111.6 g (b) 13.1 g (c) 110 g (d) 6.4 x 10^{-2} g (e) 3.9 x 10^{3} g

9. (a) 1.57 mol (b) 0.16 mol (c) 1 mol (d) 0.1 mol (e) 2 mol

11. (a) macro (b) macro (c) micro (d) macro (e) macro

Exercise 3.6

1. D

2. D

3. B

4. D

5. C

6. (a) pV = nRT

15 x 10^{6} x 3 x 10^{-2} = n x 8.31 x 298 n = 181.70 (182)

(b) number = n x NA

number = 181.7x 6.02 x 10^{23} = 1.1 x 10^{26}

(c) average volume = 3 x 10^{-2} / 1.1 x 10^{26} = 2.7 x 10^{-28} m^3

(d) average separation ≈ (2.7 x 10^{-28} m^3) 1/3 = 5.8 x 10^{-10} m.

7. the number of moles = 2 mol. pV = nRT and p = nRT/V

= (2 mol x 8.31x 298) / 0.2 m^3

= 2.5 x 10^{4} Pa.

8. (a) An ideal gas is a theoretical gas that obeys the equation of state of an ideal gas exactly. They obey the equation pV = nRT when there are no forces between molecules at all pressures, volumes and temperatures.

(b) any 3 postulates of the kinetic theory of gases. These could include:

- The range of the intermolecular forces is small compared to the average separation of the molecules.
- The size of the particles is relatively small compared with the distance between them.
- Collisions of short duration occur between molecules and the walls of the container and the collisions are perfectly elastic.
- No forces act between particles except when they collide, and hence particles move in straight lines.

(c) There are no forces between molecules/atoms so there is no potential energy and therefore the internal energy = (random) kinetic energy.

Chapter 4

Waves

A wave from underneath is still a wave!

Section 1

Waves

CONTENTS

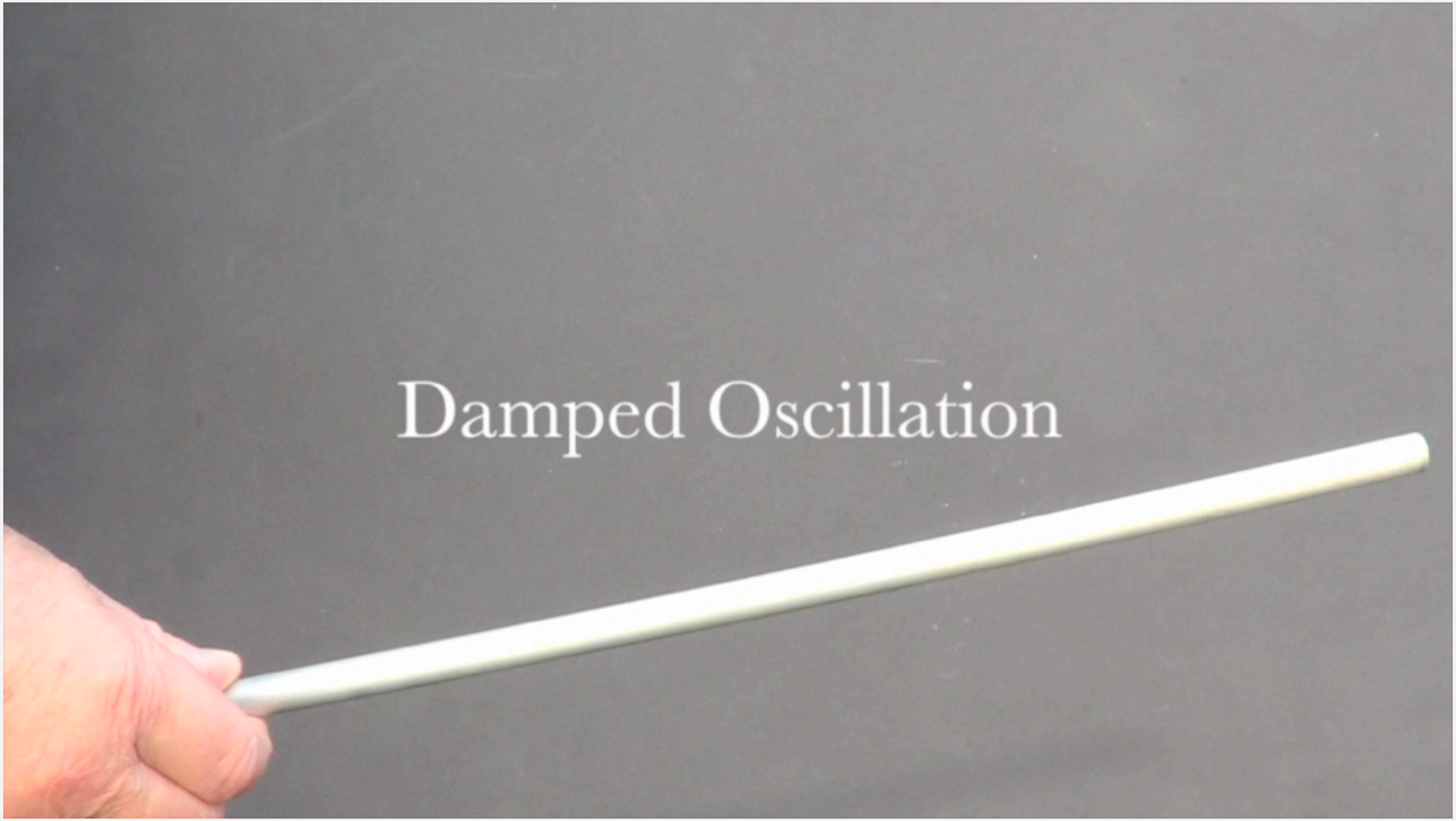
The energy in waves sculpts coastlines.

Additional material

Movie 4.1 Resonance in a bell

Generating a standing wave in a bell.

Movie 4.2 Damped Oscillation



A pipe organ.

The smaller pipes are the higher notes.

A ‘mirror passage’ on the Singapore MRT. One of the few places on the World’s subway systems where travellers linger.

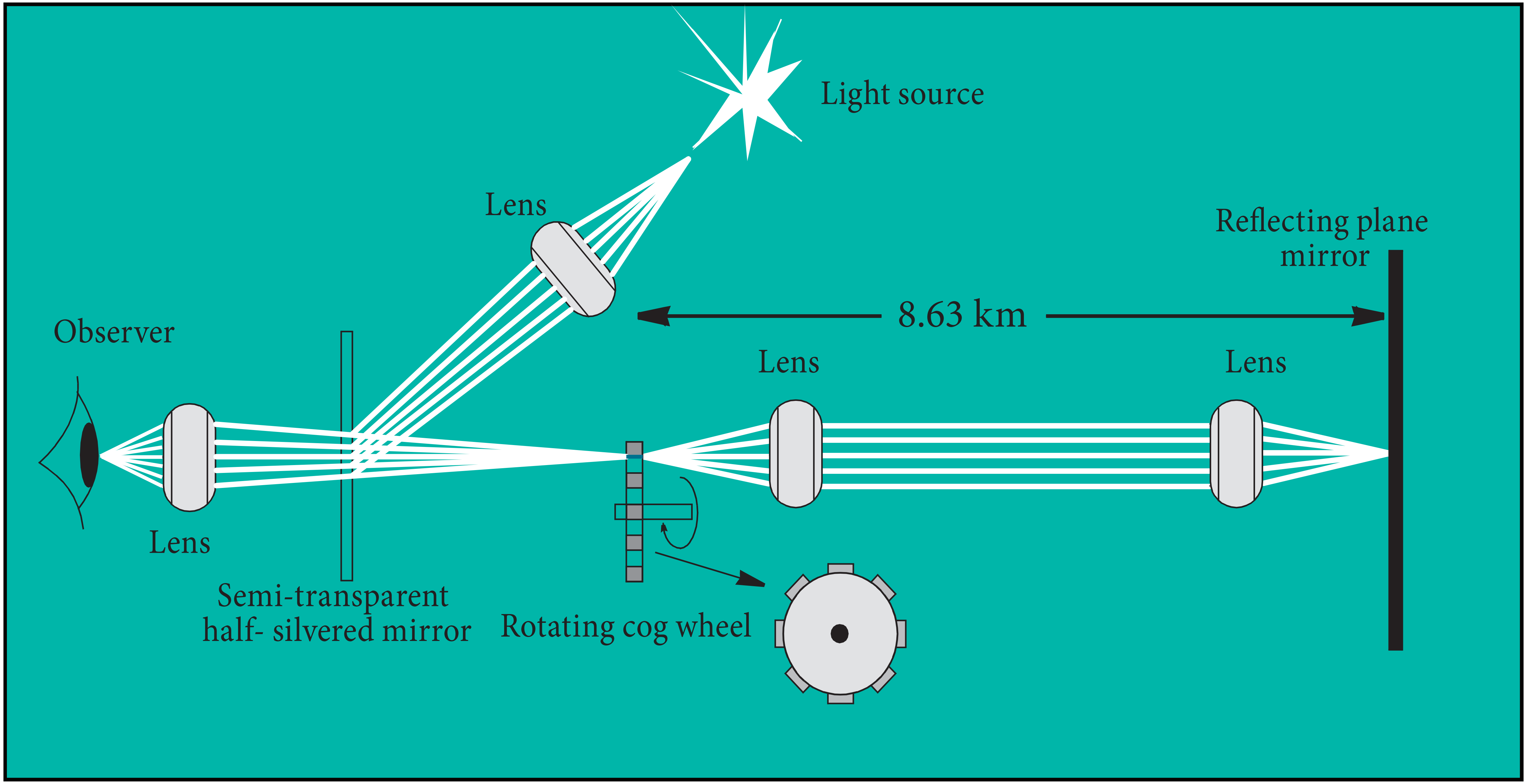


Figure 401 Fizeau's apparatus
to determine the speed of light

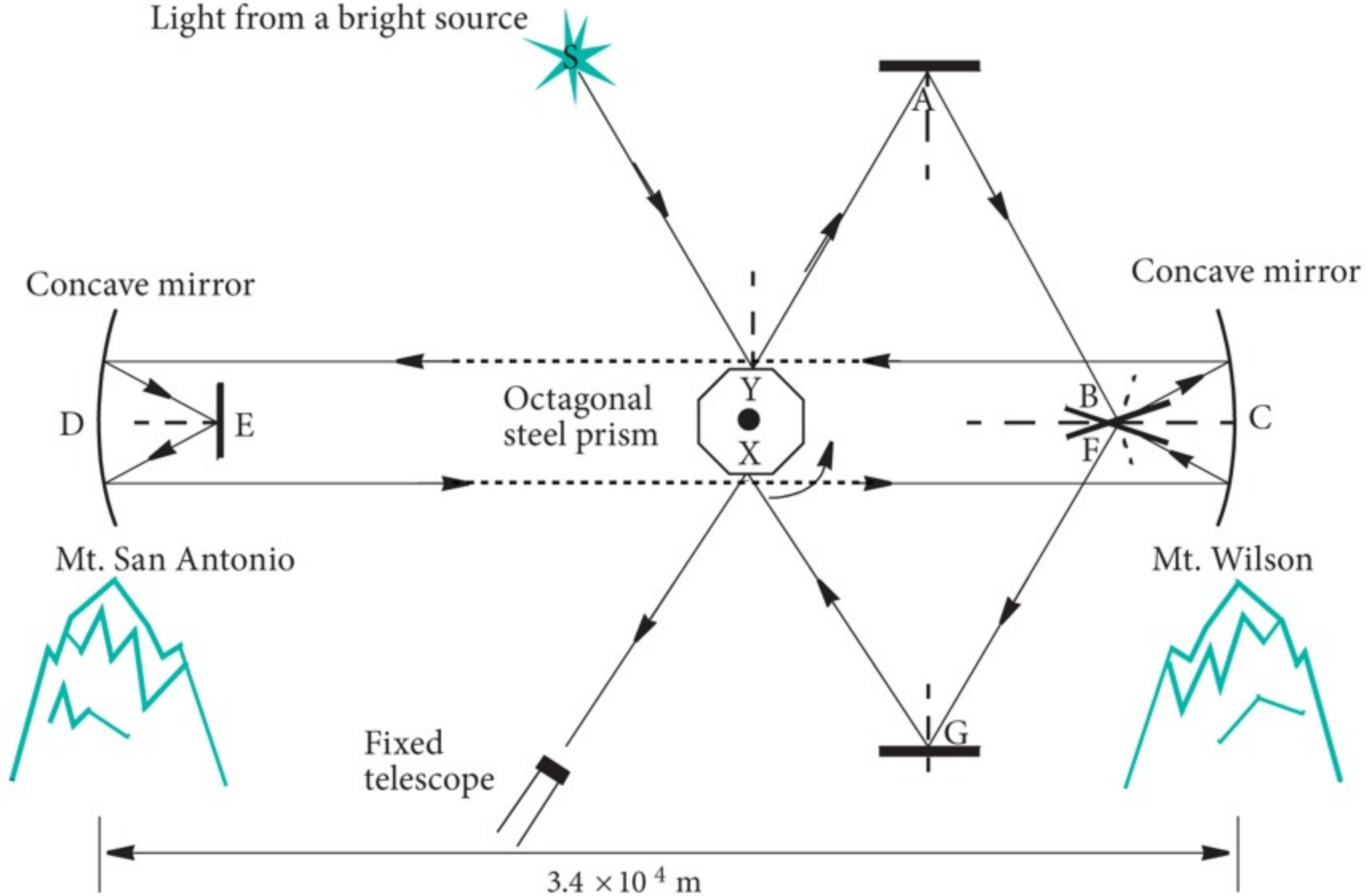


Figure 403 Michelson’s method for determining the speed of light

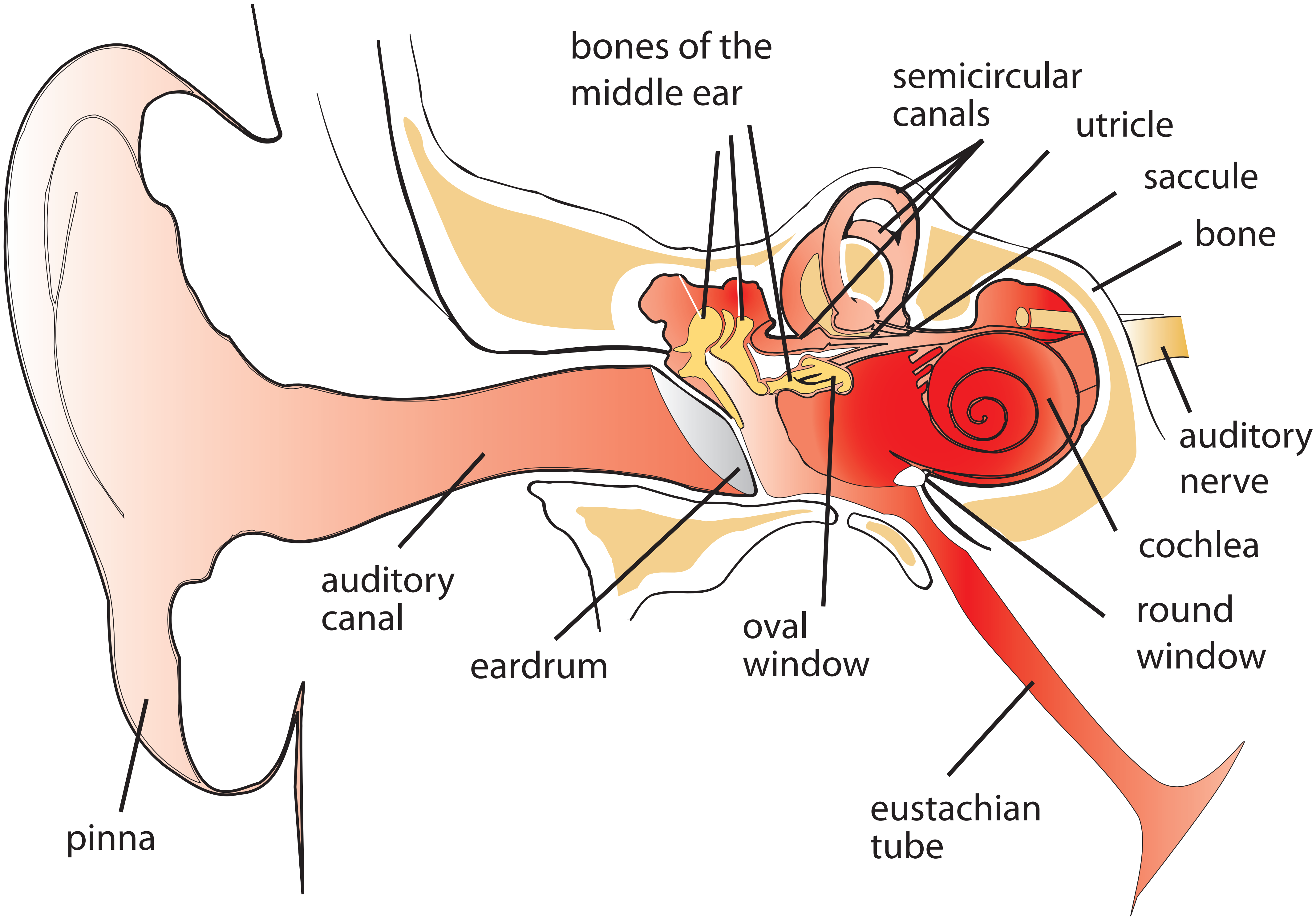


Figure 432 Typical human ear

Answers to exercises

Exercise 4.1

1 (a) (i) 2.4 s

(ii) 6.2 cm

(iii) 61 cm s–2

(b) the velocity is a maximum at t = 0 and t = 1.2s
the acceleration is a maximum at t = 0.6 s and t =1.8 s

Exercise 4.2

10^{-20} J

Exercise 4.3

Lightly damped 1, 3, 5, 8

Heavily damped 2, 4, 6, 7

Exercise 4.4

1. When electrons are accelerated in aerials or within atoms, they produce changing electric fields. These changing electric fields generate changing magnetic fields in a plane perpendicular to the electric field plane. As this process continues, a self–propagating electromagnetic wave is produced. As the charge oscillates with simple harmonic motion, the strength of the electric and magnetic vectors vary with time, and produce sine curves (sinusoidal waves) perpendicular to each other and to the direction of the wave velocity v as shown in the diagram. The waves are therefore periodic and transverse.

2. They are transverse waves. They are periodic waves. They can travel through a vacuum (or through matter). They travel at the speed of light. Characteristics such as reflection, refraction, polarisation, diffraction and interference etc. They have energy (and momentum)

3. (a) 4.3 × _1014 Hz (b) 2.8 × _10–19 J

4. Radio waves

5. Longer wavelengths can diffract more around obstacles.

6. Use the wavelengths listed in Fig 1806 (a) to calculate the range of frequencies (the wave equation) for each wave type and then construct the table.

7. The higher the frequency of x–rays, the greater the penetration.

8. RADIO WAVES

Radio waves are generated by an electric circuit called an oscillator and are radiated from an aerial. A tuned oscillatory electric circuit that is part of a radio/television receiver detects the radio waves.

MICROWAVES

They are produced by special electronic semi–conductor devices called Gunn diodes, or by vacuum tube devices such as klystrons and magnetrons. They are detected by point contact diodes, thermistors, bolometers and valve circuits.

INFRA–RED RADIATION

Is generated by electrons in atoms and the bonds of hot objects. They can be detected by our skin, by thermometers, thermistors, photoconductive cells, special photographic film etc.. . The special photographic film is used to identify heat sources such as human beings trying to hide from the scene of a crime or soldiers moving in a war situation.

VISIBLE LIGHT

Is generated by electronic transitions in excited atoms. Visible light is detected

by stimulating nerve endings of the retina of the eye or by photographic film and photocells.

ULTRA–VIOLET RADIATION

Is generated by excited atoms in the Sun and high voltage discharge tubes. Like visible light UV radiation can cause photochemical reactions in which radiant energy is converted into chemical energy as in the production of ozone in the atmosphere and the production of the dark pigment (melanin) that causes tanning in the skin. It also helps to produce vitamin D on our skin. However, too much UV radiation can cause melanoma cancers. UV radiation can be detected by photography and the photo–electric effect.

X–RADIATION

Generated in high voltage X – ray tubes. X–rays are detected by photography, the photographic plate placed beneath the body can be used to identify possible bone fractures. X–radiation can ionise gases and cause fluorescence. Because diffracted X–rays produce interference patterns when they interact with crystals in rocks and salts, the structure of these regular patterns of atoms and molecules can be determined by this process of X–ray diffraction.

GAMMA RADIATION

Generated in nuclear reactions. Gamma radiation can be detected by an ionisation chamber as found in a Geiger–Müller counter.

9. The standard unit of length, the metre, is now defined in terms of this speed. In 1960, the standard metre was defined as the length equal to 1 650 763.73 wavelengths of the orange–red line of the isotope krypton–86 undergoing electrical discharge. Since 1983, the metre has been defined as “the metre is the length of path travelled by light in a vacuum during a time

interval of 1 / 299 792 458 s". The speed of all electromagnetic waves is the same as the speed of light.

Exercise 4.5

1. C
2. B
3. A
4. C.
5. C.
6. (a) (i) 3.1 m (ii) 1500 m

   ((b) HINT : consider diffraction.

7. The low frequency, long wavelength waves are diffracted more in the open sea environment thus a wider awareness of another ship. Another explanation is that the method of generating the sound involves the production of a very strong pressure pulse.
8. The pressure patterns produced when two tuning forks are sounded together is dependent on their frequencies. If the frequencies are simple multiples of one another, the sounds are 'harmonious' (a fact discovered by the Ancient Greeks) and the pressure pattern is regular (see example graph above). If the frequencies are close to one another, the phenomenon of 'beats' is heard.

Sophia will hear a beat pattern; a series of high and low amplitudes due to the superposition of the two sounds from tuning forks A and B

9. 24.80
10. 1.25
11. 2.00 x 10^8 ms^{-1}
12. 48.8°
13. 25°
14. 51°
15. 44.5

Excercise 4.6

1. D
2. A
3. (a) (i) 384 Hz, 640Hz (ii) 256 Hz, 384 Hz(iii) 2:1

   (b) HINT: consider relative lengths of the pipes

4. 0.27 m

5. 0.53 m

Chapter 5

Electricity and Magnetism

Edison tested a range of possible filaments for the electric light globe.

The are some of his samples in the Smithsonian Institution, Washington DC, USA.

Section 1

Electricity and Magnetism

CONTENTS

The Hoover Dam on the Colorado River, USA. A very large generator of hydroelectric power.

Additional material

Gallery 5.1 Images of Electric Power

Coal awaits export from Gladstone Harbour to the thermal power stations of Asia and the Middle East.

Gallery 5.2 Solar Power Station - Lady Elliot Island, Great Barrier Reef.

The solar array with power station beneath.

