新灯塔国际教育

AS 物理逆袭宝典

A-Level Physics • AS Level

Cambridge International AS & A Level Physics 9702 • AS Level

答案手册 Answers

新灯塔国际教育

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1 Physical quantities and units（物理量与单位）

Basic Drill

1. A numerical magnitude and a unit.

2. 15 m s^{-1}

3. 3500 J (or 3.5 kJ)

4. kg m s^{-2}

5. kg m^2 s^{-2}

6. kg m^{-1} s^{-2}

7. kg m^2 s^{-3}

8. 45 N cm^{-2}

9. 1250 kg m^{-3}

10. kg m s^{-2}

11. SI base units of $\frac{T}{\mu}$ are m^2 s^{-2}, so $\sqrt{\frac{T}{\mu}}$ has units m s^{-1}, matching the units of speed v.

12. Systematic errors cause readings to differ from the true value by a consistent amount/fraction in one direction, whereas random errors cause readings to scatter unpredictably about the mean value.

13. Precision describes the closeness of agreement between repeated independent measurements; accuracy describes how close a measured value is to the true value.

14. 12%

15. ± 4 cm^2

16. 5.0%

17. 2.48 mm

18. Electric current: scalar; Momentum: vector; Kinetic energy: scalar; Weight: vector.

19. 98 N

20. 26 m s^{-1}

21. 15 N

22. 14 m s^{-1}

23. kg m^2 s^{-3} A^{-1}

24. 200 nC

25. 87 N

26. 4.7×10^{-4} μF

27. 5.0×10^{-7} m (accept 500 nm to 550 nm)

28. kg m^2 s^{-3}

29. $\sqrt{\frac{\text{kg}}{\text{kg s}^{-2}}} = \sqrt{\text{s}^2} = \text{s}$

30. Systematic error (or zero error); all measured values will be 0.15 g greater than the true mass.

31. 27 N

32. 1.3 m s^{-1}

33. 7%

34. A s

35. Acceleration and momentum

36. -14 m s^{-1} (or 14 m s^{-1} to the left)

37. (0.37 ± 0.01) mm

38. 9.0×10^6 J

39. 330 m s^{-1} (accept 300–350 m s^{-1})

40. kg m^2 s^{-1}

41. 7%

42. 37°

43. The closeness of agreement between repeated independent measurements of the same quantity.

44. kg m^{-1} s^{-1}

45. Take repeated measurements and calculate a mean; plot a graph of results and draw a best-fit line.

46. kg $m^2 s^{-3} A^{-2}$

47. 20 N

48. (0.035 ± 0.004) m (or (35 ± 4) mm)

49. (1.80 ± 0.02) s

50. 4.5%

Practice

1. (a) kg m s^{-2} (b) kg $m^{-1}s^{-2}$

2. (a) v: m s^{-1}, T: kg m s^{-2} (b) Units of RHS = $\sqrt{\text{kg m s}^{-2}/(\text{kg m}^{-1})}$ = $\sqrt{\text{m}^2\text{s}^{-2}}$ = m s^{-1}, which matches the units of the LHS.

3. (a) 70 kg (Accept 50 kg to 100 kg) (b) 0.07 m^3 (Accept 0.05 m^3 to 0.10 m^3)

4. (a) 75 N (b) 37°

5. (a) 7.68 g cm^{-3} (b) 7.7% (c) ±0.6 g cm^{-3}

6. (a) kg m s^{-2} (b) kg $m^{-1}s^{-1}$

7. (a) A zero error occurs when an instrument gives a non-zero reading when the true value is zero; it causes a systematic error. (b) Random errors cause readings to be scattered around the true value; taking a mean of multiple measurements cancels out some of this scatter, improving the reliability of the result.

8. (a) A vector has both magnitude and direction, whereas a scalar has only magnitude. (b) 28 m s^{-1} (c) South-East (or 135° clockwise from North)

9. (a) kg m^2s^{-3} (b) kg $s^{-3}K^{-4}$ (c) 17% (d) ±120 K

10. (a) East component: 169 m; North component: 141 m (b) 143 m (c) ±3.0 m (d) Systematic error (or zero error); it affects the accuracy of the measurements but does not affect their precision.

11. (a) 74 N (b) 43 N

12. (a) kg m^2s^{-3} (b) kg $m^2s^{-3}A^{-1}$

13. (a) Precision refers to how close measurements are to each other, while accuracy refers to how close measurements are to the true value. (b) Student B is more precise because the spread of their readings is smaller. Student A is more accurate because their average value is closer to the true length.

14. (a) 500 kg (Accept 300 kg to 800 kg) (b) 15 m s^{-1} (Accept 10 m s^{-1} to 25 m s^{-1}) (c) 56000 J (Value depends on estimates, e.g., $\frac{1}{2} \times 500 \times 15^2 = 56250$ J)

15. (a) 155 m s^{-1} (b) 15°

16. (a) kg m^2s^{-2} (b) kg m^2s^{-1}

17. (a) L: 0.83%, W: 0.67% (b) 360 cm^2 (c) ±5 cm^2

18. (a) A quantity that has both magnitude and direction. (b) Displacement, velocity, acceleration (c) Mass, temperature, kinetic energy

19. (a) 5 cm (accept reasonable estimates between 4 cm and 6 cm) (b) 100 μm (accept values derived from (a), e.g., 80 μm to 120 μm) (c) Close the jaws of the micrometer fully with nothing between them and check if the reading is exactly zero.