Enlarged diagrams

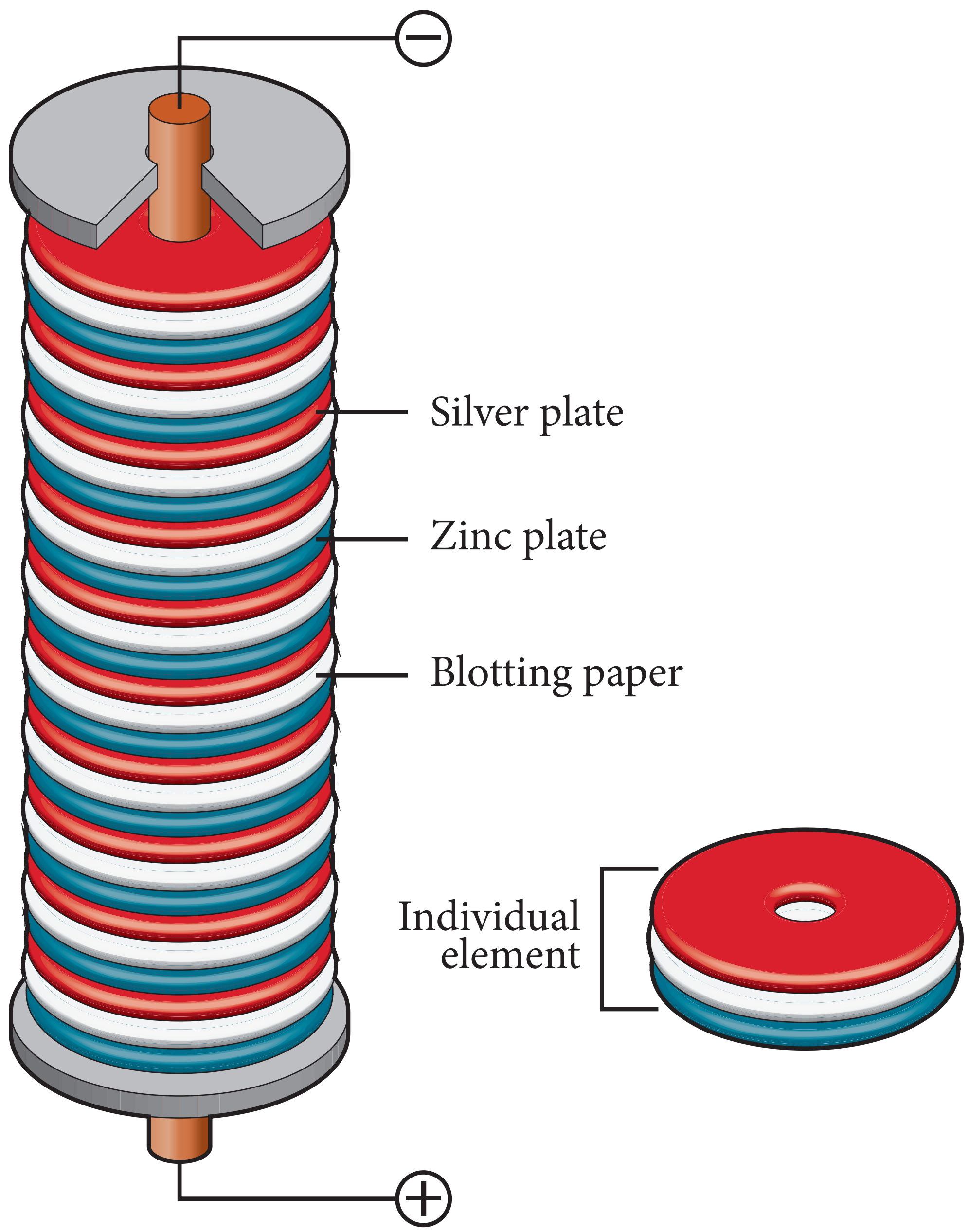


Figure 535 voltaic pile

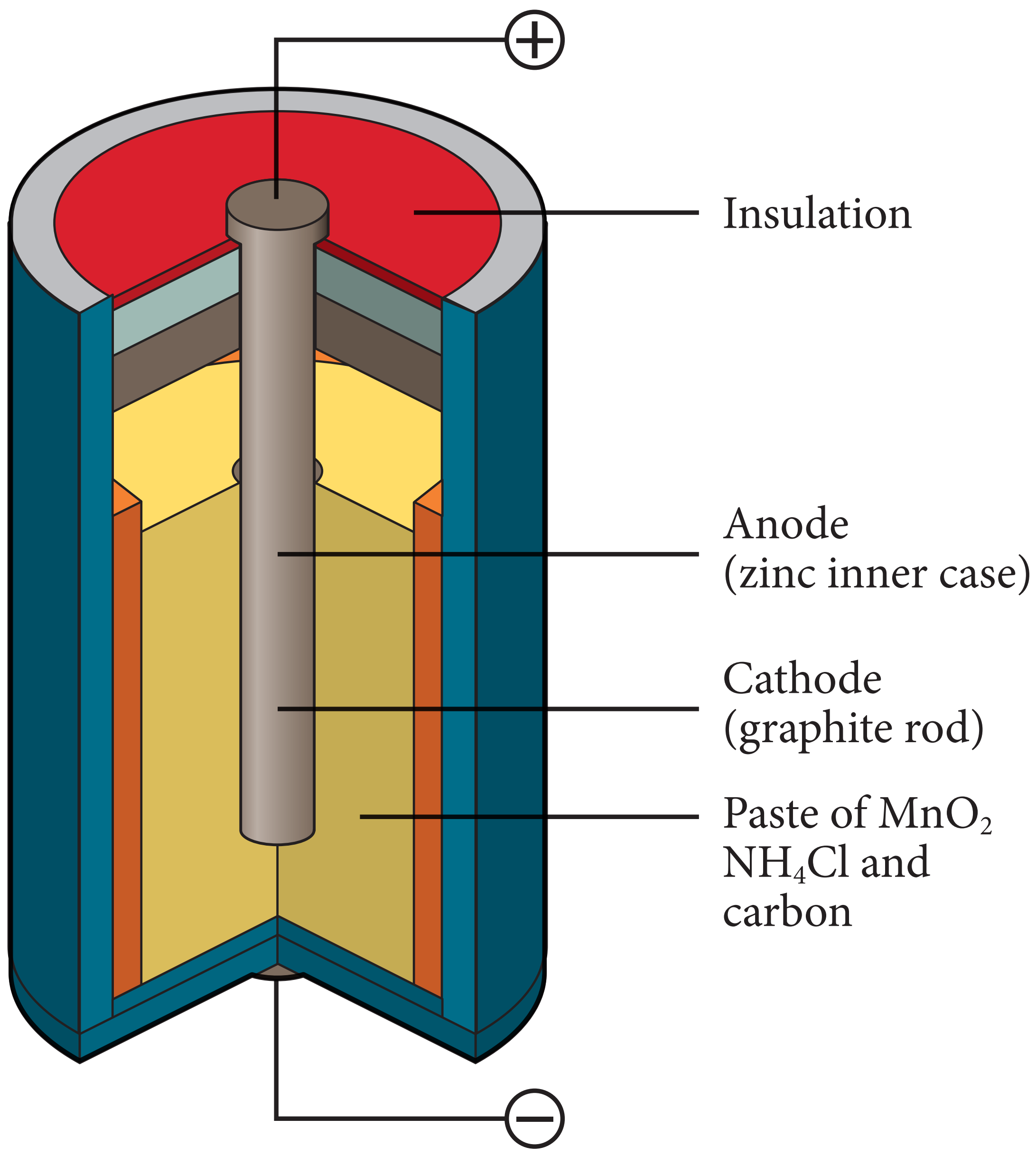


Figure 537 schematic diagram of a dry cell.

Answers to exercises

Exercise 5.1

1. C

2. D

3. B

UNCORRECTED

DRAFT

4. D

5. B

6. C

7. B. (F α 0.5q × 0.5q /¼2 = 16 × 0.25 = 4F)

8. D.

9. C. (F α q1 × q2 F α ½ × ½ = ¼)

10. B. (Charge is a scalar. Potential difference is the work done per unit charge and power is the time rate of doing work. Work is a scalar.)

11. A. F α 1/d2

12. The outside of the tanker can become charged due to air resistance friction. The chain ensures that there is no build–up of charge. If there was an excess of charge, sparking could occur.

13. The droplets of paint all will have the same charge. Therefore, they repel each other causing the paint to spread out.

14. Plastic containers are insulator and can accumulate charge.

15. The conductor (the golf stick) brings electrons from earth through your body. An electrical discharge can occur between the charged clouds and the golf stick.

16. The charge on the inside of a hollow conductor is zero.

17. 64 C

18. 1.2 cm

19. 8.9×10^{3} N C^{-1}

20. 9.5×10^{4} N C^{-1}

21. Similar – region of influence around a body that causes a force when another body is moved in its field of influence. Different – g is force per unit mass and E is force per unit charge.

22. One charge with twice as many lines of electric flux. Electric field of zero closer to the smaller point charge.

23. 1.9×10^{-12} N repulsion

24. 6.2 N at 30° below the line joining BA and to the left.

25. F = k. q1q2 /r^2 = (9.0 × 10^9 N.m^2.C^{-2}).
(+10μC) . (–5μC) / (0.1 m^2)
= 45 N attraction

26. If several point charges are present, the net force on any one of them will be the vector sum of the forces due to each of the others. Since the three point charges are positive, then there will be repulsion on the bottom charge due to each of the top two charges.

The force on the charge on the right angle due to the top two charges is calculated

F_1 $= k.\ q_1q_2 / r^2 = (9.0 \times 10^9\ N.m^2.C^{-2}) \times (+1C) \times (+1C) / (1\ m^2)$

$= 9 \times 10^9$ N

F_2 $= k.\ q_1q_2 / r^2 = (9.0 \times 10^9\ N.m^2.C^{-2}) \times (+1C) \times (+1C) / (1\ m^2)$

$= 9 \times 10^9$ N

The resultant force is given by the vector addition of the two forces that can be obtained by Pythagorean theorem.

$F_{R2} = (9 \times 10^9\ N)^2 + (9 \times 10^9\ N)^2$

$F_R = 12.7 \times 10^9$ N

The direction of the resultant force can be calculated using trigonometry

tan θ = opposite/adjacent = 9×10^9 N / 9×10^9 N = 1

hence θ = 45°

The resultant force is 1.3×10^{10} N in a vertical direction downwards.

27. $5.7 \times 10^6\ NC^{-1}$ away from the charge $E = kq / r^2$

$E = (9 \times 10^9)(5.7 \times 10^{-3}) / 32 = 5.7 \times 10^6\ NC^{-1}$

28. The electric potential at infinity is zero. For convenience, the zero of potential is taken as the Earth's surface.

29. 250 eV or 4.0×10^{-17} J. An electron–volt is defined as the energy gained by one electronic charge when accelerated by a potential of one volt.

30. 0.33 m from the 1μC charge.

Let x = the distance from the 1 μC charge where the magnitude of the electric field equals zero.

kq1 / x2 = kq2 / (1–x)2

1 × 10–6 C / x2 = 4 × 10–6 C / (1–x)2

1 / x2 = 4 / (1–x)2 x2 + 2x – 1 = 0

Factoring (3x – 1) (x + 1) = 0, 3x – 1 = 0, x = 0.3333m from the 1 μC charge.

Exercise 5.2

1. C

2. A

3. B

4. B

5. A

6. B

7. a. electrons
b. Na+ and Cl–
c. charged particles

8. a. collisons with the crystal lattice atoms
b. collisions with lattice atoms transfers energy.

9. 0.2 Ω

10. 5.0×10^{-3} A

11. 1.35 V

12. 280 m

13. 50 m

14. Electrons drift through the lattice, as temperature increases the lattice atoms vibrate more and this increases the probability of collision and hence resistance to electrons has increased.

15. 14400 °C

16. Ohmic: constant resistance, I-V graph is linear through origin;

Non-ohmic: non-linear I-V graph

Appliance	Power (Watt)	p.d (Volt)	Current (Ampere)	Fuse rating needed (3,5,10,13 A)
Digital clock	4	240	1.7×10^{-2}	3
Television	200	240	0.83	3
Hair dryer	550	110	5	10
Iron	920	230	4	5 or 10
Kettle	2400	240	10	13

18. 23 cents

19. 9.3° C

20. $2.86

21. $1.5 . 10^{-6}$ J

22. 2.5×10^{3} eV

Exercise 5.3

1. A
2. D
3. C
4. D
5. A
6. A
7. C
8. A. (1 / R = 1/3 +1/3 + 1/3 = 3/3 R = 1Ω)
9. B. (W = qV V = 18 J / 2 C = 9.0 V)

10.C. (One ampere is defined as the current flowing in 2 infinitely–long wires of negligible cross–sectional area separated by a distance of one metre in a vacuum that results in a force of exactly 2 . 10–7 N per metre of length in each wire).

11. C. (P = VI. If the voltage is constant, power is directly proportional to the current).

12. A. (Closing the switch will create a short–circuit, and the electrons will by–pass lamp 2, other lamps will then be brighter).

13. C. (1/ R = 1 / R1 + 1 / R2 1 / R = R2 + R1 / R1R2 R = R1R2 / R1 + R2)

14. B. (V1 = I1R1 = (100) (2.2 × 10–3) = 0.22 V

V2 = I2R2 = (150) (1.5 × 10–3) = 0.225 V

V1 = –I1r + ε .22 = –(2.2 × 10–3) r + ε

V2 = –I2r + ε .225 = –(1.5 × 10–3) r + ε

Subtracting equations 0.005 = – (0.7 . 10–3)r

r = 7.143 Ω)

15. C. (V = IR I = V/R = 12/2 = 6A)

16. C. (1 / R = ¼ + ¼ = 2/4 R = 2 Ω eff = 2 + 3 = 5Ω

I = 15 / 5 = 3A in 3Ω _resistor = 3Ω × 3A = 9V

Therefore, voltage across XY = 15 – 9 = 6V)

17. a) 22 Ω b) 2 Ω _

18. 2.9 . 10 –3 J

19. a) 24.4 Ω b) 0.5 A
c) 10 V d) 1.2 V e) 0.3 A

20. 4.7 Ω

21. When a dry cell goes "flat" its internal resistance has become large. Therefore it can't really charge it. NiCad batteries have a very low internal resistance. Also dry cell chemistry is not reversible.

22. a) 1.54 V b) 0.74 Ω.

23. I = Δq/Δt (2.40 . 103 C) / (3.0 min) (60 s.min–1) =13.3 A.

The current flowing is 13A.

24. V = IR, /I=R= (240 V) / (6.0 A) = 40 Ω.

The resistance of the iron is 4.0 . 101 Ω.

25. (a) P = V . I = P / V
I = 2.5 × 103 J / 240 V = 10.4 A

The current drawn is 1.0 x 101 A.

(b) W = V.I.t = (240 V) . (10.4 A) .
(7.2 .103 s) = 1.8 × 107 J

The energy consumed is 1.8 . 107 J.

26. Energy consumed = power . time = 2.5 kW . 8 h = 20 kW.h

Cost = (20 kW.h) . $0.14 =$ 2.40

27. (i) Voltage in bottom arm is 100 V

V=IR 100 = I(1.0 Ω+ 3.0 Ω) Current in bottom armI = 25 A

The current entering the top arm = 35 – 25 = 10 A

Voltage in 4.0 Ω resistor = IR = 10 A × 4.0 Ω= 40 V

Voltage in R and 24.0 Ω resistor = 100 – 40 V= 60 V

The current in the 24.0 Ω resistor = V / R = 60 / 24 = 2.5 A

Current in R 10 – 2.5 A = 7.5 A

R=V/I = 60 V / 7.5 A 8.0 Ω

(ii) 40 V – 25 V 15 V

28. (i) 12 V means that it requires 12 J of energy to move 1 coulomb of charge between two points.

(ii) ε = I R =2/5.0 = 0.4 Ω

29 (a)

R ± 0.5Ω	I ± 0.1 A	$1/I$ A^{-1}
2.0	5.0	0.20
6.0	1.7	0.59
12	0.83	1.2
16	0.63	1.6
18	0.56	1.8

(c) the resistance is directly proportional to 1/I OR the resistance is inversely proportional to the current OR other correct statement

(d) the e.m.f. is the slope of the graph

e.m.f. = 10 / 1.0 = 10V

30. From the law of conservation of charge: $I = I_1 + I_2$

From the law of conservation of energy: $V = V_1 = V_2$

From Ohm's law $R = V / I$ ∴ $1/R = I/V$

$1/R = I_1 / V + I_2 / V$ ND $V = V_1 = V_2$

∴ $1/R = I_1 / V_1 + I_2 / V_2 = 1/R_1 + 1 / R_2$

31. a) $R_{ABC} = 3\Omega$ $R_{ADC} = 1.5\Omega$

$1/R = ⅓ + ⅔ = 1$ $R_{AC} = 1\ \Omega$

Effective resistance = 1 + 1 = 2 Ω

(b) Total current $I = V / R_{eff} = 1.5 / 2 = 0.75$ A

Voltage in 1Ω series resistor = (1)(0.75) = 0.75 V

Voltage in each network = 1.5 – 0.75 = 0.75 V

$I_{ABC} = (0.75) / 3 = 0.25$ A $I_{ADC} = 0.75 / 1.5 = 0.5$ A

(c) $V_{AB} = (1)(0.25) = 0.25$ V$V_{AD} = (0.5)(0.5)$ = 0.25 V

(d) 0 V

32. Voltage in the 1 kΩ resistor:
$V = IR = 1000 \times 4.5 \times 10^{-3} = 4.5$ V

Therefore, voltage in the LDR = 4.5 V.

Resistance in the LDR = $4.5 / 4.5 \times 10^{-3} = 1000 = 1$ kΩ

Exercise 5.4

1. During welding processes the iron becomes hot and semi–liquid. When it cools it will often retain the magnetic fields of the Earth or any fields due to the electric currents of the equipment being used at the time (Not ac. currents, only dc.).
2. The magnets cause magnetic induction in the iron casing of the refrigerator causing a force of attraction between them.
3. Draw a diagram to show a north pole of one magnet and the south pole of another magnet side by side. Have the pole with the weaker field strength closer to the other pole. Have the lines of flux coming out of the north pole and going into the

south pole between the poles. Then have other lines of flux radially at the corners of their poles.

4. North pole.

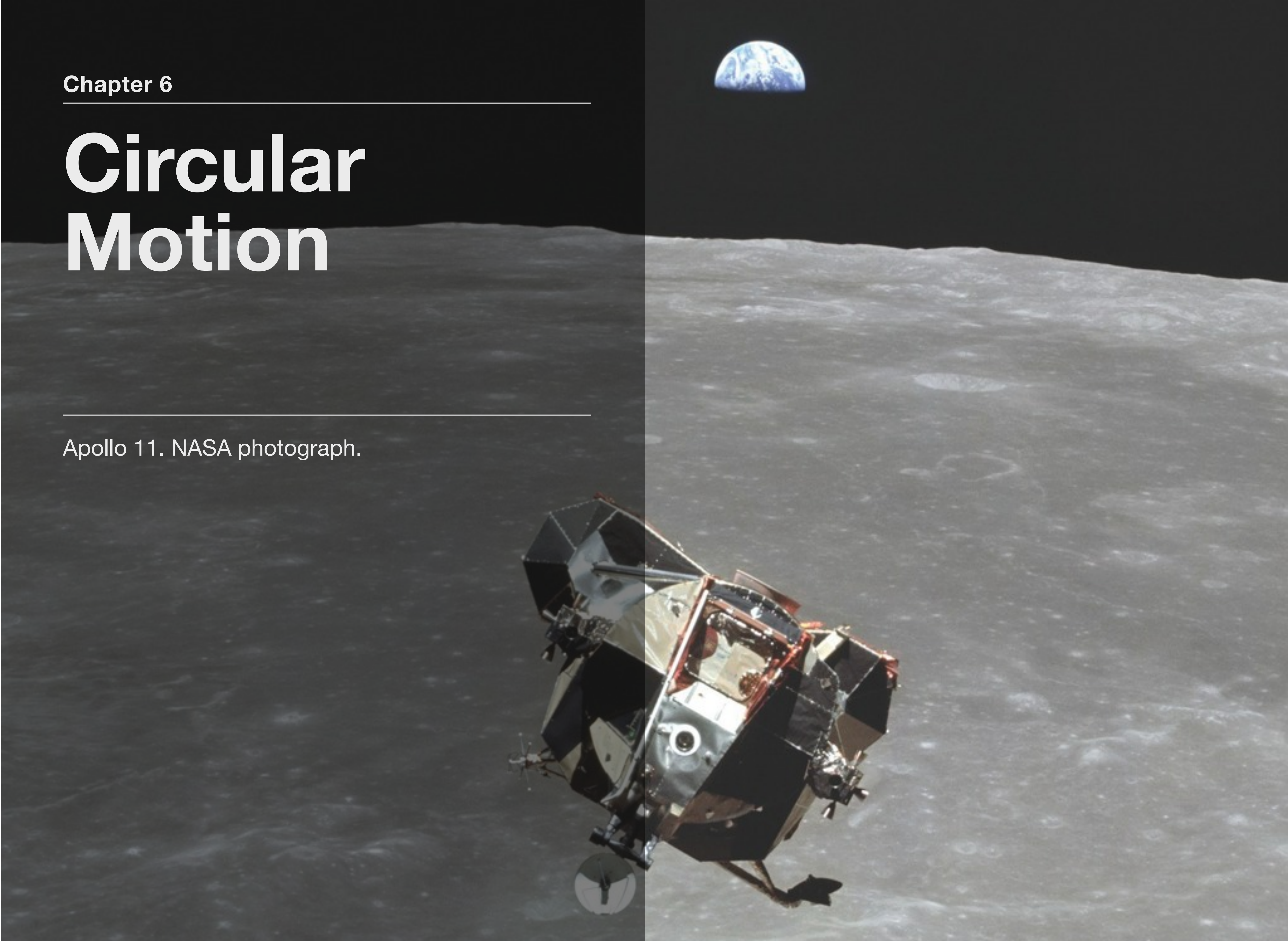
Exercise 5.5

1. B (B = F / Il = kg m s^{-2} / A m)
2. A
3. D
4. B
5. A
6. B
7. D
8. B
9. 1.2×10^{-13} N
10. 7.5 N
11. 1.0 N
12. 3.0×10^{6} m s^{-1}
13. (a) 6.5 × 107 m s^{-1} (b) 0.62 m
14. F = qvB = –15C × 1.0 × 103 ms–1 × of 1.2 × 10–4 T = 0.18 N east
15. (a) B = F / I l = 0.2 N / 1.5 A × 0.5 m = 0.2666 = 0.3 T

    (b) increase the product BI by a factor of 10.

Chapter 6

Circular Motion



Apollo 11. NASA photograph.

Section 1

Circular Motion

CONTENTS

Wheels within wheels...

Enlarged diagrams

Labelling exercises

Internet resources

Answers to exercises

Additional material

Links to some devices that use circular motion

Centrifuges

http://promos.thermoscientific.com/LP=2067?
wt.mc_id=led_centrifuge_bing&wt.srch=1&adwordskeyword=cent
rifuge

http://en.wikipedia.org/wiki/Centrifuge

Youtube search ‘human centrifuge’

http://www.youtube.com/watch?v=9cjzdAdcXsA

http://www.navairdevcen.org/astronauts/index.html

Satellites

http://en.wikipedia.org/wiki/Telstar

http://www.iridium.com/default.aspx

http://en.wikipedia.org/wiki/Global_Positioning_System

Answers to exercises

Exercise 6.1

1. 8.4 m

2. (a) 0.79 rad (b) 4.7 rad

(c) 0.61 rad

UNCORRECTED

DRAFT

3. (a) 7.2×10^{-9} m

(b) 1.2 x 1021 m s^{-2}

4. (a) .14 rad s^{-1}

(b) .64 m s^{-1}

(c) 4.8 m s^{-2}

(d) 9.6 N

5. (a) 52 N

(b) 92 N

6. 20 m s^{-2}

7. (a) 1 m s^{-2} b) 7 N c) .1 s

8. A

9. 2.1 m s^{-2}

10. 6.3 N

11. 19 m s^{-2}

12. see text

13. (a) 55 N (b) 85 N

14. (a) 3 mg (b) 6 mg (c) 9 mg.

Exercise 6.2

1. (a) 6.40×10^{6} m

(b) 6.00×10^{24} kg

(c) 5.48×10^{3} kg m^{-3}

2. 1.25×10^{-9} N attraction

3. (a) 1.09 m s^{-2} towards the earth's centre

(b) 71 N towards the earth's centre

(c) There is no net reaction force between the astronaut and the satellite because they are both accelerating towards the earth at the same rate.

4. C

5. 24.2 N kg^{-1}

6. 2.64 x 10^6 m above sea level.

7. 5.0 km.

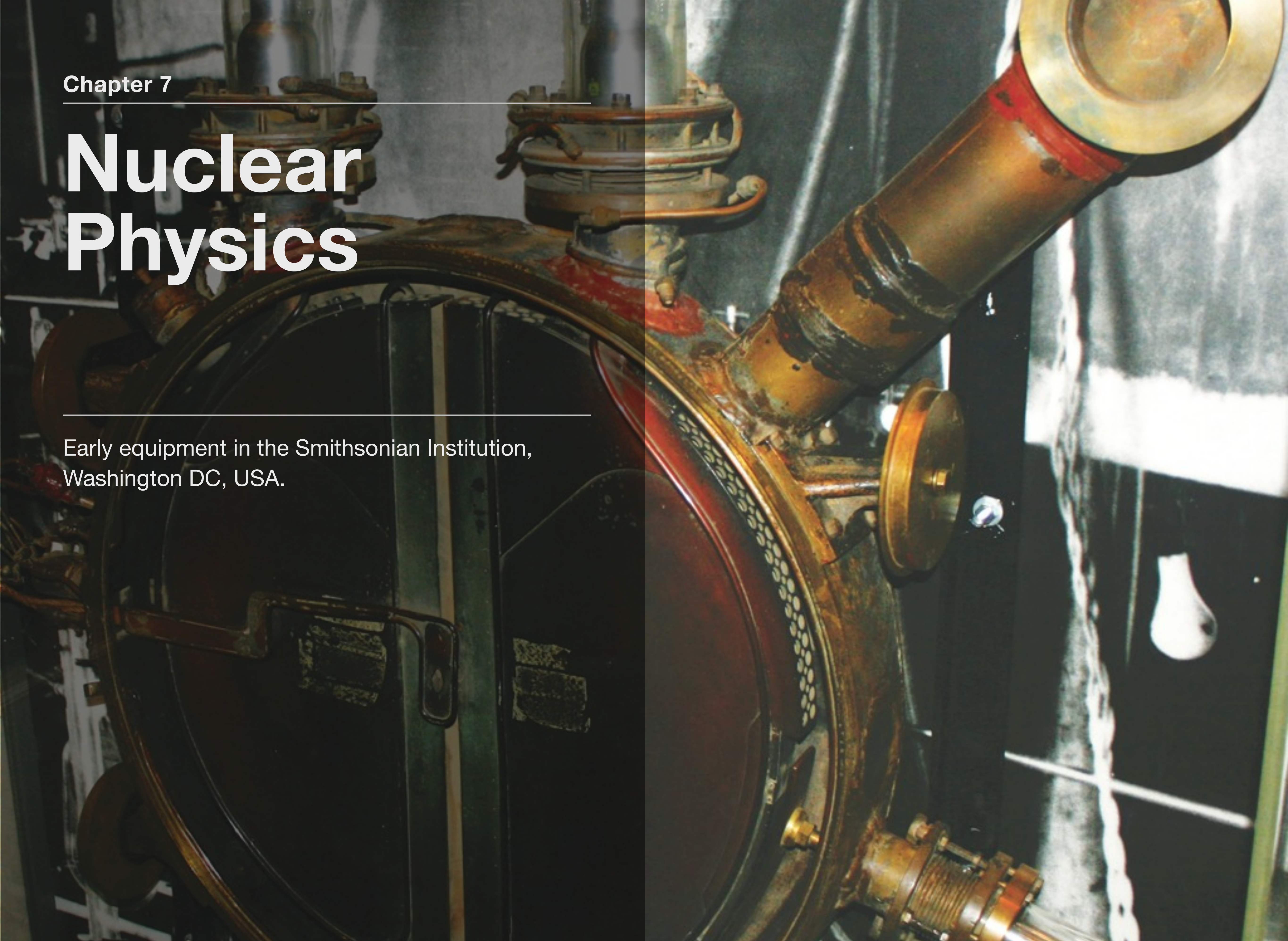
8. 1.87 x 10^{27} kg.

9. 2.0 x 10^{30} kg.

10. (a) 6.28 x 10^3 m s^{-1} (b) 6.0 x 10^{26} kg.

Chapter 7

Nuclear Physics

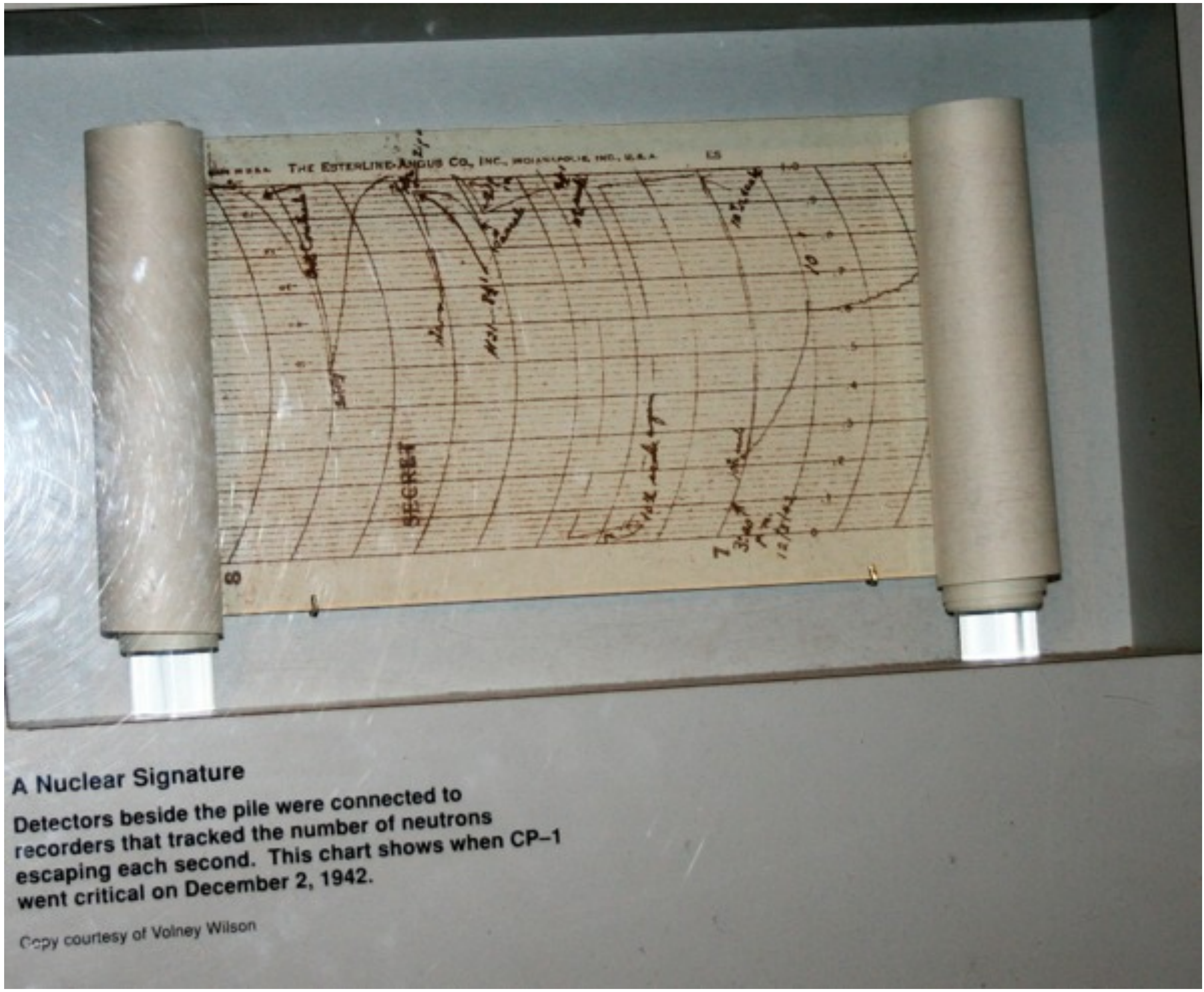


Early equipment in the Smithsonian Institution, Washington DC, USA.

Section 1

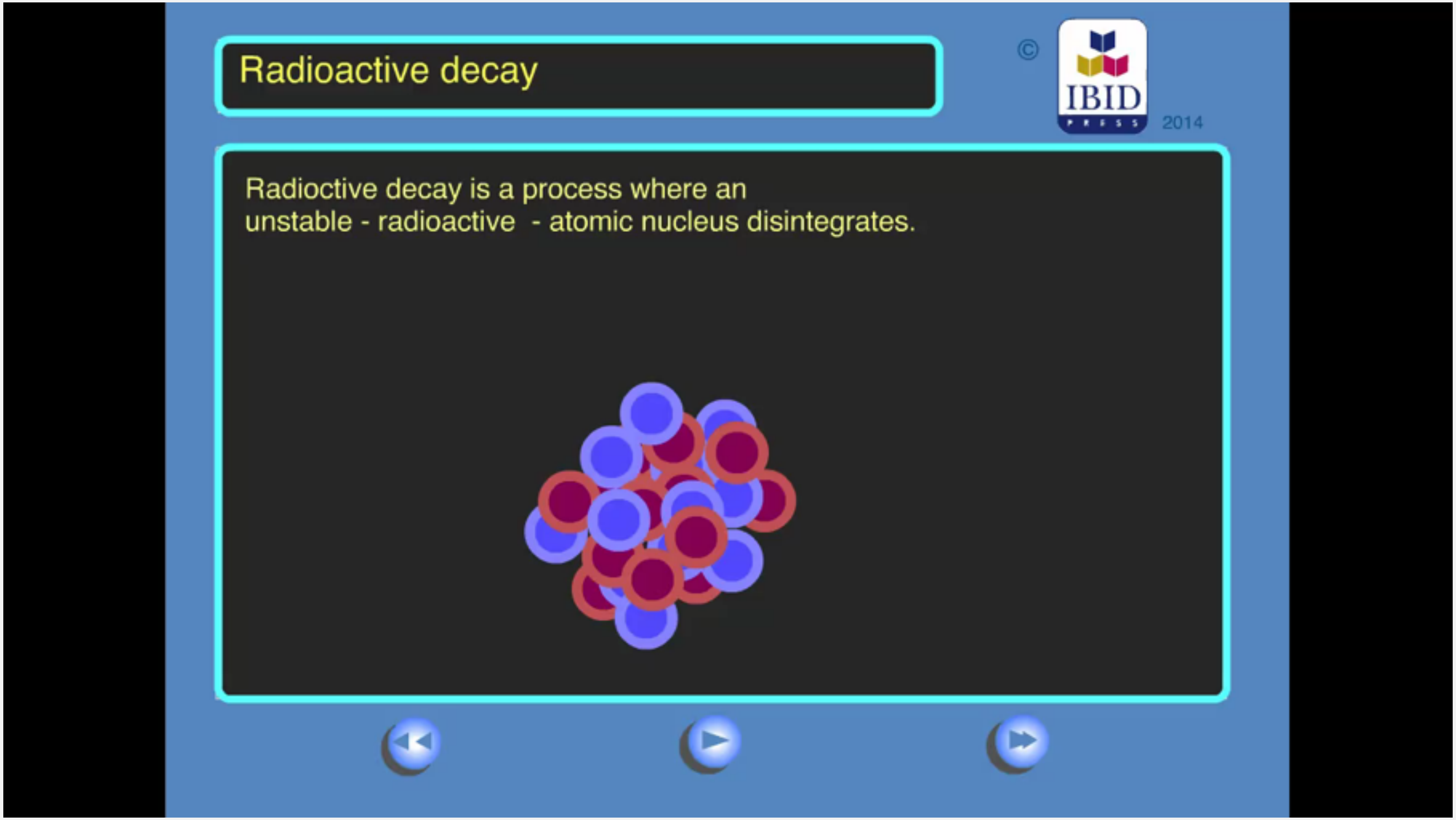
Nuclear Physics

CONTENTS



Additional material

Movie 7.1 Radioactive Decay



What is the difference between a mathematical model and a simulation?

A mathematical model of radioactive decay would work like this:

Suppose we have an element for which 5% of the atoms decay in a ‘time period’. By ‘time period’ we might mean ‘second’, ‘minute’, ‘day’, ‘year’ etc. This is explained in the text. For the moment, we will refer to ‘time period’.

If we start with 100 atoms, in the first time period, $100 \times 0.05 = 5$ atoms will decay, leaving 95 in the sample.

In the second time period, we will have $95 \times 0.05 = 4.75$ atoms decaying and 90.25 left in the sample. Continuing gives:

Time	Atoms
0	100
1	95
2	90.25
3	85.7375
4	81.450625
5	77.3780938
6	73.5091891

Do the ‘fractions of an atom’ matter?

Yes and no. If we really do have 100 atoms, then we should report 90 atoms present at the end of two time periods. However, in line with the principles outlined in the text, we must use the full figure (90.25) for the next calculation. This give 86 atoms at the end of the next time period.

Remember, use full calculator accuracy during a calculation and round appropriately at the end.

The characteristics of this model are that, if it is run a number of times, it will always give the same result.

We say that it has no ‘stochastic’ component. There is no random element in the model.

This is a shortcoming. Every atom has the same probability as every other identical atom of decaying in a given time period. The process is essentially entirely random. It is only the fact that a sample usually consists of billions of atoms and that we are dealing with what mathematicians call a ‘long run proportion’ that the actual observations of radioactive decay usually closely resemble the model.

On the next page, we will consider an alternative approach that is entirely stochastic in its approach and which is usually known as a ‘simulation’.

The spreadsheet Half Life.xlsx contains a block of one hundred random numbers (at left). To the right there is a corresponding block that registers 1 if the random six cells to its left is less than 0.05. This percentage of decaying atoms can be altered in cell F1.

The first run indicates 5 decays in the first period.

	A	B	C	D	E	F	G	H	I	J	K
1	Percent of atoms that decay in one time period:				5						
2	Fraction of atoms that decay in one time period:				0.05		Atoms that decay = 1				
3											
4											
5	0.14722171	0.8077384	0.63590184	0.99711864	0.64744387		0	0	0	0	0
6	0.4016082	0.19148035	0.16340457	0.42909825	0.78014161		0	0	0	0	0
7	0.08920784	0.66288193	0.09145147	0.09624213	0.85560654		0	0	0	0	0
8	0.41301544	0.33269721	0.07036017	0.23840911	0.65114824		0	0	0	0	0
9	0.71060544	0.1539405	0.36701403	0.00181672	0.21909306		0	0	0	1	0
10	0.92649228	0.8353617	0.02970054	0.84473993	0.76035545		0	0	1	0	0
11	0.8316232	0.53890239	0.18400828	0.37548483	0.60367154		0	0	0	0	0
12	0.96899097	0.37607178	0.77450155	0.3700811	0.47084889		0	0	0	0	0
13	0.14292017	0.46094818	0.60160341	0.43644982	0.70640815		0	0	0	0	0
14	0.72770294	0.20874185	0.88125395	0.46224713	0.07807441		0	0	0	0	0
15	0.54374145	0.79726192	0.43043502	0.54401016	0.32208232		0	0	0	0	0
16	0.96305577	0.32360235	0.57139245	0.47995281	0.81667936		0	0	0	0	0
17	0.67164265	0.96975232	0.80297066	0.9626545	0.29908882		0	0	0	0	0
18	0.61946474	0.60996778	0.04697359	0.99271848	0.0112041		0	0	1	0	1
19	0.43940319	0.93958187	0.85335405	0.13743593	0.08194658		0	0	0	0	0
20	0.69588245	0.12833851	0.36597331	0.94784543	0.32573158		0	0	0	0	0
21	0.50764538	0.4374187	0.16727113	0.98262062	0.21360494		0	0	0	0	0
22	0.29020125	0.23988129	0.59335352	0.45231564	0.07201674		0	0	0	0	0
23	0.02294164	0.2098637	0.81216493	0.78328817	0.82955711		1	0	0	0	0
24	0.82147739	0.89000557	0.48165111	0.67292703	0.29614878		0	0	0	0	0

There are now only 95 atoms left, so we must disregard the bottom row (or any row) from here on.

Generate a new set of random numbers by pressing Command = (on the Mac) and you get a new simulation.

	A	B	C	D	E	F	G	H	I	J	K
1	Percent of atoms that decay in one time period:				5						
2	Fraction of atoms that decay in one time period:				0.05		Atoms that decay = 1				
3											
4											
5	0.32031134	0.02913297	0.35315341	0.49047668	0.39372321		0	1	0	0	0
6	0.12024146	0.69263945	0.80734423	0.70960748	0.56465353		0	0	0	0	0
7	0.00372222	0.12490205	0.62205648	0.7077937	0.10353125		1	0	0	0	0
8	0.97518889	0.14406152	0.11468787	0.44884547	0.68328023		0	0	0	0	0
9	0.61589426	0.94385494	0.69701341	0.82655936	0.20346641		0	0	0	0	0
10	0.56593565	0.4546102	0.62745265	0.5544279	0.90216164		0	0	0	0	0
11	0.99468325	0.33137352	0.47765783	0.92033644	0.53709438		0	0	0	0	0
12	0.08428592	0.80443384	0.84518536	0.83700356	0.88254155		0	0	0	0	0
13	0.15912132	0.92053401	0.97682492	0.86723064	0.72377193		0	0	0	0	0
14	0.49153099	0.10500089	0.91972927	0.870297	0.08306554		0	0	0	0	0
15	0.11321138	0.99811293	0.00373346	0.70863298	0.9844169		0	0	1	0	0
16	0.29410711	0.70010702	0.2346087	0.08648629	0.61784501		0	0	0	0	0
17	0.96361547	0.7675627	0.3343632	0.3544574	0.79377923		0	0	0	0	0
18	0.84811469	0.94334797	0.41556094	0.37599502	0.89820776		0	0	0	0	0
19	0.50802696	0.5365381	0.90493799	0.41797063	0.71597315		0	0	0	0	0
20	0.69180063	0.66656455	0.63224805	0.6469926	0.87085013		0	0	0	0	0
21	0.44000302	0.37472562	0.49336489	0.62459024	0.27380561		0	0	0	0	0
22	0.82309156	0.27562096	0.33655184	0.43091408	0.14183554		0	0	0	0	0
23	0.99549163	0.34113126	0.26779894	0.15176673	0.84987421		0	0	0	0	0
24	0.22450334	0.79703801	0.57840354	0.0258574	0.72558871						

The bottom row is blanked out because it represents the atoms that have decayed.

This time, we have 3 decays.

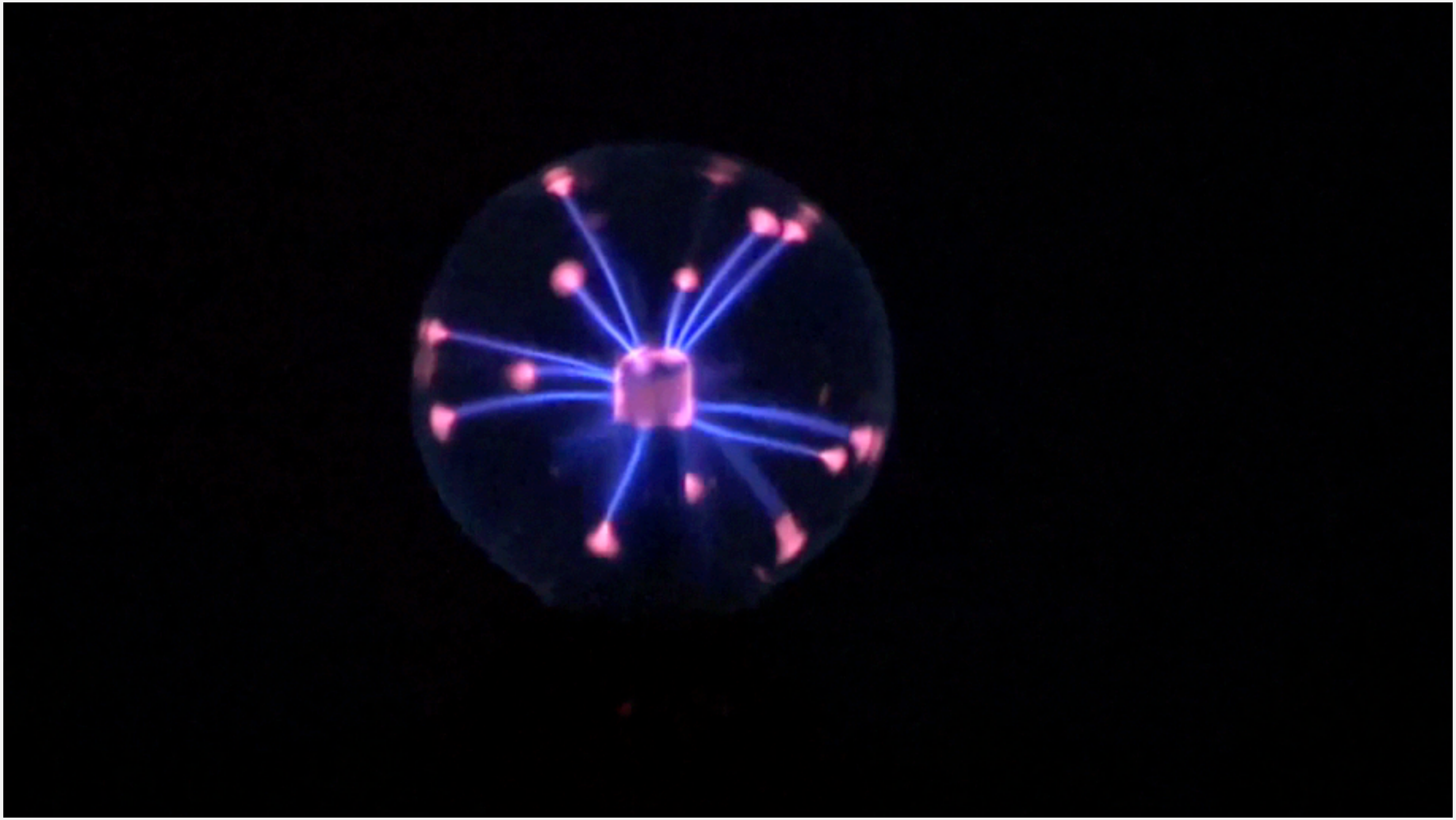
This leaves 92 atoms in the sample and means that in the next time period, we must blank out three more cells.

This is a very simplified simulation. Capable programmers will certainly be able to improve upon it!

Run the whole thing twice and it is unlikely that the results will match.

That is a simulation.

Movie 7.2 Plasma



Answers to exercises

Exercise 7.1

1. C
2. D
3. A
4. A
5. B
6. C
7. 2.55×10^{-19} J
8. 1.5×10^{33} Hz
9. 1.7×10^{-27} kg
10. 3.1×10^{-7} m
11. 6.37×10^{14} Hz
12. The transition occurred between levels 2 and 3.
13. 6
14. (a) 8.166×10^{-19} J
    (b) 4.96×10^{-19} J, 1.60×10^{-19} J, 3.36×10^{-19} J

UNCORRECTED

DRAFT

Exercise 7.2

1. D
2. B
3. D
4. C
5. A
6. C
7. D
8. C
9. 16 hours
10. Although it has a small half-life, it is an alpha emitter. The alpha particles could be taken into the lungs and cause ionisation in the cells.
11. 22.5 hours
12. 10 seconds

Exercise 7.3

1. B
2. A
3. B
4. 30.57 MeV, 5.1 MeV
5. 6.82 MeV
6. Yes
7. x = 2, 180 MeV
8. 0.030266 u, 28.3 MeV, 7.12 MeV.
9. (a) 6, 12, 56

    (b) 41.3 MeV, 6.88 MeV; 92.2 MeV, 7.68 MeV; 49.2 MeV, 8.79 MeV.

(c) Iron-56 because it has the highest binding energy per nucleon.

Exercise 7.4

1 Particles are called elementary particles if they have no internal structure, that is, they are not made out of any smaller constituents. The elementary particles are the leptons, quarks and exchange particles. Composite particles such as the proton are composed of elementary particles. (For the proton, uud quarks).

2. Hadrons (mesons and baryons) are associated with the strong nuclear force. They decay via the hadrionic interaction in 10–10s. Leptons are particles that interact or participate in the weak interaction.

3. (a) Neutrino travels at the speed of light. It has no charge, spin of . ,and their mass is much much less than the rest mass of the electron.

   (b) In beta–decay n → _p + e– + ?. The energy of the beta particle is lower than expected. The law of conservation of energy seemed to be violated. Fermi suggested that the missing energy could be accounted for by predicting and ultimately finding the neutrino.

4. C

5. C

6.

positron, charge +1, lepton.

down quark, charge –1/3.

plus pion, charge +1, meson.

elctron neutrino, charge 0, lepton.

lamda, charge 0, baryon.

sigma–plus, charge +1, baryon.

antitau, charge +1, lepton.

xi–zero, charge 0, baryon.

minus–kaon, charge –1, meson.

gluon, charge 0, gauge boson.

omega–minus, charge –1, baryon.

photon, charge 0, gauge boson.

antimuon, charge +1, lepton.

Z gauge boson, charge 0.

antimuon neutrino, charge 0, lepton.

anti–up, charge –2/3, quark.

tau, charge –1, lepton.

charm, charge +2/3, quark.

7. (a) conserved
   (b) conserved
   (c) not conserved
   (d) not conserved.

8. A

9. All particles have antiparticles which are identical to the particle in mass and half–integral spin but are opposite in charge to their corresponding particle. Antiparticles have antimass.

10. Baryons are usually much heavier than mesons.

11. a) eutron) roton and electron
    c) roton (since it is heavier).

12. proton – uud – 2/3 + 2/3 + –1/3 = 1 neutron – ddu – –1/3 + –1/3 + 2/3 = 0.

13. (a) When matter (such as an electron) collides with its corresponding antimatter (such as a positron), both particles are annihilated, and 2 gamma rays with the

same energy but with a direction at 1800 to each other are produced. This is called pair annihilation.

(b) Total energy of the photons is 1.022 MeV, therefore the energy of each photon is 511keV

(c) the direction is the same as the vector sum of the momentum of the electron and the positron. (d) 2.5 × 1020Hz

14. C

15. a) 3.01 × 10 –10 J b) 3.09 × 10 –10 J.

16. 1.88 × 103 MeV.

17. Photons emitted by one electron cause it to recoil, as it transfers momentum and energy to the other electron. Then the second electron undergoes the same process almost immediately. The closer two charges are, the more energetic the virtual photons exchanged, while the further away two charges are, the less energetic their virtual photons. Because the exchange must be very rapid, the photons exchanged are called virtual photons, suggesting they are not observable. These virtual photons are said to carry the electromagnetic force, or in other words, to mediate the force.

18. (a) a muon neutrino interacts with a photon exchange particle to become a muon.

(b) a down quark emits an exchange particle and becomes an up quark. This is an example of a flavour change as it transforms into a member of another generation.

(c) a positive muon emits a W+ particle and becomes an anti–muon neutrino. The W+ particle changes to particle–antiparticle pair in the form of an positron and an electron neutrino.

(d) a positive minus–pion decays into a negative muon and a muon neutrino. The down quark and the antiup quark annihilate to produce a W– particle. Note the backward direction of the antidown quark. The W– then decays into a negative muon and a muon neutrino.

19. B

20. D

21. Z0. Neutrinos mean the weak force is involved. Because the electron remains an electron and there is charge, the Z0 would be involved.

22. See text.

23. See text.

24. (a) yes

(b) no. charge and lepton number not conserved.

(c) no. charge not conserved.

(d) no. lepton number not conserved.

(e) no. lepton number is not conserved.

(f) yes.

(g) yes.

(h) yes. Strangeness is not conserved but it can take place via the weak interaction.

(i) no. since this is a decay, the mass of Λ0 must be greater than the some of the product masses. Energy is not conserved.

Chapter 8

Energy

Energy galore at Iguazu Falls, South America.

Section 1

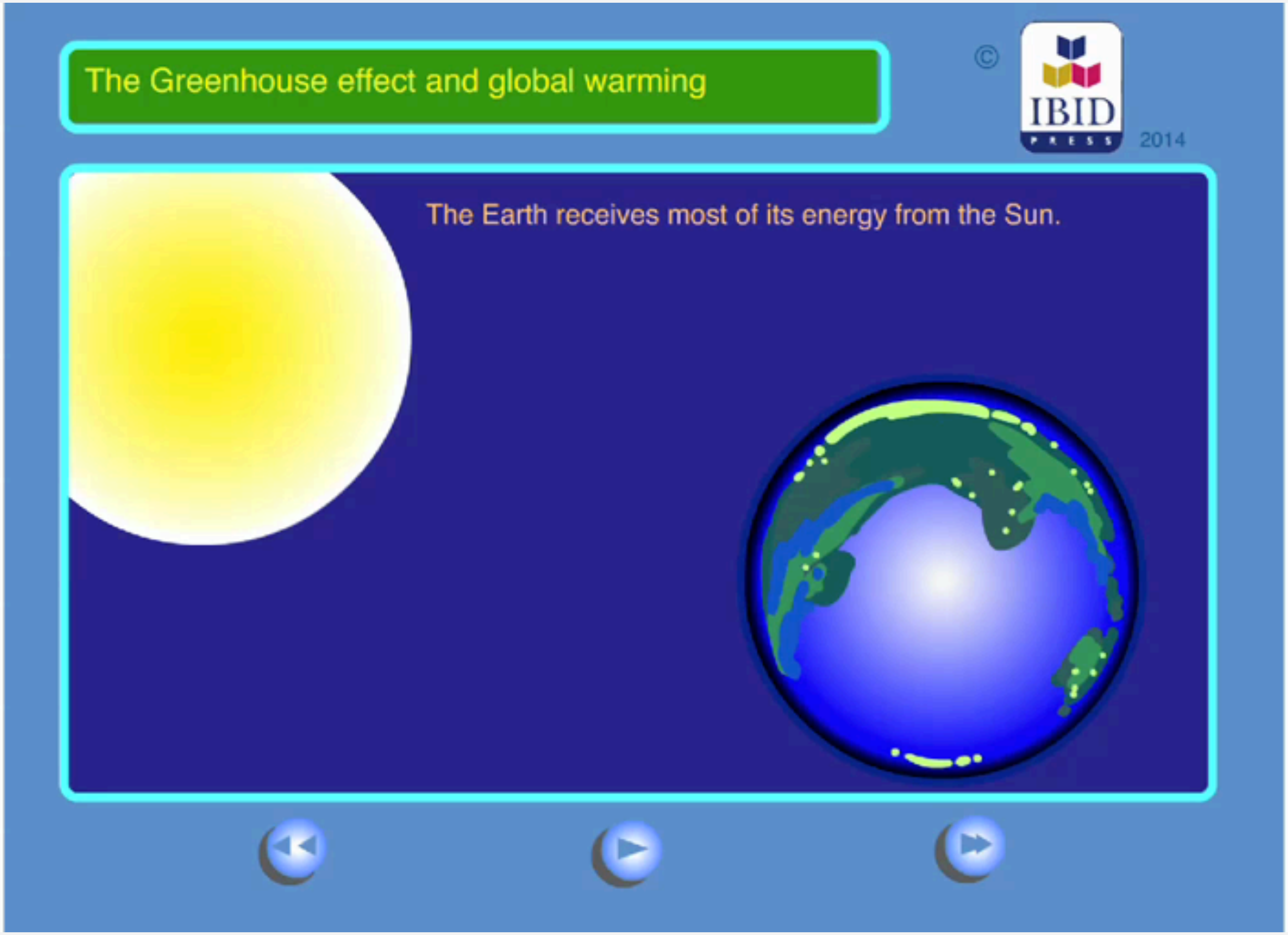
Energy

CONTENTS

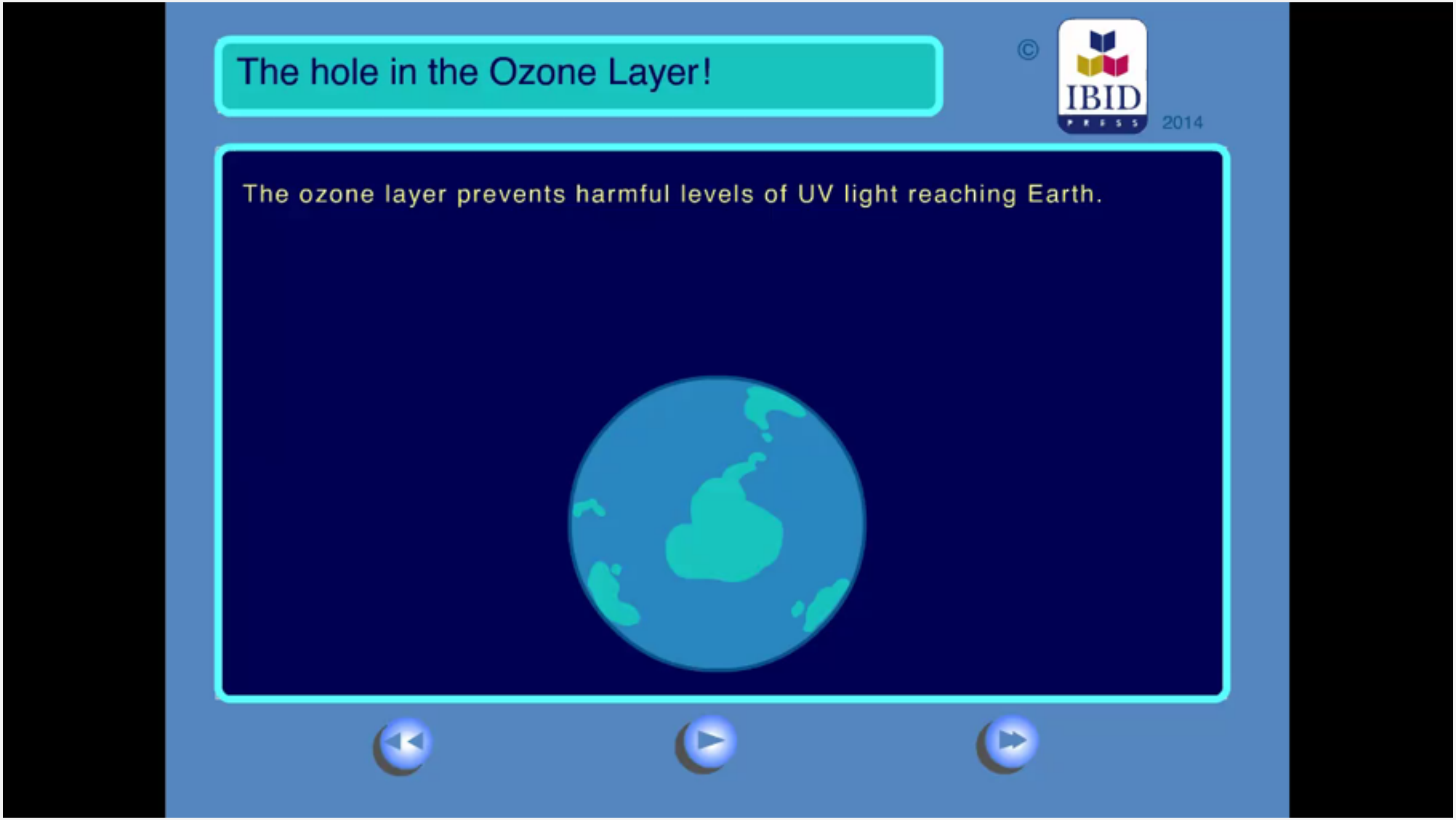
A small hydro-electric power station - Clyde Dam, New Zealand.

Additional material

Movie 8.1 The Greenhouse Effect



Movie 8.2 The Ozone Hole



Movie 8.3 Water Power untapped at Iguazu Falls, South America.

Control over energy has allowed us to turn night into day.

Gallery 8.1 A coastal windfarm in Western Australia

Gallery 8.2 Huge Tidal Flows in The Kimberley, Western Australia.

Internet resources

Exercise 8.1

1. D

2. A

3. C

4. D

5. D

6. B

7. Approximately 15% lost in furnace, 40% lost in heat exchanger, 10% lost as friction in turbine and the generator, 35% output as electrical energy. Therefore the power station is about 35% efficient.

8. Chemical to thermal and light

   Chemical to thermal and kinetic

   Sound to electrical

   Chemical to thermal and kinetic and sound

   Electrical to light and thermal

   Electrical to light

   Electrical to thermal

   Electrical to sound

   Thermal to electrical

   Nuclear to thermal, sound and light

Exercise 8.2

1. B

2. C

3. D

4. It is determined in joules per gram J g $^{-1}$ or kilojoules per gram kJ gas bomb calorimetry is used to determine the value and this technique requires only small masses of a sample. A mole can be a large mass. And we buy fuels by mass/volume not moles thus it is more useful to use this unit.

5. To increase the surface area of the coal to allow for a greater rate of combustion.

6. Energy required to convert the water to steam = $mc\Delta T + mLV$. Since there is 65% moisture content, there is 65 g of water per 100g of coal. The heat energy absorbed to turn 65 grams of water into steam would be:

   $Q = 65g\ x\sim\ 4.18\ Jg^{-1}\ K^{-1}\ .\ (100\ ^{\circ}C - 20\ ^{\circ}C) + 65g\ .$

$(22.5 \times 10^2 \text{ J g}^{-1}) = 167986 \text{ J} = 168 \text{ kJ}$

The energy density in the other 35 grams of lignite is

$28 \text{ kJ g}^{-1} \times 35 = 980 \text{ kJ}$

The total usable energy in 100 grams = 980 – 168 kJ = 812kJ

For one gram this would be 8.1 kJ g^{-1}

The energy density as it is mined will be 8.1 kJ per gram less than when the coal is dried. = 28 kJ g^{-1} – 8.1 kJ g^{-1}

The energy density of the coal as it is mined is 19.9 kJ g^{-1} .

7. (a) Assuming the hydrogen and oxygen is converted to steam, the total amount of steam

= 30% + 30% of the remaining 70% = 51%

51% of 1000 tonnes = 510 tonnes.

(b) 510 Å~ 24 Å~ 7 = 8.6 x 104 tonnes

(c) 1 tonne = 1000 kg 1dm3 = 1kg

8.6 Å~ 104 tonnes . 1000 = 8.6 . 107 dm3

8. Crude oil is used in the petrochemical industry to produce many products such as plastics, polymers, pharmaceuticals, synthetic textiles and fabrics. Other fuels such as LPG and LNG have a higher energy density than petrol and there are more supplies of gases than crude oil. The petrol engine is only 25% efficient and a greater efficiency can be obtained from cars that run on liquid petroleum gas. LPG is cleaner than petrol as it burns more efficiently and it contains less pollutants. In the future, the petrochemical industries will need feedstock to continue to produce products for consumers.

9. (a) $C_5H_4 + 6\ O_2 \rightarrow 5CO_2 + 2H_2O$

(b) One mole of coal (64 grams per mole) requires 6 moles of oxygen (32 grams per mole).The mass in grams in 1000 tonne of coal = 1000 tonne x 1000 kg x 1000g = 10^9 g.

The number of mole of coal = 109 g / 64 g per mol

= 1.56×10^7 mol.

The number of mol of oxygen = 1.56×10^7 mol . 6

= 9.36 Å~ 107 mol.

Therefore, the mass of oxygen required = $32 \times 9.36 \times 10^7$ g

= 300×10^7g = 3.0×10^6 kg = 3000 tonnes of oxygen.

(c) Volume of oxygen = 25 $dm^3 \times 9.36 \times 10^7$ mol =

$2.34 \times 10^9\ dm^3$.

(d) Volume of air = $5 \times 2.34 \times 10^9\ dm^3 = 1.2 \times 10^{10}\ dm^3$.

10. (a) Since 35% efficient heat must be supplied at

500 MW / 0.35 = 1429 MW

(b) 1 kg consumed for 31.5 x 106 J s^{-1}. So for 1429 x 10^6 Js^{-1} the kg s^{-1} is 1429 / 31.5 = 45.4 kg s^{-1}.

(c) The amount of heat entering the cooling towers =1429 – 500 = 929 MW.

Q = mcΔT. So Q / t = mcΔT / t. Therefore, m/t = Q / cΔT

m / t = 929 x 10^6 / 4180 x 10 = 2.2 x 10^4 kg s^{-1}.

Exercise 8.3

Exercise 8.4

1. C

2. C

3. D

4. A

5. solar panel: solar energy → _thermal energy (heat). solar cell: solar energy → _electrical energy.

6. (a) power = energy / time = 150 . 1012 J / 60 . 60 x 24 . 365 = 4.75 . 10^6 MW

therefore, for one turbine = 4.75 . 106 / 25 = 0.19 MW

(b) Power = . A ρ _v^3 and A = πr^2

0.19 . 10^6 Js^{-1} = 0.5 . π _. r^2 m^2 . 1.3 kgm^{-3} . 153 m^3s^{-3}

r = √ _2P / πρv^3 √[(2 . 0.19 . 10^6) / (π _. 1.3 kgm^{-3} . 3 375 m^3s^{-3})]

= 5.25 m

7. (a) mass of water = 2.4 . 10^3 kg; energy required = 2.4 . 10^3 kg . 4.18 . 10^3 Jkg $^{-1}$ 0C. 40 0C

= 4.0 . 10^8 J.

(b) energy provided in 2 hours = 7 200 . 1000 . A. therefore A

= (4.0 . 108 J) / (7200 s . 1000 Js^{-1}) = 55.6 m^2. (note change to Q)

8. Power / λ _= . ρ _g A2 f

= 30 m . 0.5 . 1020 kgm^{-3} . 10 ms^{-2} . (6)2 m^2 . 1m . 0.1s^{-1}

= 550 . 10^3 kg m^2 s^{-3}

= 550 kW per metre. (note change to Q)

9. Power = . ρ _g A2 λ _/T

= 0.5 . 10^{20} kgm^{-3} . 10 ms^{-2} . (6)2 m^2 . 25m . 1m / 8s

$= 5.74 . 10^5$ kg m^2 s^{-3}

= 574 kW per metre.

Wave speed = wavelength / period = 25 m / 8 s = 3.1 ms^{-1}

10. 880 MW

11. 1.9 . 10^3 m^2 ~ 2000 m^2

Exercise 8.5

1. B

2. D. (The temperature is doubled.

So the factor is 2 = 16 4× 300 = 4800 W.)

3. B. (The radius is double so the factor is (2r) = 4 2× 300 = 1200 W.)

4. A. (The same as the rate is only dependant on the temperature of the black body.)

5. A. (There is no thermal energy transfer and so no net rate of heat loss)

6. B. (It is only dependant on temperature.)

7. (a) Black–body radiation is the radiation emitted by a "perfect" emitter. A non–black body is not a perfect radiator of energy.

(b) The spectrum extends into the red region of the visible spectrum at 1500 K. It extends into the ultra–violet region at 3000 K.

(c) The total area under a spectral emission curve for a certain temperature T represents the total energy radiated per metre 2 per unit time E and for that assigned temperature it has been found to be directly proportional to the fourth power T4.

(d) The energy distribution of the wavelengths move into shorter wavelength regions while still being found in the infrared and visible regions.

8. $P = 2\pi\, r\, \sigma\, (T^4 - T_0^4) = 2\pi \times 0.01 \times 5.67 \times 10^{-8}\, (340^4 - 300^4) =$ 18.75 = 19 Wm^{-1}

9. (a) Power from the Sun $= 4\pi r_S^2\, \sigma\, T^4$. Power

received by the earth = the area on which the Sun's radiation is normally incident ÷ the total suface area on which the Sun's radiation falls when the earth is 1.5×10^{11} m from the Sun × the power radiated by the Sun.

$= (\pi r E^2 \div 4\pi r^2) \times 4\pi r_S^2\, \sigma\, T_S^4$.

If the earth is in radiative equilibrium with the Sun, the power received by the earth = the power radiated by the earth.

$4\pi r_E^2 \sigma T_E^4 = (\pi r_E^2 \div 4\pi r^2) \times 4\pi r_S^2 \sigma T_S^4$

$T_E 4 = (r_S^2 \div 4\pi r^2) \times T_S^4$

$T_E = T_S \text{ x } (r_S / 2r)^{½} = 6000 \times (6.5 \times 10^8 / 3 \times 10^{11})^{½}$
$= 306$ K

(b) Assumptions: both bodies are black bodies, no radiation is lost in the atmosphere, no heat is radiated by the earth's interior.

Chapter 9

Waves

Wavy sculpture.

Section 1

Waves

CONTENTS

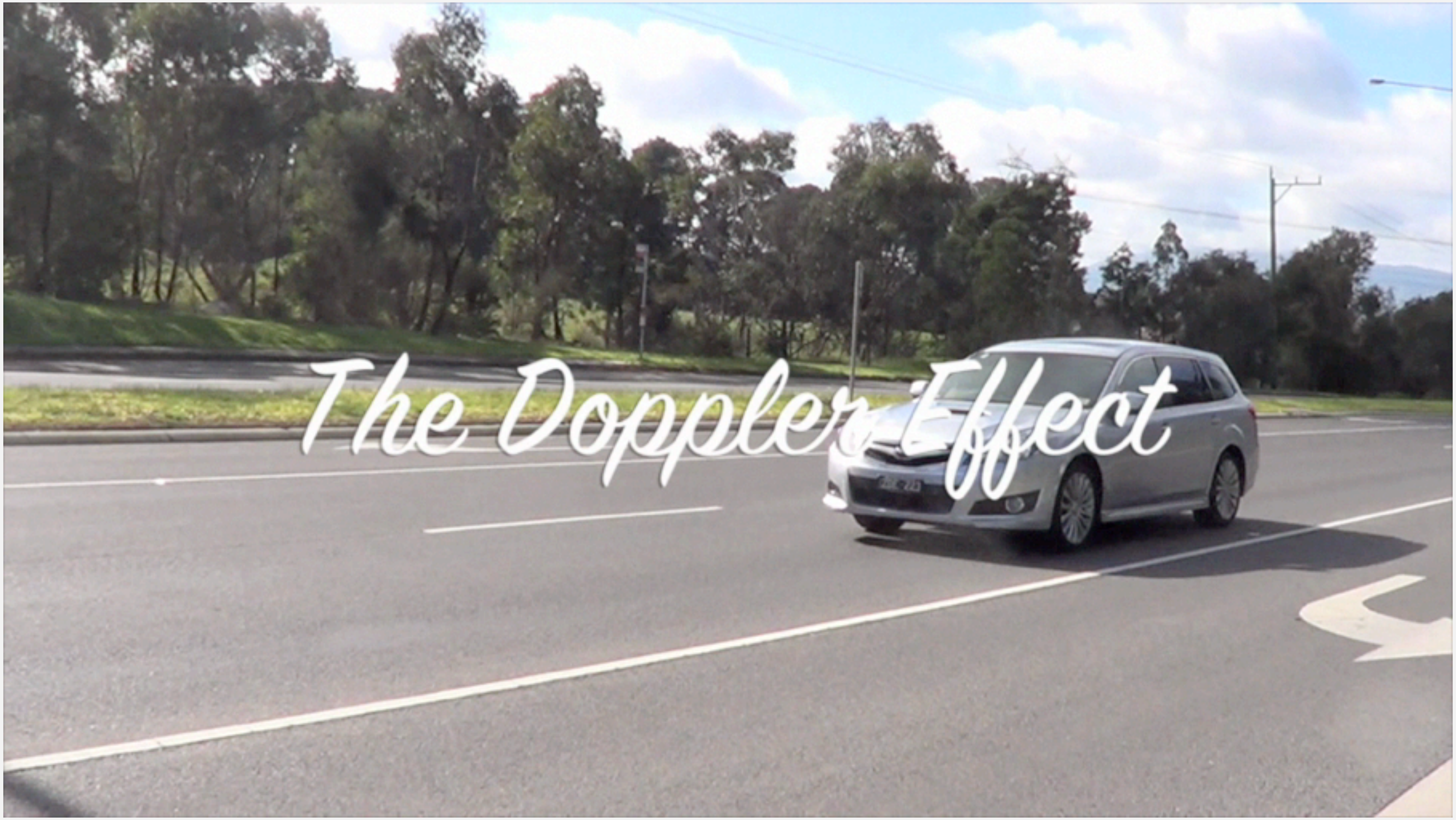
Enlarged diagrams

Labelling exercises

Diffraction grating glasses. FUN!

Additional material

Movie 9.1 The Doppler Effect



The classic demonstration of the Doppler Effect.

Considerable research had to be done to prevent the pantographs (the devices that collect electricity from the overhear wires) from setting up destructive resonances in the wires.

This is the Shinkansen - the Japanese ‘bullet train’.

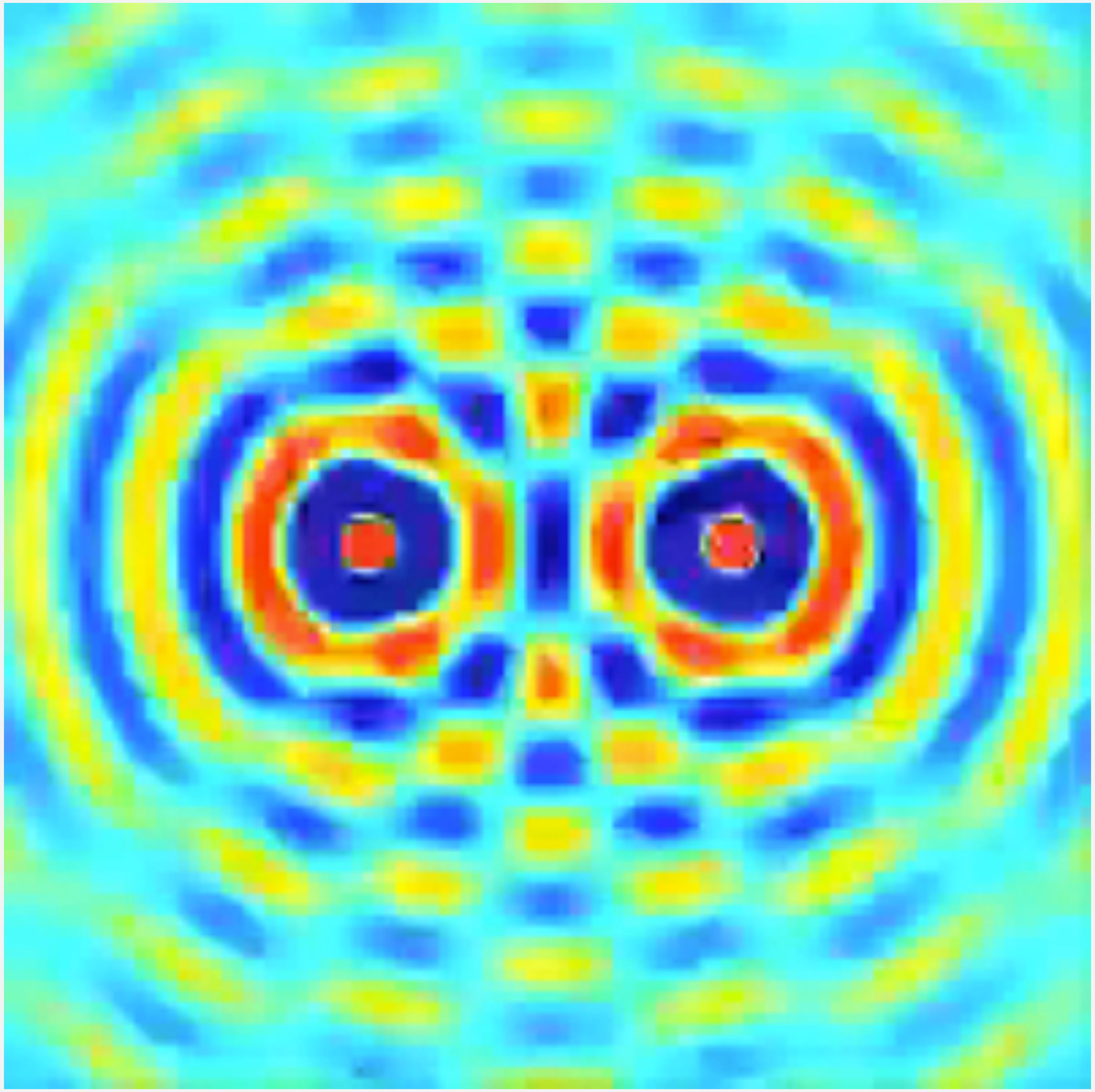
This rainbow might result from raindrops in the clouds or from sea water droplets thrown up by the boat.

Does a sea water rainbow have the same curvature as a fresh water rainbow?

Are sunsets redder than sunrises?

If so, why?

Movie 9.2 Two source interference



A public domain simulation from Wikipedia

Internet resources

Internet based wave simulations

http://www.falstad.com/wavebox/

http://www.falstad.com/mathphysics.html

http://phet.colorado.edu/en/simulation/wave-on-a-string

http://www.physicsclassroom.com/mmedia/waves/lw.html

http://www.walter-fendt.de/ph14e/stwaverefl.htm

http://www.acs.psu.edu/drussell/demos.html

http://www.sciencejoywagon.com/physicszone/09waves/

http://www.grc.nasa.gov/WWW/K-12/airplane/sndwave.html

Answers to exercises

Exercise 9.1

1. A.

2. C.

3. A.

UNCORRECTED

DRAFT

4. B.

5. C.

6. (a) 47.3 Nm^{-1}
(b) 0 038 J

7. (a) (i) .4 s

(ii) 6.2 cm

(iii) 16 cm s^{-1}

(iv) 1.3ms^{-1}

(v) 61 cm s^{-2}

(b) (i) the velocity is a maximum at t = 0 and t =1.2s

8. 2×10^{-20} J

9. (a) displacement is proportional to acceleration; because graph is straight-line passing through the origin; acceleration always directed towards origin; because of the negative gradient;

(b) 350 Hz

Exercise 9.2

1. 2.0 x10–3 rad, 3.0 cm

2. 430 nm

3. 8.60, 26.70 and 48.60 from the central axis to the first order minima

Exercise 9.3

1. 330 m s-1

2. 0.24 m

3. (a) .5 mm (b) 1.25 mm

Exercise 9.4

1. 630 nm

2. (a) Since d = 3a, the third order in the interference pattern is missing because its position coincides with that of the first minimum in the diffraction envelope.

(b)N = 6. Therefore, the number of subsidiary maxima = N-2 = 6 – 2 = 4

(c)(i) 5 (ii) 3

Exercise 9.5

110 nm

Exercise 9.6

1. $\approx 10^{-9}$ rad

2. Yes, separation of images is 12×10^{-6} m

3. 1.6 m

Exercise 9.7

1. (a) 64.7 m s^{-1}

(b) 512 Hz

2. 6.91×10^{-7} m

Chapter 10

Fields

Igneous rock. The flows visible after solidification.

Section 1

Fields

CONTENTS

An equatorial marker in Peru. What is meant by ‘magnetic declination’? What is the magnetic declination at your home? Does it very with time?

Additional material

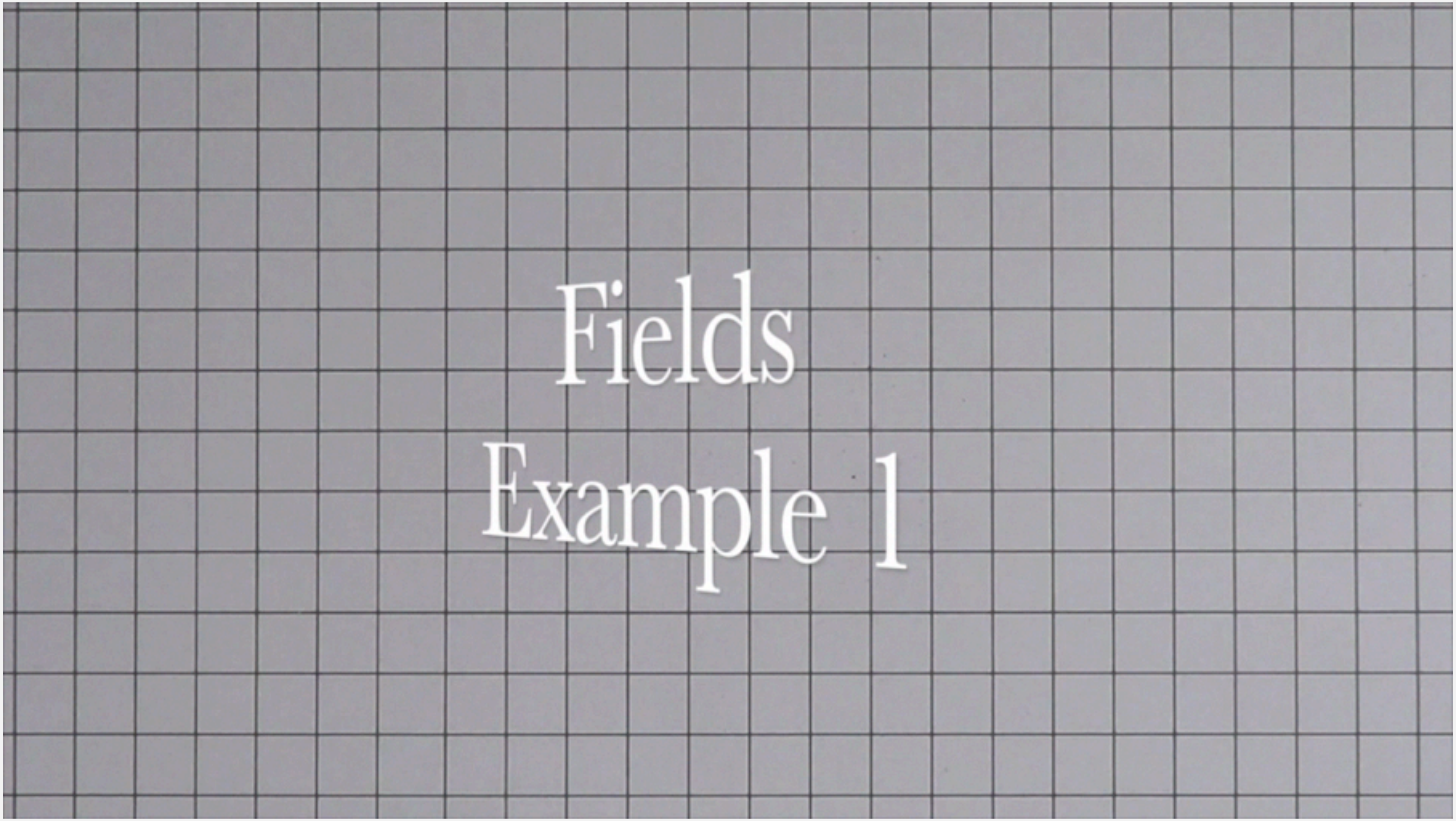
Raj, the pilot, has two measures of heading.

At right there is a GPS base heading and at left a gyro-compass.

Both are relative to the Earth’s magnetic field, not the grid of latitude and longitude.

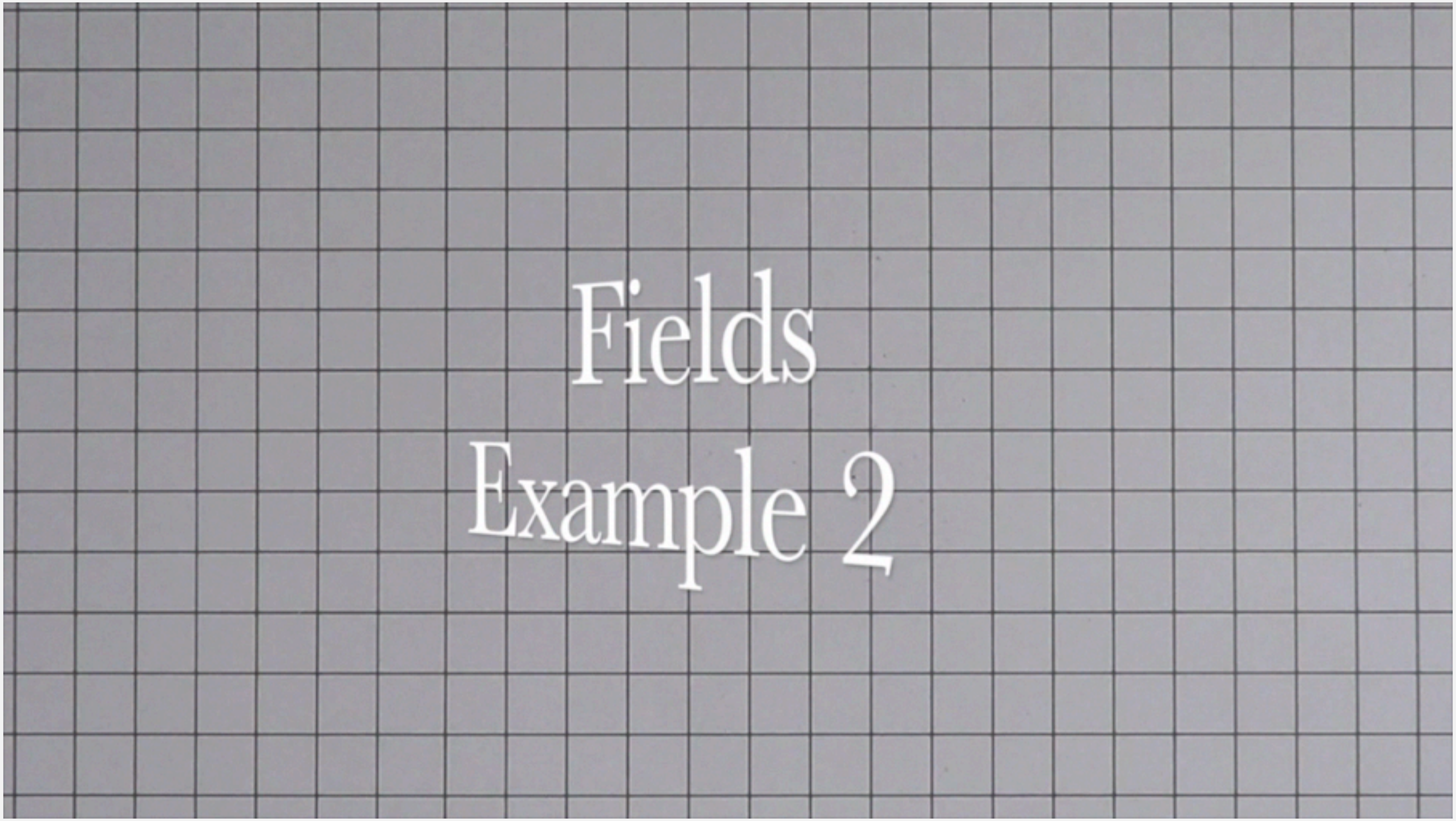
Does Raj have his instruments aligned?

Movie 10.1 Fields Example 1



What type of field is affecting the paths of these ball bearings?

Movie 10.2 Fields Example 2



What type of field is affecting the paths of these ball bearings?

Answers to exercises

Answers

Movie 10.1. This is a radial field - actually a magnet under a plane table. A shallow bowl would produce similar results.

Movie 10.2. This is a linear field - created by tilting the plane.

Exercise 10.1

UNCORRECTED

DRAFT

1. (a) 10^{10} J

(b) 1.3×10^{10} J

(c) 10 = numerical value of ‘g’ at surface

Exercise 10.2

1. B

2. The electric potential of the +2 μC charge at B due to the 2 μC charge at A is:

V = (9 × 109 N m2 C–2 × 2 × 10–6 C) ÷ 0.25 m
= 7.2 × 104 V

The electric potential of the +2 μC charge at B due to the 2 μC charge is:

$V = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \times 2 \times 10^{-6} \text{ C}) \div 0.25$
$= 7.2 \times 10^4$ V

The net absolute potential is the sum of the 2 potentials

7.2×10^4 V + 7.2×10^4 V = 1.4×10^5 V.

3. $E = -V / x = 20 / 0.05 = 400 \text{ Vm}^{-1}$

4. (a) N.B.– Sufficient arrows to show decreasing radial field, direction, no field in the centre. –

– Three concentric circles, with increasing radii.

(b) The field strength is the gradient of the potential so E must be decreasing since the distance is increasing.

(c) (i) Use $E = kq / r^2 = 9 \times 10^9 \times 6 \times 10^{-6} / 0.0252$

$E = 8.6 \times 10^7 \text{ V m}^{-1}$

(d) (i) along a field line outwards.

(ii) F =ma = qE, = Eq/m =
$(1.6 \times 10^{-19}/9.11 \times 10^{-31}) \times 8.6 \times 10^7$
$= 1.5 \times 10^{19} \text{ m s}^{-2}$.

5. $W = qV = 10 \times 10^{-9} \times 1.50 \times 10 = 1.5^2 \times 10^{-6}$ J

6. The electric potential of the +2 μC charge at B due to the 2 μC charge at the apex is:

$V = (9 \times 10^9\ N\ m^2\ C^{-2} \times 2 \times 10^{-6}\ C) \div 0.25\ m = 7.2 \times 10^4\ V$

The electric potential of the +2 μC charge at B due to the 2 μC charge is:

V = (9 × 109 N m2 C–2 × 2 × 10–6 C) ÷ 0.25 = 7.2 × 104 V

The net absolute potential is the sum of the 2 potentials

$7.2 \times 10^4\ V + 7.2 \times 10^4\ V = 1.4 \times 10^5\ V.$

7. Using E = – V/x , x = V / E = $2.5 \times 10^2 / 2.00 \times 10^3$
= 0.125 m

8. (i) $W = qV = 1.6 \times 10^{-19}\ C \times 1.0 \times 10^4 = 1.6 \times 10^{-15}\ J$

(ii) $½\ mv^2 = 1.6 \times 10^{-15}\ J$
$v = \sqrt{}(1.6 \times 10^{-15}\ J \times 2 \div 9.11 \times 10^{-31}\ kg)$
$= 5.9 \times 10^7\ ms^{-1}$.

(iii) E = – V/x
E = 1.0 × 10^4 V / 1.00 × 10–3 m = 1.0 × 107 Vm–1.

9. $W = qV = 1\ eV \times 2.5 \times 10^3 = 2.5 \times 10^3\ eV$.

10. Using the formula V = kq / r , we have
$V = 9 \times 10^9 \times -1.0 \times 10^{-5} \div 2.0 \times 10^{-2}$
$= 4.5 \times 10^6\ V$.

11. The electric potential due to the +5 pC charge at the mid point is:

$V = (9 \times 10^9\ Nm^2C^{-2} \times +5 \times 10^{-12}\ C) \div 0.05\ m = +0.9\ V$. The electric potential due to the –20 μC charge is
$V = (9 \times 10^9\ N\ m^2C^{-2} \times -20 \times 10^{-12}\ C) \div 0.05 = -3.6V$
The net absolute potential is the sum of the
2 potentials = –3.6 + 0.9 = – 2.7 V

12. $1.0 \times 10^9\ eV$

13. (a) $\Delta W = -qE\Delta x = -1.5 \times 10^{-6}\ C \times 1.4 \times 10^3 N\ C^{-1}$
× –0.055 m = 1.2 × 10 J. –4

(b) $\Delta V = Ex = 1.4 \times 10^3\ N\ C^{-1} \times 0.055\ m = 77\ V.$

(c) $\Delta V = Ed = 1.4 \times 10^3\ N\ C^{-1} \times 0.15\ m = 210\ V.$

14. (a) $\Delta W = q\Delta V = 32\ C \times 1.2 \times 10V = 3.8\ 9 \times 10^{10}\ J$

(b) KE = ½ mv2 and v = √ (2 × KE ÷ m)
= √ (2 × 3.8 × 10 10 J / 1000 kg)
$= 8.7 \times 10^3\ ms^{-1}$

(c) $Q = mL$ and $m = Q / L = 3.8 \times 10^{10}\ J / 3.34\ 10^5$
$\times 10\ Jkg^{-1} = 1.1 \times 10^5\ kg$

15. (a) – 2.25 V (b) 2.25 V (c) V

16. $V = kq / r = k(-6 + 3 + 2 + 5\ \mu C) / \sqrt{2} \times 0.5 = 5.1 \times 10^4\ V$

Exercise 10.3

1. D
2. 2.6×10^3 ms^{-1}, $T = 1.6 \times 10^4$ s
3. 1.0×10^4 m s^{-1}
4. 8:1
5. (a) GM/5R

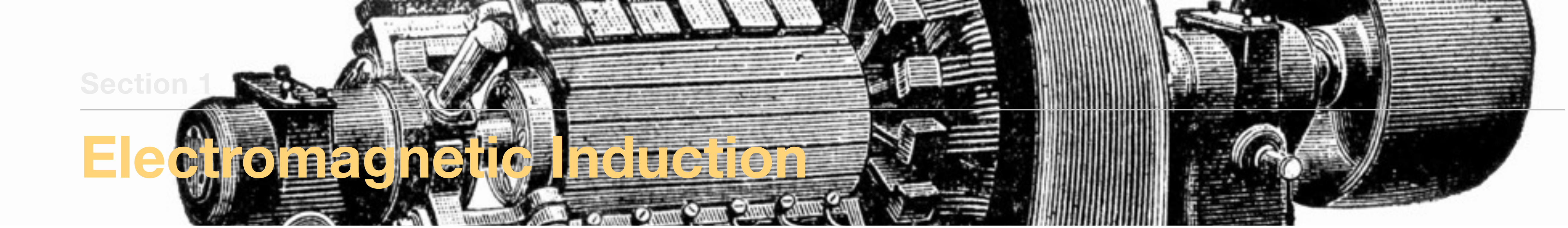
   (b) GM/10R

   (c) GmM / 5R
6. 9.6×10^3 m s^{-1}
7. gEarth = 4g Moon
8. 1.67 N kg^{-1}, 1.68×10^3 m s^{-1}

Chapter 11

Electromagnetic Induction

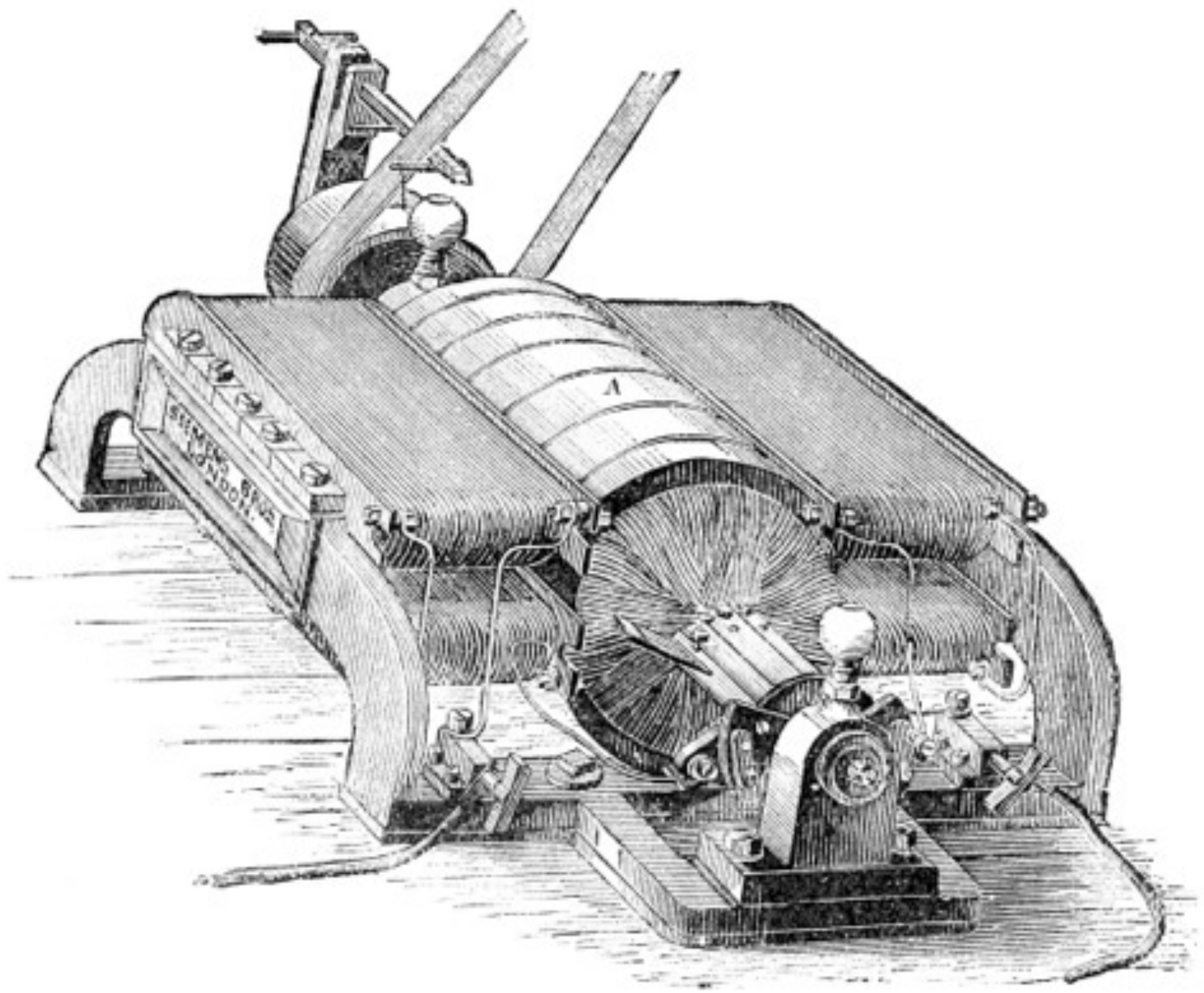
Our cover picture is one of Joseph Henry's first electromagnets, Smithsonian Institution, Washington DC, USA.



Section 1

Electromagnetic Induction

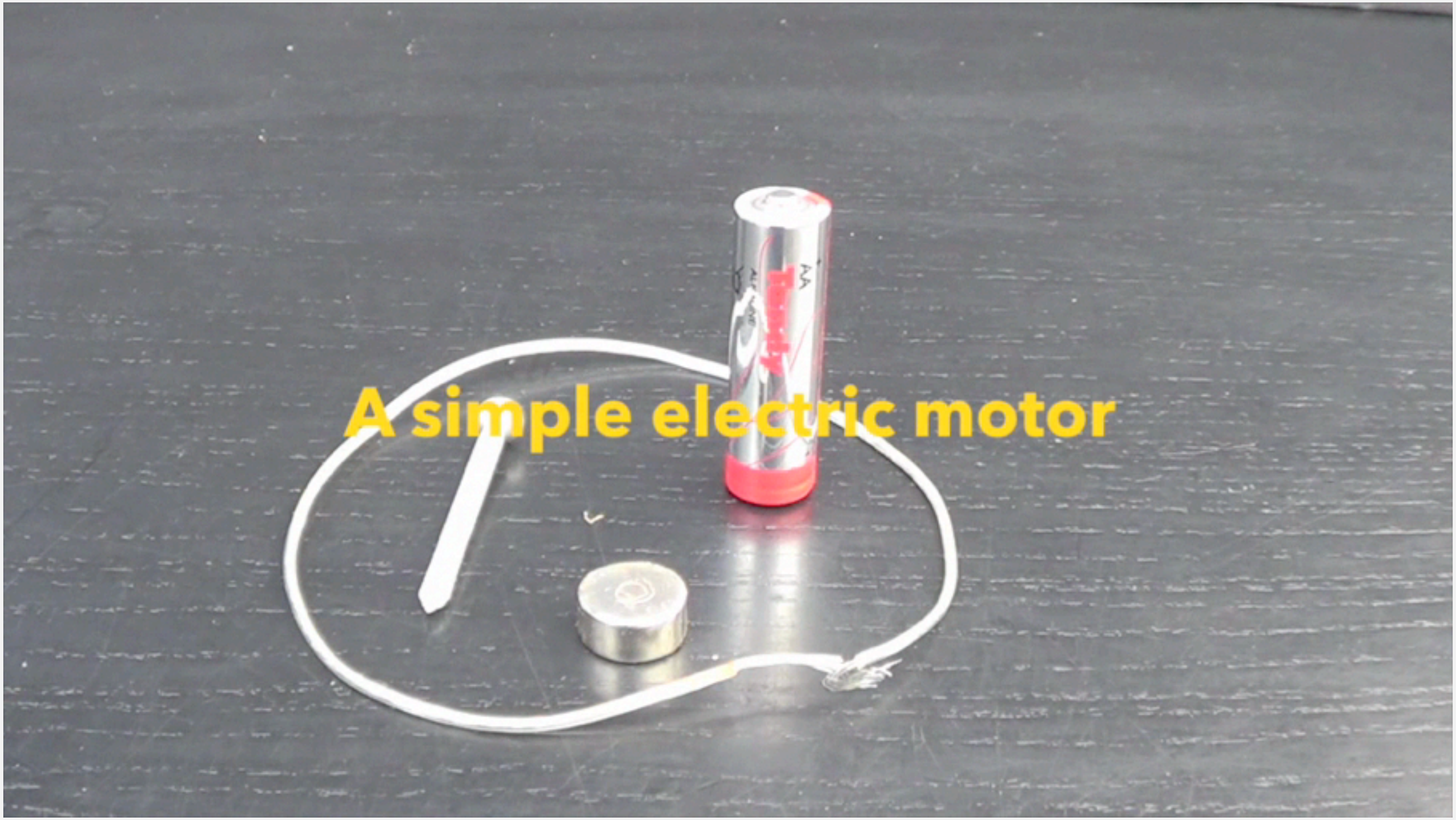
CONTENTS



Early train dynamo/motor manufactured by Siemens.

Additional material

Movie 11.1 Electromagnetic Induction



A simple electric motor can be made from a magnet, a battery, a screw and a length of wire. Why does it work?

Answers to exercises

Exercise 11.1

1. A
2. D
3. C
4. D
5. B. ($F = BIl \quad = F / Il = ma / Il = kg\ m\ s^{-2}A^{-1}m^{-1}$)
6. D
7. A
8. Speed of movement, strength of the magnetic field, the number of turns and the area of the coil
9. When the coil is moved towards the north pole of the magnet, an induced current is produced that moves anti–clockwise at that end of the coil. When the coil is stationary, there is no induced current. When the coil is moved in the opposite direction, the induced current direction is clockwise. But remember, it is the relative motion that is important – so in effect, there is no difference.
10. (a) double e.m.f

(b) quarter e.m.f

(c) no difference

11. A magnetic field has a flux density B of one tesla if there is one line of magnetic induction of one weber passing through an area A of one square metre. The magnetic flux Φ is the total magnetic flux through an area and is given by $\Phi = BA$
12. 1.7×10^3 V
13. 1.6 V
14. 0.05 Wb
15. 7.0 T
16. (a) $\Phi = BA = 0.2\ T \times 5 \times 10^{-4}\ m^2 = 1 \times 10^{-4}$ Wb

(b) Parallel so $\Phi = 0$ Wb

(c) $\Phi = BA \cos 60 = 0.2\ T \times 5 \times 10^{-4}\ m^2 \times 0.5$

$= 5 \times 10^{-5}$ Wb

17. $\varepsilon = B.l.v = (4.0 \times 10^{-3}\ T) \times (2.5\ m) \times (35\ m\ s^{-1}) = 0.35$ V
18. $\Phi = A.B \cos \theta = (0.05\ m)^2 \times (0.60\ T) = 1.5 \times 10^{-3}$ Wb

$\varepsilon = -N\ \Delta\Phi / \Delta t = -(120\ turns) \times (0–1.5\ .10^{-3}\ Wb) / (3.0\ s)$

$= 0.060$ V.

19. $\phi = BA = (45 \times 10^{-4}\ m^2)(0.65\ T) = 2.925 \times 10^{-3}$ Wb

e.m.f. $= -N\Delta\phi / \Delta t = -1500\ (0 - 0.002925) / 5 = 0.88$ V

20. area = 3.14 × (1.5)2 × 10^{-2} = 7.1 × 10^{-2} m^2 rate of flux change = 7.1 × 10^{-2} m × 1.8 × 10^{-3} = emf = 1.278 × 10^{-4} V current = 1.278 × 10^{-4} V / 2.0 × 10^{-2} Ω = 6.4 mA.

Exercise 11.2

1. C

2. C

3. B (np / ns = Vp / Vs 5000 / 250 = 240 / Vs Vs = 12V

P =VI = 24 / 12 = 2A

V_p / V_s = I_s / I_p 240 / 12 = 2 / I_p I_p = 0.1A)

4. D (V_{rms} = V_{peak} / √2

= 12 / √2 (√2 / √2) = 12√2 / 2 = 6√2)

5. D

6. A

7. To increase the magnetic field strength. It is also soft and easy to laminate – to increase efficiency and reduce eddy currents. It doesn't become a permanent magnet and there is less hysteresis losses.

8. We need a changing magnetic flux to induce an e.m.f, therefore we need ac.

9. (a) 60 V
(b) 180 V
(c) 360 V

10. 0.29 T

11. Find the total of the square of each term = 372
Find the average = 37.2 then find the square root of 37.2 = 6.1 A

12. Vp = 1.414 × 230 V = 325.22 V

Ip = V / R = 325.22 V / 2.4 × 103 Ω =0.136 A

13. (a) Yes, provided high voltages are used there is no difference between a.c and d.c transmission.

(b) For 1 000 V I = 1 × 10^4 W / 1 000 V

= 10 A

For 100 000 V P =VI

I = 1 × 10^4 W / 100 000 V

= 0.1 A

Power dissipated in cable: P = I2R

P = 100 A × 5.0 Ω P = 0.01 A × 5.0 Ω
P = 500 W P = 0.05 W

The higher the voltage, the less power loss occurs in the cables.

(c) To minimise the eddy currents, the yoke of the transformer is laminated

(d) I = P/V = 60 W / 110 V = 0.55 A

Total # of lamps = max current / current in each lamp
= 8 A / 0.55 A
= 14.5 lamps = 14 lamps

(e) $Q = VIt = mc\Delta T_{water} + mc\Delta T_{stainless\ steel}$

110 V . 30.2 A × 2.5 min × 60 s = 4.983 × 105 J

4.983 × 105 J = 1.5 kg × 4180 $J.kg^{-1}.K^{-1}$ × 73 K + 0.72 kg × c × 73 K

= 4.577 × 105 J + 25.55 × c

4.06 × 104 J = 52.56 c

c = 7.7245 × 102 = 7.7 .102 J.kg–1.K–1

(f) Energy consumed
= 6kW + (2 × 300 W) + (5 × 100 W) = 7.1 kW

Cost = 7.1 × 10.5 × 1 h = 74.6 cents

14. (1) The speed of the movement
(2) The strength of the magnetic flux density
(3) The number of turns on the coil
(4) The area of the coil

15. Power loss (the reduction of which is our aim) is proportional to the square of induced voltage. Induced voltage is proportional to the rate of change of flux, and each of our laminations carries one quarter of the flux. So, if the voltage in each of our four laminations is one quarter of what it was in the solid core,

Exercise 11.3

1. (a) 0.67 μF
   (b) V1 = 2 V, 2 = V3 = 4 V
   (c) q1 4 μC, q2 = q3 = 2 μC
2. (a) 1.6 μF
   (b) 29.0 μC
   (c) 2.4 V
3. 1.4 × 10 -6 C
4. (a) 4 s
   (b) 60 μC
   (c) 46.6 μC

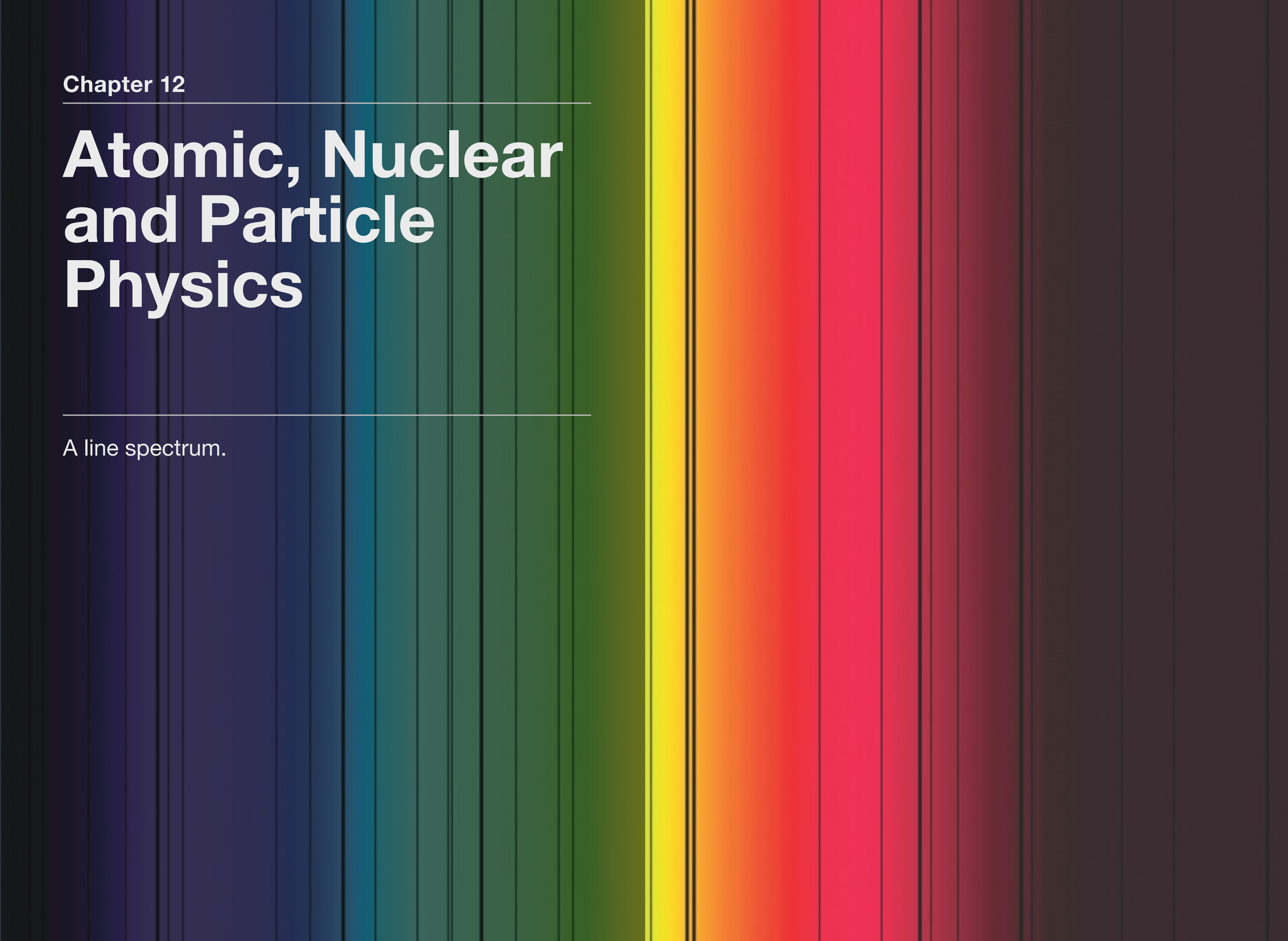
5. (a) 5 V

(b) Initial energy = 4.5×10^{-3} J.

Final energy = 0.75×10^{-3} J.

Chapter 12

Atomic, Nuclear and Particle Physics

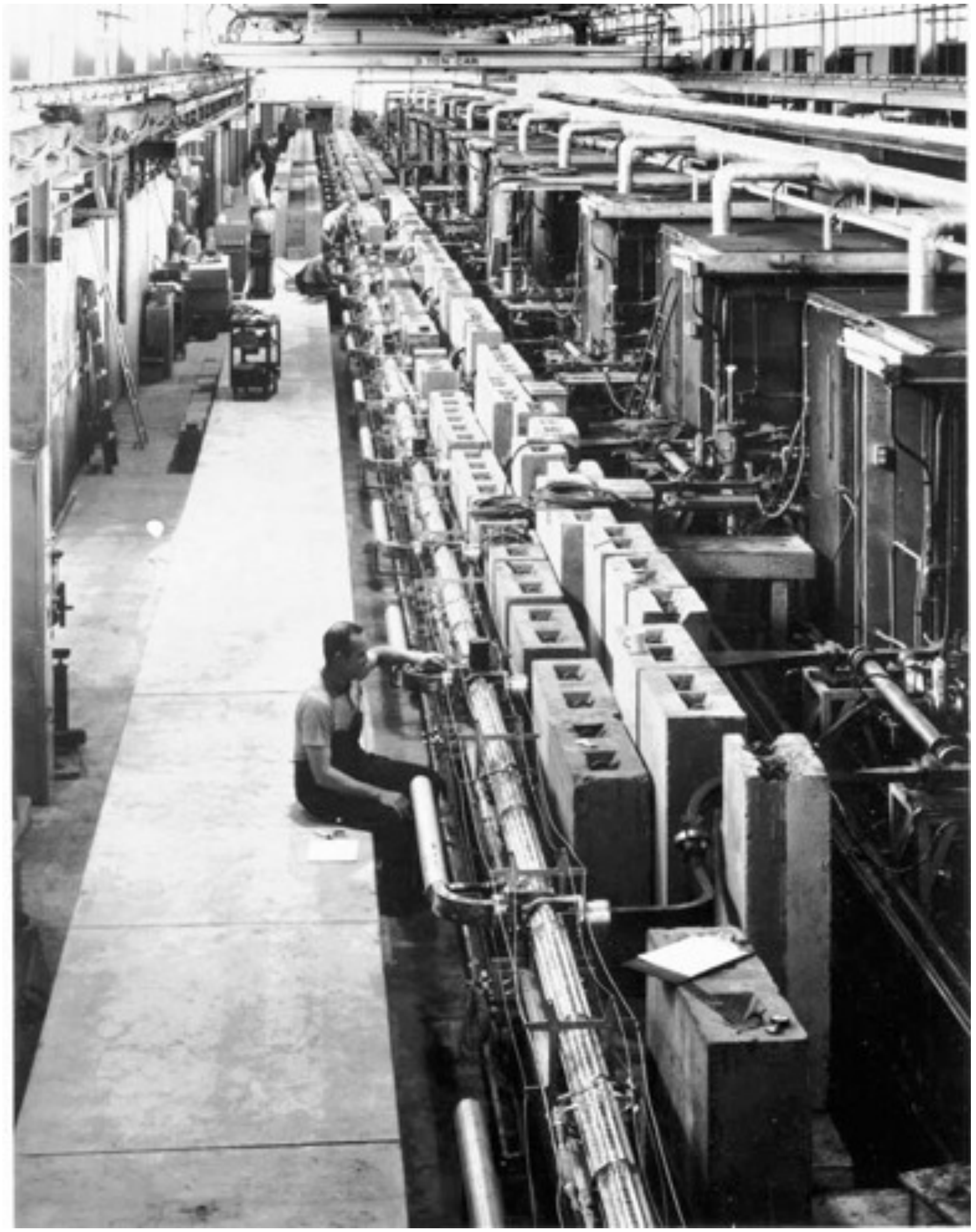


A line spectrum.

Section 1

Atomic, Nuclear and Particle Physics

CONTENTS



The Mark III linear electron accelerator at Stanford University which allowed Robert Hofstadter to study the charge and magnetic structure of nuclei and nucleons, work that earned him the 1961 Nobel Prize in Physics.

Additional material

One of the tragic spin-offs from Nuclear Physics.

The ‘Hiroshima Dome’ - the site of the first destructive use of nuclear power.

Answers to exercises

Exercise 12.1

1. B
2. C
3. D

4. A
5. 6.06×10^{-19} J
6. (a) 7.71×10^{14} Hz
   (b) 4.84×10^{-19} J
   (c) 1.03×10^{6} ms^{-1}
7. If light consisted of a continuous wave, there would be no threshold frequency. Any light that shone on the metal surface long enough would eventually supply enough energy to photoelectrons to release them from the metal.
8. 8.3 eV
9. (i) $6.4(\pm 0.1) \times 10^{-34}$ Js
   (ii) 2.0 ($\pm$0.1) eV

Exercise 12.2

1. C
2. B
3. B
4. 8.93×10^{-60} m
5. 6.03×10^{-9} m
6. The electron will have the longer de Broglie wavelength
7. (a) $.67 \times 10^{-10}$ m
   (b) .30
8. 3.3×10^{-12} m
9. 44

Exercise 12.3

1. D
2. A
3. C
4. C

5. C

6. (a) 1.28×10^{-5} s^{-1}

(b) 2.73×10^{3} Bq

7. (a) 3.01×10^{-10} J

(b) 3.09×10^{-10} J

8. 1.88×103 MeV

9. (i) 0.0619 day^{-1}

(ii) 0.134

10. 254.8 Bq

11. 13 days

12. 1.1×10^{9} years

Chapter 13

Option A Relativity

Satellites travel at relativistic speeds.

Section 1

Option A: Relativity

CONTENTS

The mythology of science has it the the Town Clock in Bern was the inspiration for Albert Einstein to start thinking about Relativity.

Internet resources

Some useful websites:

http://www.spacetimetravel.org

http://www.theoryrelativity.com/index.php?option=com_content&view=article&id=7%3Aarticle4&catid=1%3Aall-articles&Itemid=3&lang=EN

http://www.phys.unsw.edu.au/einsteinlight/

http://www.highexistence.com/einsteins-theory-of-relativity/

http://www.ehow.com/video_5112662_einstein_s-theory-relativity-explained.html

https://www.youtube.com/watch?v=ev9zrt__lec

https://www.youtube.com/watch?v=xvZfx7iwq94

... and the splendid explanation in *The Ascent of Man* by Jacob Bronowski.

The episode you need is 7 - *The Majestic Clockwork*.

You school should own the DVD and the Book!

Answers to exercises

Exercise 13.1

1. (a) (i) $5.0\ m\ s^{-1}$

(ii) $1.0\ m\ s^{-1}$

(iii) $3.6\ m\ s^{-1}$

(iv) $3.6\ m\ s^{-1}$

2. (b) X:Y = 1 : 2.2

Exercise 13.2

1. 0.5c 1.35 × 1011 m .8c zero .95c 75 m

2. 0.6c

3. (a) (i) 2.3×10^{9} m

(ii) zero

(b) 75 m

4. 0.86c

5. Refer to text

Exercise 13.3

1. See text

2. Hint – Remember that the atomic mass unit is 1/12th the mass of an atom of carbon-12.

3. (a) $1.2 MeVc^{-2}$ (b) $0.29\ MeVc^{-2}$

4. $0.59 MeVc^{-2}$ and $0.85 MeVc^{-2}$

5. (i) $1740 MeVc^{-2}$

(ii) 0.843c

(iii) 1470 MeV c^{-1}

(iv) 1740 MeV

6. 7×10^{15} m

7. 0.628c

8. 5.5×10^{-12} m

9. See text

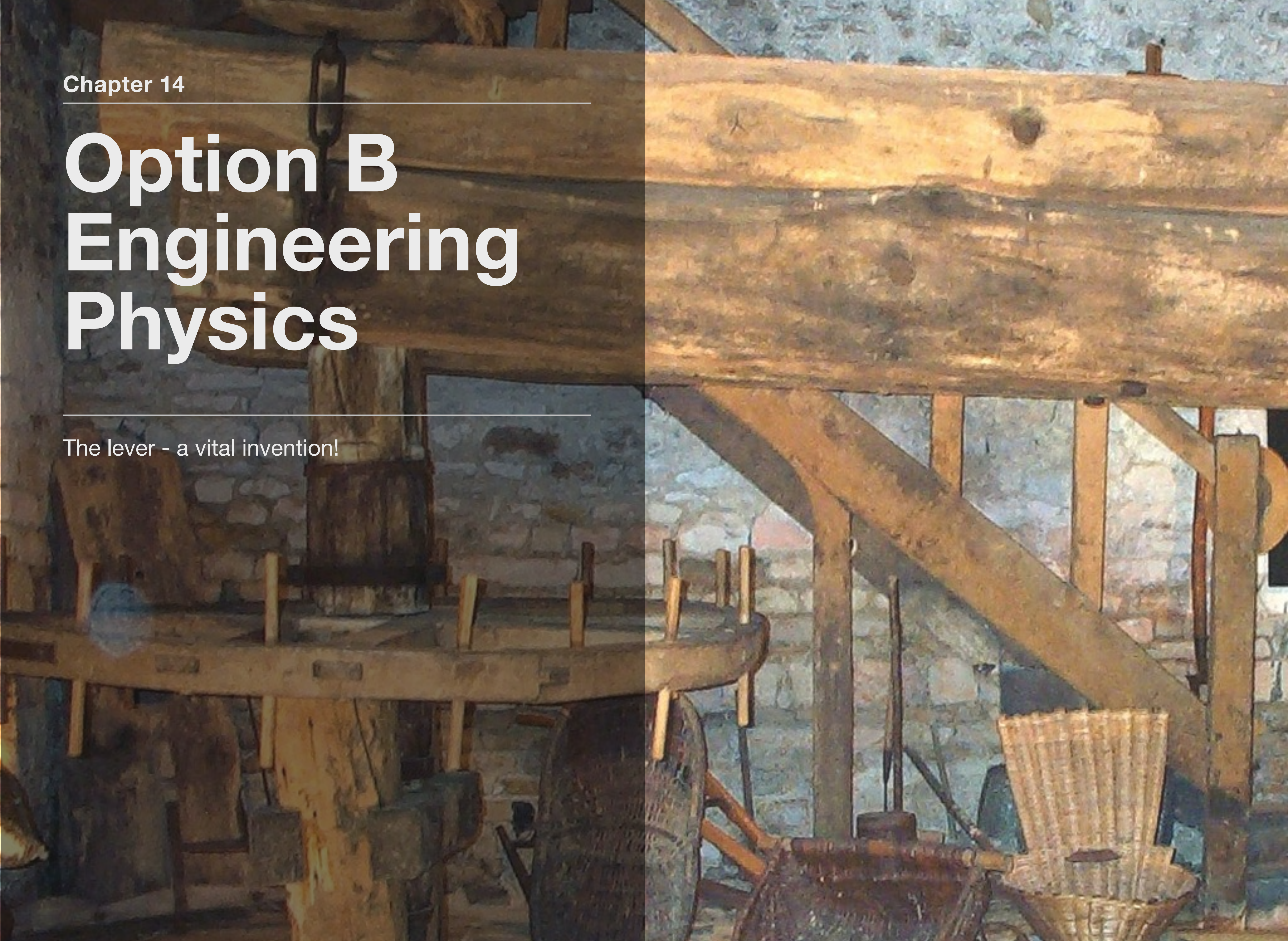
10. See text

11. See text

12. 500 m

13. Self-evident

14. 0.87c



Chapter 14

Option B Engineering Physics

The lever - a vital invention!

Section 1

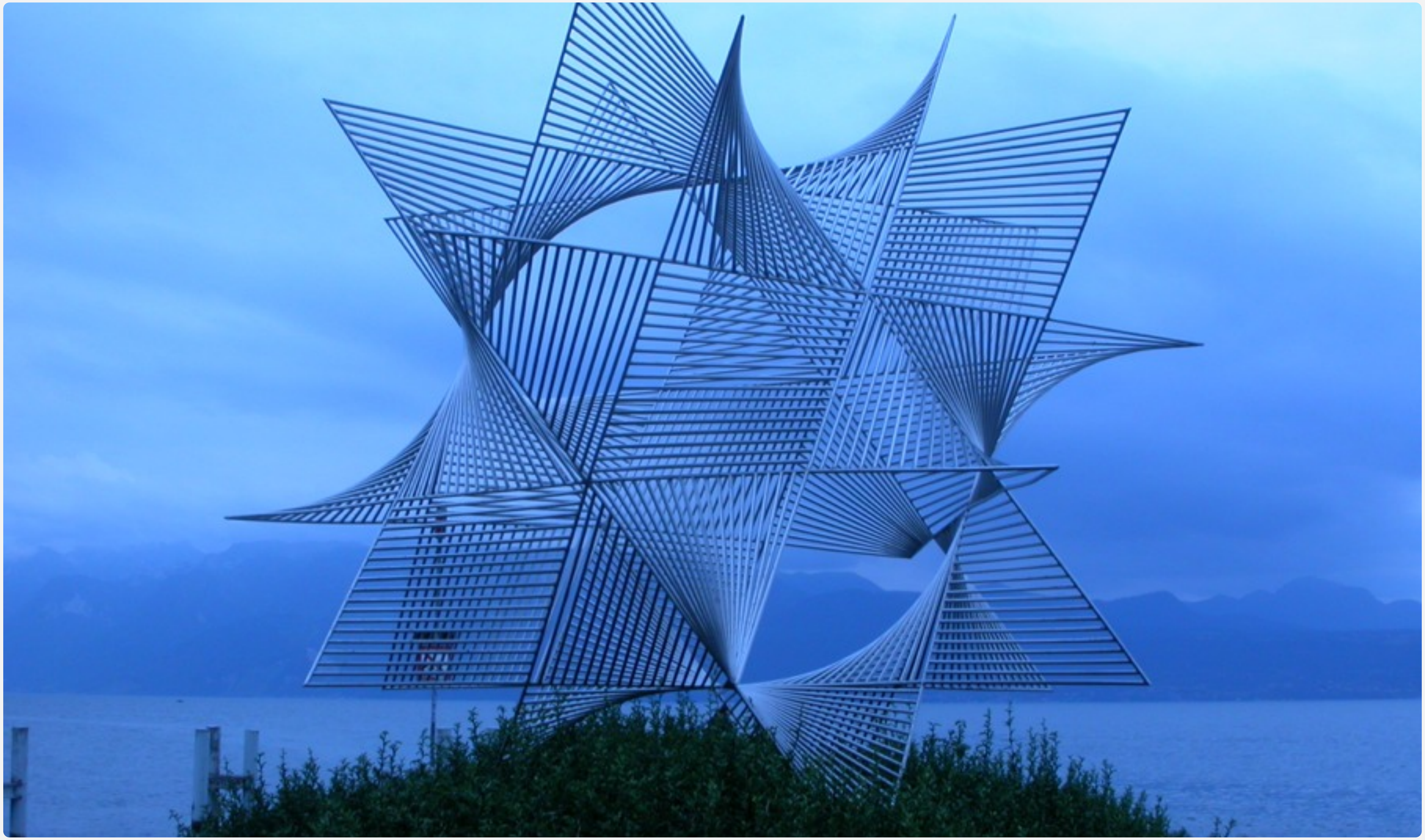
Option B: Engineering Physics

CONTENTS

A famous piece of engineering.

Additional material

Gallery 14.1 Engineering with a touch of poetry!



Answers to exercises

Exercise 14.1

1. $T_1 = 45N$ $T_2 = 23N$
2. 5.2 m from the other end.
3. 58.8 N

UNCORRECTED DRAFT

4. At the 0.70 m mark
5. 2.30×10^2 N and 574 N
6. 1.04×10^3 N and 1.26×10^3 N
7. 897 N in the 30.00 rope and 634 N in the 45.00 rope
8. (a) 42 N
(b) 2.0×10^2 N at 780 to the horizontal
9. Bolt = 950 N Fulcrum = 1480 N
10. 28 N at 600 and 48 N at 300

Exercise 14.2

1. 0.34 s
2. (a) 0.83Hz
   (b) 5.2 rad s^{-1}
   (c) 2.47 J
   (d) 0.23 Js
3. 2.8 m s^{-1}
4. (a) -0.35 rad s^{-2}
(b) -0.012 N m
5. 0.118 N m
6. 0.11 rad s^{-1}
7. (a) 3.00 s
   (b) 18.9 rad
8. 12.3 kg m^2

Exercise 14.3

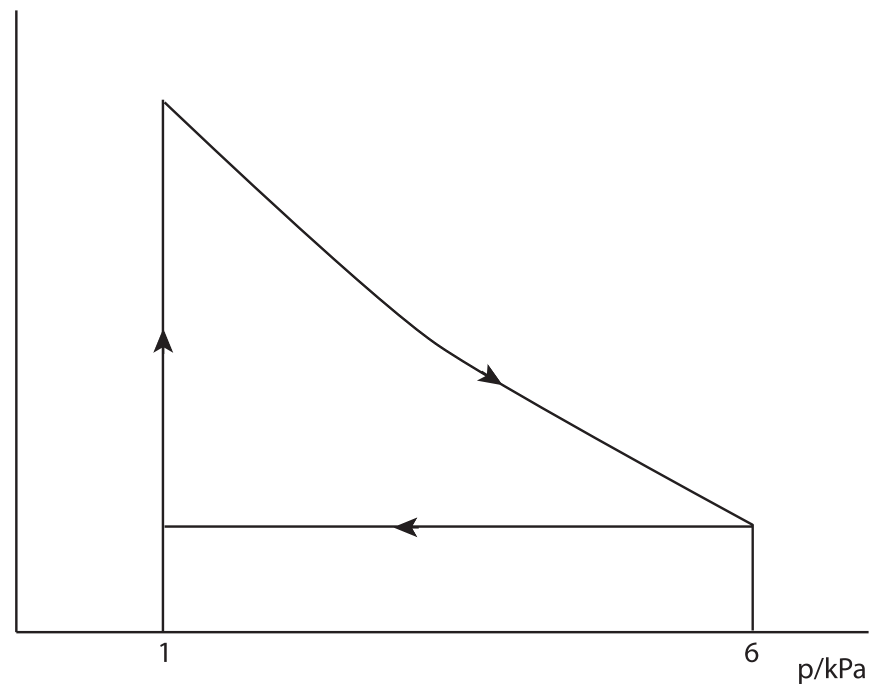
1. B
2. B
3. C
4. C
5. B
6. A

7. C

8. 1.29×10^6 J

9. $\Delta U = -6.4 \times 10^5$ J.

10.



11. ΔU = –3.8 × 104 J, new temp = 72 °C.

12. (a) Q = 0

(b) ΔU = Q – W = –1750 J. i.e., Internal energy drops, so temp falls

13.

Process	Q	W	ΔU
Isobaric compression of an ideal gas	–	0	+
Isothermal compression of an ideal gas	–	–	0
Adiabatic expansion	0	+	–
Isochoric pressure drop	–	0	–
Free expansion of a gas	0	0	0

14. (a) PV = nRT, × 101.3 × 103 Pa × 48.8×10^{-3} m^3

= n × 8.31 $JK^{-1}mol^{-1}$ × 312 K

n = 3.8133 = 3.8 mol.

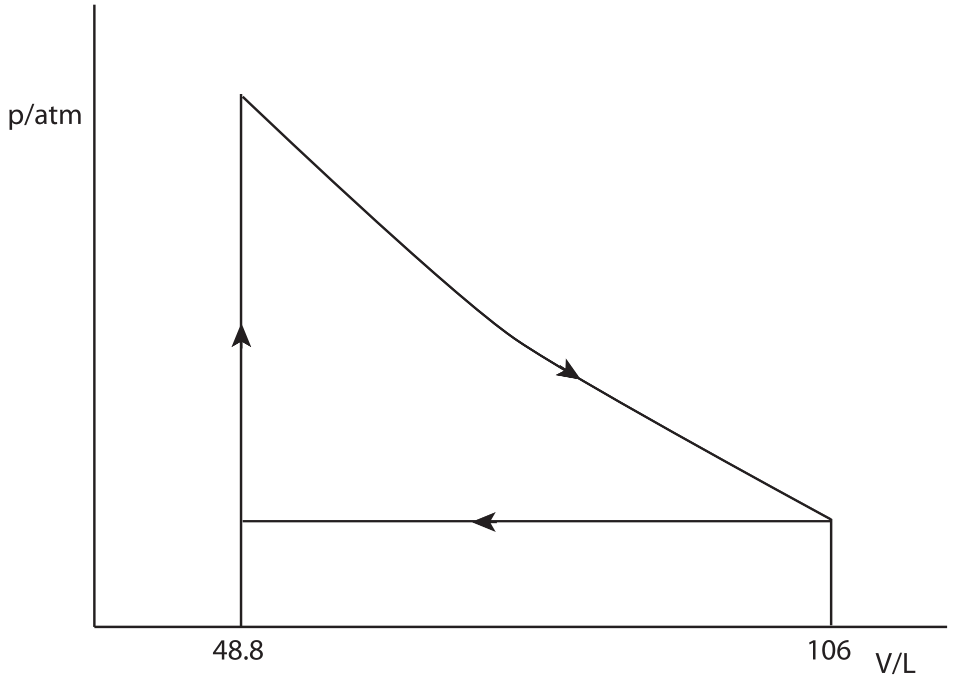
(b) Temperature the same for an isotherm.

So, use PV = nRT P = nRT / V

P = 3.8133 × 8.31 × 312 / 106 × 10–3

= 9.3 × 104 Pa = 0.92 atm

(c)



d) Work = area under the curve = area of triangle + area of rectangle

$= [½ (106 – 48.8) \times 10^{–3} \times 1.08 \times 101.3 \times 10^3]$

$+ [0.92 \times 101.3 \times 103 \times 57.2 \times 10^{–3}]$

$= 3128.9 + 5330.8 = 8.5$ kJ.

(e) –5.3 kJ.

(f) 0 J

(g) 8.5 – 5.3 = 3.2 kJ

(h) $T = PV / nR = 9.3 \times 10^4 \times 48.8 \times 10^{–3} / 3.8133 \times 8.31 = 144$ K.

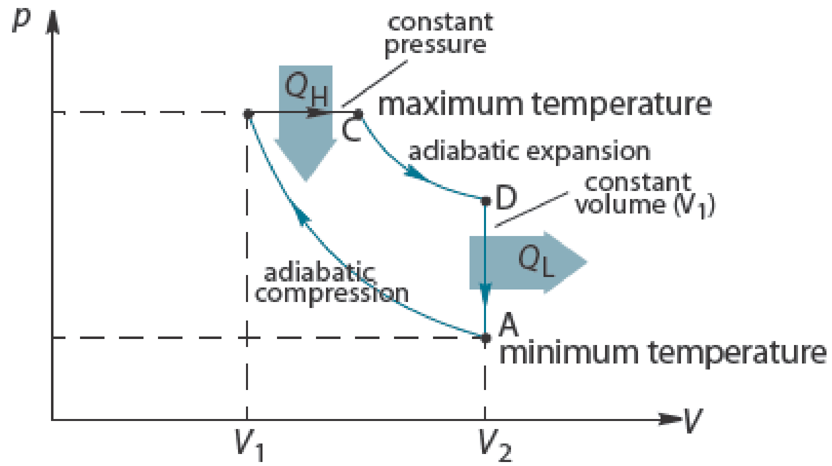
15. (a) isothermal: takes place at constant temperature.
adiabatic: no energy exchange between gas and surroundings

(b) (i) neither

(ii) $\Delta W = P\ \Delta V = 1.5 \times 10^5 \times 0.06 = 6.0 \times 10^3$ J;

(iii) $\Delta Q = \Delta U + \Delta W$. $\Delta U = 7 \times 10^3 – 6.0 \times 10^3 = 1.0 \times 10^3$ J.

16.



Exercise 14.4

1. 2.16×10^{-2} kg

2. 1.59×10^{-2} m

3. 4.5×10^6 N

4. (a) 1×10^6 N m^{-2}

(b) 2000 N

5. 3.52×10^{-2} m

6. 0.0632 m

7. 5.40×4 N

8. 0.936 m s^{-1}

9. 11.4 m s^{-1}

Exercise 14.5

Lightly damped 1, 3, 5, 8

Heavily damped 2, 4, 6, 7

Chapter 15

Option C Imaging

Close-up of a giant screen. Pixels upon pixels.

Section 1

Option C: Imaging

CONTENTS

Close-up of a modern light microscope. Imaging has come a long way since the invention of this classic device - *circa* 1670.

Additional material

Antoine Henri Becquerel's photographic plate, fogged by exposure to radiation from a uranium salt. Note the shadow of a metal Maltese Cross placed between the plate and the uranium salt.

Answers to exercises

Exercise 15.1

UNCORRECTED

DRAFT

1. C

2. The light reflected is diffuse. You need regular reflection off a surface in order to see multiple images.

3. 12 cm in front of mirror, $m = -0.5$

4. 60 cm behind the mirror. Image is magnified 5 times, erect and virtual.

5. 2.4 m

6. Concave mirror placed 1.2 cm from the tooth.

Exercise 15.2

1. $1 / d_0 + 1 / d_i = 1 / f$ $1 / 5.0$ cm $+ 1 / d_i = 1 / 12.0$ cm $d_i = -8.57$ cm

   The image is a virtual image located 8.6 cm in front of the lens.

   $m = -d_i / d_o = -(-8.57 \text{ cm}) / 5.0 \text{ cm} = +1.71$

   The image is erect and has a magnification of 1.7.

2. See text Figure 1508.

3. $1 / d_0 + 1 / d_i = 1 / f$ $/ 16.0$ cm $+ 1 / d_i = -1 / 12.0$ cm $d_i = -6.86$ cm

   The image is a virtual image located 6.0 cm in front of the lens.

   $m = -d_i / d_o = -(-6.86 \text{ cm}) / 12.0 \text{ cm} = +0.57$

   The image is erect and has a magnification of 0.57.

4. $1/d_0 + 1/d_i =$ $/f / 6.0$ cm $+ 1/d_i = 1 / 12.0$ cm $d_i = -12.0$ cm

   The image is a virtual image located 12.0 cm in front of the lens.

   $m = -d_i / d_o = -(-12.0 \text{ cm}) / 6.0 \text{ cm} = +2$

   The image is erect and has a magnification of 2.0.

Exercise 15.3

1. D

2 D

3. Real, inverted image, 7.5 cm on opposite side of lens to object, $m = -0.5$, image height is 2 cm.

4. Image is virtual, erect, 3.8 cm from the lens on the same side as the object. $m = 0.25$, image height is 1.0 cm high

5. All are convex except for the short– sightedness

6. Image is 30 cm from the lens on the opposite side to the object. It is real, inverted and magnified by two.

7. 6 cm from the lens

8. 0.83 m

9. 0.037 m from the concave lens and in between the two lenses.

10. 12 cm

11. –195

12. 46°

13. Yes. When the angle of incidence is equal to the critical angle.

14. An aberration is an image defect of which blurring and distortion are the most common image defects. Aberrations can occur with the use of both lenses and mirrors.

    Spherical aberration is most noticeable in lenses with large apertures. Rays close to the principal axis (called paraxial rays) are all reflected close to the principal focus. Those rays that are not paraxial tend to blur this image causing spherical aberration.

To reduce spherical aberration, parabolic mirrors that have the ability to focus parallel rays are used in car headlights and reflecting telescopes.

In practice it is found that a single converging lens with a large aperture is unable to produce a perfectly sharp image because of two inherent limitations:

- spherical aberration
- chromatic aberration

The nonparaxial rays do not allow for a sharp image. However, with lenses, spherical aberration occurs because the rays incident near the edges of a converging lens are refracted more than paraxial rays. This produces an area of illumination rather than a point image even when monochromatic light is used. To reduce spherical aberration, a stop (an opaque disc with a hole in it) is inserted before the lens so that the aperture size can be adjusted to allow only paraxial rays to enter.

Because visible light is a mixture of wavelengths, the refractive index of the lens is different for each wavelength or colour of light. Consequently, different wavelengths are refracted by different amounts as they are transmitted in the medium of the lens. For example, blue light is refracted more than red light. Each colour must therefore have a different focal length and it further follows that focal length is a function of wavelength.

Chromatic aberration produces coloured edges around an image. It can be minimised by using an achromatic doublet. Since the chromatic aberration of converging and diverging lenses is opposite, a combination of these two lenses will minimise this effect.

15. D

Exercise 15.4

1. (a) 80.6°
(b) HINT: Consider the geometry of the situation.

2. (a) 180 dB
(b) 64 km

3. 48.8°

4. 4.5 km

Exercise 15.5

1. 5.0×10^{-11} m

2. 6.9×10^{-11} m

3. (a) to produce electrons by thermionic emission
   (b) to accelerate the electrons
   (c) to decelerate electrons producing heat and X-rays

4. wavelength = 4.1 × 10–11m frequency = 7.2 × 1018Hz

5. To reduce the heating effect of the bombarding electrons by spreading the heat over a larger area.

6. They are very penetrating and show poor contrast.

7. (a) 4 kW
   (b) 2.5 ×1017 electrons per second.
   (c) 1.6 × 10–14 J
   (d) 1.24 × 10–11 m

8. (a) 6.1 × 101 kW m–2
   (b) 0.144 mm–1
   (c) 2.2 × 10–2 kWm2

9. The quality of an X-ray beam is a term used to describe its penetrating. (As the relative intensity of the X-rays is increased so too does the spectral spread. We say the X-ray quality has increased). There are a number of ways that the quality of an X-ray machine can be increased

   1. increasing the tube voltage
   2. Increasing the tube current
   3. Using a target material with a relatively high atomic number Z
   4. Using filters.

10.(a) Intensity after passing through 2.4 mm would be half the original intensity.

Intensity after passing through 4.8 mm would be a quarter of the initial intensity.

Intensity after passing through 7.2 mm would be an eighth of the initial intensity.

Intensity after passing through 9.6 mm would be a sixteenth of the initial intensity.

New intensity = 1/16(4.0 × 102 kWm–2) = 25 kWm–2

(b) x1/2 = 0.6931 /µ µ = 0.6931 /x1/2= 0.6931/ 2.4 mm

= 0.29 mm–1 or 2.9 x102 m–1

(c) I = I0 e– _µx_= 4.0 x 105 Wm–2 e– _290 x_ 0.0015)

= 2.59 x 102 kWm–2

11. (a) Images of body volume are obtained.

The sections produced can be cross- sections or longitudinal.

(b)(CAT) imaging uses a radial array of X–ray sources, scintillation detectors and computer technology to build up an axial scan of a section of an organ or part of the body with 256 grey shades. A patient lies on a table that passes through a circular scanning machine about 60–70 cm in diameter called a gantry. The gantry can be tilted, and the table can be moved in the horizontal and vertical directions. X–rays from the gantry are fired at the organ being scanned and attenuation occurs depending on the type of tissue being investigated. The image produced on the computer monitor is a series of sections or slices of an organ built up to create a three–dimensional image.

(c)CAT scans provide detailed cross–sectional images for nearly every part of the body including the brain and vessels, the heart and vessels, the spine, abdominal organs such as the liver and kidneys etc... They are being used in many diagnostic applications including the detection of cancerous tumours, detection of strokes and blood clots.

(d)Both use X–radiation that penetrates matter where it is absorbed to differing degrees by different tissues. Both are invasive.Conventional X–rays are limited in that they show only denser bone structures with organs having the same attenuation as skin tissue (unless a radiopharmaceutical is introduced). CAT has many more applications.The two–dimensional image produced on a computer monitor has good resolution.

12. (a) MRI uses radiation in the radio region of the

electromagnetic spectrum and magnetic energy to create cross–sectional slices of the body. The patient is laid on a table and moved into a chamber containing cylindrical magnets that can produce constant magnetic fields around 2 T.

Protons in the atoms of the patient line up with the magnetic field so that the axes of their spins are parallel. Pulses of radio–frequency (RF) electromagnetic waves bombard the patient. At particular RF frequencies, the spin is tilted as the atoms in the tissues absorb energy.

When the pulse stops, the protons return to their original orientation and emit radio frequency energy. Different tissues emit different amounts of energy in this process.

This differing amounts of energy are sent to a computer that decodes the information and produces a two–dimensional or three–dimensional image on a computer monitor screen.

(b) The single proton in the hydrogen atom has a strong resonance signal and its concentration is abundant in body fluids due to the presence of water.

(c) MRI is ideal at detecting brain and pituitary tumours, infections in the brain, spine and joints and in diagnosing strokes.

(d) See text.

13. (a) Ultrasound is sound with frequencies greater

than 20 000 Hz. Just as transverse electromagnetic waves interact with matter as is the case with X–radiation, CAT and MRI, so too ultrasound mechanical waves interact with matter.

(b) Ultrasound from 20 000Hz to several billion hertz can be produced by ultrasound transducers (a device that converts energy from one form to another) using mechanical, electromagnetic and thermal energy. (Normal sound waves are not useful for imaging because their resolution is poor at long wavelengths. Medical ultrasound uses frequencies in the range greater than 1 MHz to less than 20 MHz. In this range with speeds around 1500 m.s–1 in body tissue the wavelengths are about 1–2 mm).The common transducer used in ultrasound is the piezoelectric crystal transducer. When ultrasound meets an interface between two media, the ultrasound wave can undergo reflection, transmission, absorption and scattering. In ultrasound imaging, it is the reflected portion of the ultrasound beam that is used to produce the image. The greater the difference in the characteristics of the media boundary, the more energy will be reflected to give an echo.

(c) (i)

Medium	Velocity ms-1	Density kg m-3	Acoustic Impedance kg m-2 s-1×106
Air (20 °C, 101.3 kPa)	344	1.21	0.0004
Water (20 °C)	1482	998	1.48
Whole blood (37 °C)	1570	1060	1.66
Brain	1541	1025	1.6
Liver	1549	1065	1.65
Kidney	1561	1038	1.62
Skull bone	4080	1912	7.8
Muscle	1580	1075	1.7

(ii) Ultrasound could not be used to obtain images of lung tissue.

The greater the difference in acoustic impedance between two materials, the greater will be the reflected proportion of the reflected pulse.

Lung tissue is encased by the rib cage and contains air – strong reflections from these media would obscure images of the lung tissue.

(d) In a typical ultrasound scan, a piezoelectric transducer is placed in close contact with the skin. To minimise the acoustic energy lost due to air being trapped between the transducer and the skin, a gel is applied between the transducer and the skin.

(e) If the ultrasound beam is reflected, transmitted, absorbed and scattered the intensity (attenuation) will decrease. IF the frequency of the source is increased too much, the attenuation in fact decreases as does the penetration depth. Furthermore, the resolution also decreases if the frequency is increased beyond an optimum point. In a typical pulse–echo diagnostic procedure, the maximum mean ultrasound power delivered is about 10–4 W, and the frequency is in the range 1–5 MHz.

(f) A scan produced by a single transducer when a single bit of information with a one–dimensional base is displayed is called an A–scan (amplitude mode). The transducer scans along the body and the resulting echoes are plotted as a function of time. The A–mode measures the time that has elapsed between when the pulse is sent and the time the echo is received. The first echo is from the skin, the second and third pulses are from either side of the first organ, the fourth and fifth echo is from either side of the second organ. The pulse intensity decreases due to attenuation. This mode is seldom used but when it is, it measures the size and distance to internal organs and other organs such as the eye. In the B–scan mode (brightness scan), an array of transducers scan a slice in the body. Each echo is represented by a spot of a different shade of grey on an oscilloscope. The brightness of the spot is proportional to the amplitude of the echo. The scan head containing many transducers is arrayed so that the individual b–scans can be built up to produce a two–dimensional image. The scan head is rocked back and forth mechanically to increase the probability that the pulse will strike irregular interfaces.

(g) see text.

14. (i) Ultrasound because it gives reasonably clear images in the womb without harmful radiation.

(ii) X–rays because they can easily distinguish between flesh and bone to get a clear image of the fracture.

(iii) CAT or MRI because they are able to detect tumours of the brain.

15. (a) 0.09mm

(b) the half–value thickness is that thickness of lead which (for this particular beam) reduce the intensity of the (transmitted) beam by 50 %.

(c) the half–value thickness corresponds to an intensity of 10 units; This value wou would be at an intensity of 10. So the half–value thickness would be 2 mm.

(d) the transmitted intensity = 40% × _20 = 8. This corresponds to a thickness of about 2.5 mm.

(e) the transmitted intensity would be (1 – 0.8) × 20 = 4 units. 4 × 10^{-3}m = 0.6931 / μ. μ = 0.6931 × 4 × 10^{-3} m = 1.73 × 10^{2} m^{-1}.

So $I = I_0e^{-\mu x}$, $4 = 20 \times (e)^{-\mu x}$. So $0.2 = e^{-173}$ x.

That is –ln 0.2 = 173x.

Therefore, x = 0.015 m = 10.5 mm.

16.(a) 1 MHz → 20 MHz.

(b) (i)

(ii) he pulse takes 50 μs to travel 2d.

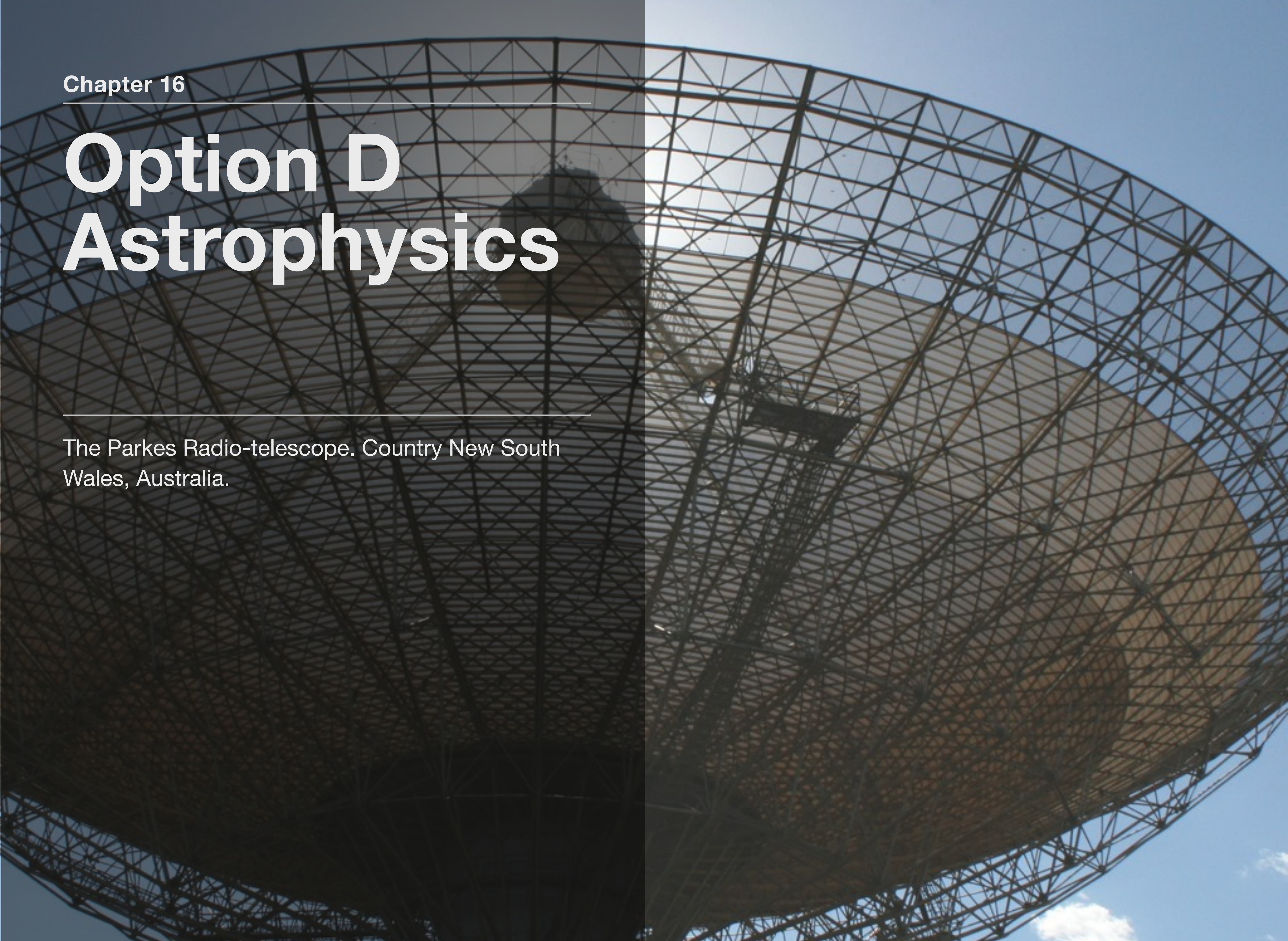
So d = vt / 2 = 2.0 × 103 ms–1 × 50 × 10–6 μs / 2
= 50 mm,

and l = vt / 2 = 2.0 × 103 ms–1 × (275 –100) × 10–6 μs / 2 = 175 mm.

(c) A–scan. A–mode measures the time lapsed between when the pulse is sent and the time the echo is received. A B–scan gives a three–dimensional image.

Chapter 16

Option D Astrophysics



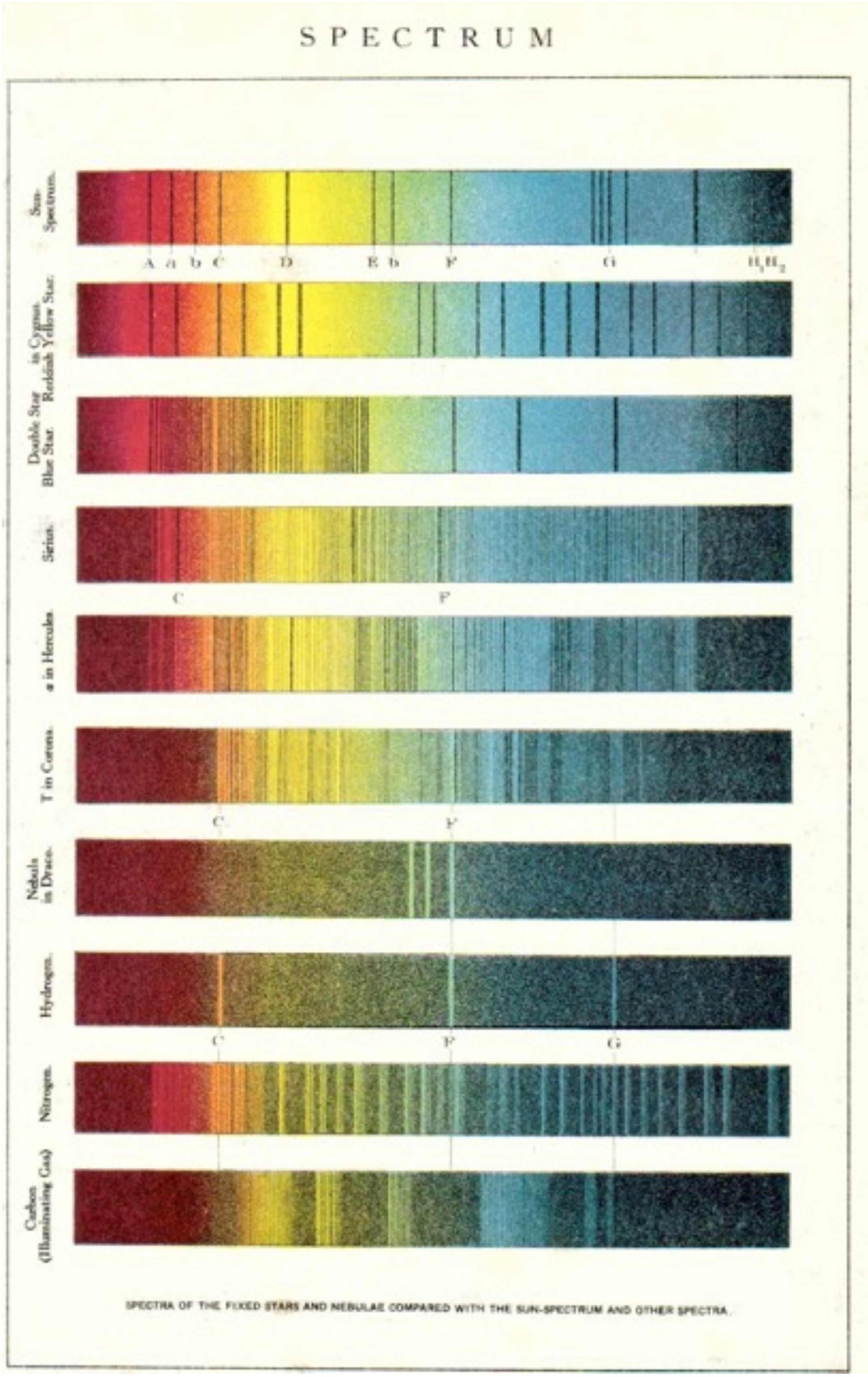
The Parkes Radio-telescope. Country New South Wales, Australia.

Section 1

Option D: Astrophysics

CONTENTS

Additional material

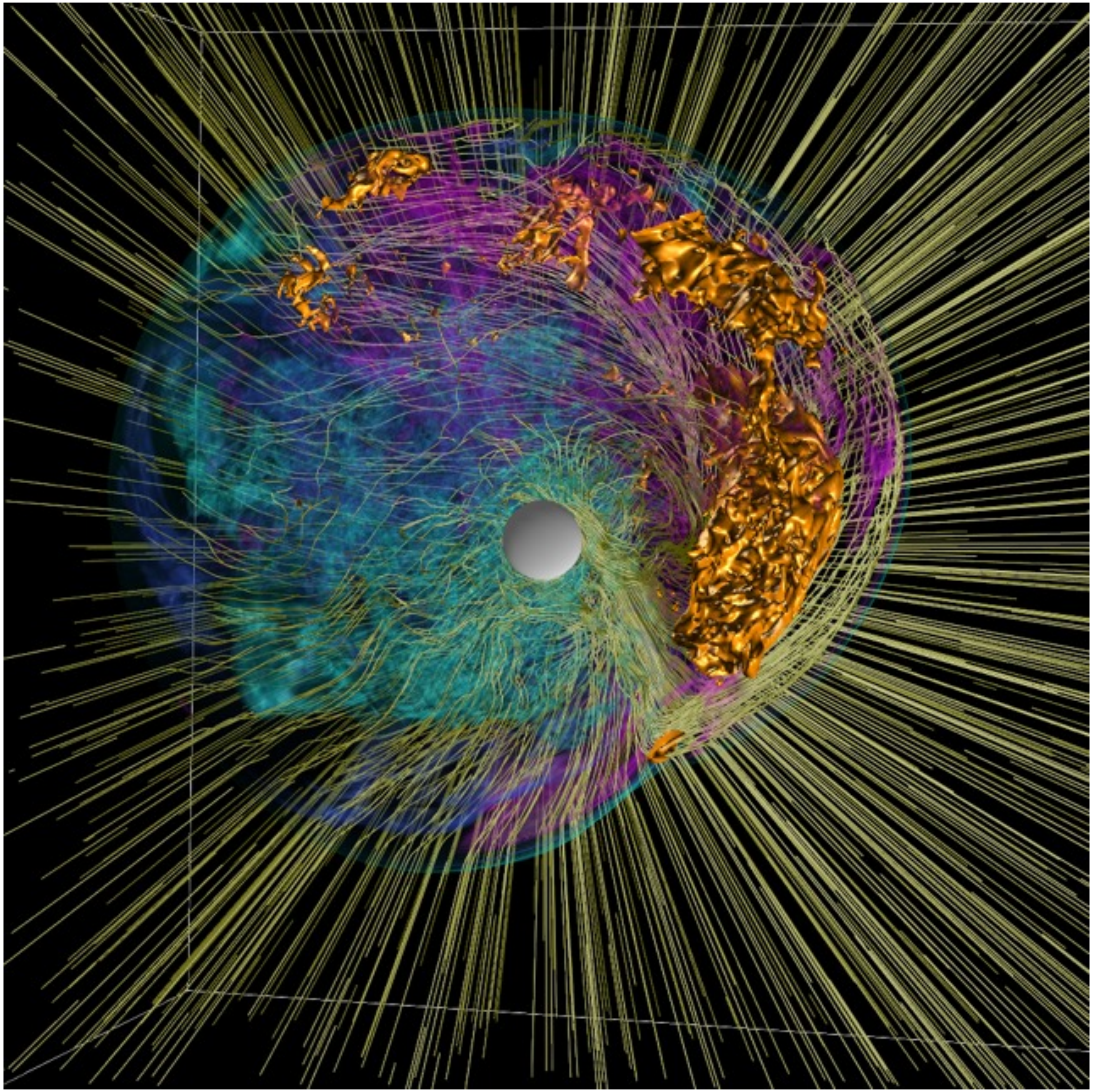


Early Stellar Spectra.

Public Domain USA.

Simulation of a supernova.

Public Domain USA.



The Spiral Galaxy NGC 4414

It is about 56,000 light-years in diameter and 60 million light-years distant.

Stained glass window in the Catholic Cathedral, Cairns, Queensland, Australia.

It depicts the aftermath of the Big Bang or Creation - depending on your point of view.

Answers to exercises

UNCORRECTED

DRAFT

Exercise 16.1

1. 1 ly = 63240AU

   1 pc = 206265AU

   Hence 1 pc = 205265/63240 = 3.26ly

2. 0.76 arc sec

3. Energy / m^2 / year = 4.5×10^{10} J

Assumptions include:

- the intensity of the radiation is the same at all points on the surface of Earth
- the distance of Sun from Earth is constant

Exercise 16.2

1. Andromeda is 28 times brighter than the Crab Nebula

2. 1.3×10^{10} y

3. (a) 2.50×10^5 AU

   (b) 4.00×10^{-6} rad;

4. B (×100);

5. (a) Yes. Its apparent magnitude at 10 pc is +4.8 which is just within the visible limit

(b) 10^{10}

(c) Greater. At 10pc Sirius is brighter than the Sun at 10pc.

6. Refer to text.

7. Refer to text.

8. 0.216 c/6.50×10^6 m s^{-1}

9. Refer to text.

10. 500 nm

11. (a) See Figure 1611.

    (b) See Figure 1611.

    (c) Vega/ Barnard's star