20. (a) P: kg m^2s^{-3}; ρ: kg m^{-3} (b) SI base units of right-hand side: kg m^{-3} × m^2 × (m s^{-1})^3 = kg m^{-3} × m^2 × m^3s^{-3} = kg m^2s^{-3}. This matches the SI base units of P, so the equation is homogeneous. (c) 20 m s^{-1}

21. (a) The difference between the bearings is 120° − 030° = 090°, which is a right angle. (b) 72 km (c) 086°

22. (a) ρ: kg m^{-3}, $\langle c^2 \rangle$: m^2s^{-2} (b) Units of RHS = kg m^{-3} × m^2s^{-2} = kg $m^{-1}s^{-2}$. Units of pressure $p = F/A$ = kg m s^{-2}/m^2 = kg $m^{-1}s^{-2}$. Both sides match.

23. (a) 25 N upwards (b) 43 N (c) 36°

24. (a) 23 m s^{-1} (b) 39 m s^{-1} (c) Vector quantities.

25. (a) Q: kg m^2s^{-2}, ΔT: K (b) $m^2s^{-2}K^{-1}$

Advanced Practice

1. kg $m^{-1}s^{-1}$

2. $g = 9.8 \pm 0.2$ m s^{-2}

3. Magnitude: 21 m s^{-1}. Direction: 135° clockwise from North (or South-East).

4. Estimated dimensions: 10 m × 8 m × 3 m (volume ≈ 240 m^3). Estimated mass: ≈ 300 kg (Accept range 100 kg to 1000 kg).

5. (a) Not accurate, as the mean value (1.41 mm) is significantly different from the true value (1.25 mm). (b) Precise, as the readings have a very small spread (0.02 mm) around the mean. (c) A zero error on the micrometer.

6. C has no units (it is dimensionless).

7. Temperature rise = 3.5 °C. Percentage uncertainty = 29% (or 30%).

8. (a) North component: 6.3 km, East component: 39.2 km. (b) Magnitude: 40 km.

9. 10^{-2} kg s^{-3}

10. Estimated mass: 3×10^5 kg, Estimated speed: 250 m s^{-1}. Estimated kinetic energy: ≈ 10^{10} J. (Accept mass $10^5 - 10^6$ kg, speed 200 − 300 m s^{-1}, energy $10^9 - 10^{11}$ J).

11. $\rho = 8.0 \pm 0.6$ g cm^{-3}

12. (a) kg m^{-1} (b) Homogeneity only checks if the base units on both sides are equivalent; a dimensionless constant like k has no units and therefore does not affect the unit balance.

13. (a) 89 m s^{-1} (b) 16° North of East

14. 14% (or 15%)

15. 4.18×10^3 $m^2s^{-2}K^{-1}$

16. 338°

17. Estimated wavelength: 500 nm (accept 400 − 700 nm). Estimated frequency: 6×10^{14} Hz (accept 4×10^{14} to 8×10^{14} Hz).

18. (a) Systematic error (or zero error). (b) The student should calculate the gradient of the straight line, as the gradient is equal to k and is unaffected by a constant systematic error.

19. (a) 4182 mm^2 (b) ±180 mm^2

20. (a) The base units of $\mathbf{r}$ are m. The base units of $\mathbf{u}t$ are (m s^{-1})(s) = m. The base units of $\frac{1}{2}\mathbf{a}t^2$ are (m s^{-2})(s^2) = m. Since all terms have the unit m, the equation is homogeneous. (b) 62 m

2 Kinematics（运动学）

Basic Drill

1. Rate of change of velocity.

2. 4.0 m s^{-2}

3. 120 m

4. 360 m

5. 2.0 m s^{-2}

6. 260 m

7. 24 m s^{-1}

8. 16 m

9. 11 m

10. 1.5 s

11. 7.0 m s^{-2}

12. (a) Velocity (b) 7.0 m s^{-1}

13. (a) 400 m (b) 0 m

14. (a) 8.0 m s^{-1} (b) 0 m s^{-1}

15. 0.61 s

16. 36 m

17. (a) 12 m s^{-1} (b) 15 m s^{-1}

18. $v^2 = u^2 + 2as$

19. (a) $h = \frac{1}{2}gt^2$ (b) Height / vertical displacement h

20. 9.70 m s^{-2}

21. 28 m

22. A reversal of the direction of motion (rebound).

23. 15 m

24. 195 m

25. 125 m s^{-1}

26. Distance moved in a specified direction

27. 14 m s^{-1}

28. Velocity

29. 10 m

30. 40 m

31. 3.0 s

32. 3.0 m

33. (a) 8.0 m s^{-1} (b) 0 m s^{-1}

34. $s = \frac{u+v}{2}t$

35. 4.0 m s^{-2}

36. The length of the card and the time duration for which the light beam is interrupted.

37. 21 m s^{-1}

38. 0 m s^{-1}

39. Distance is a scalar quantity representing the total path length, while displacement is a vector quantity representing the straight-line distance in a specified direction from the initial to the final position.

40. 2.4 m s^{-2}

41. 8.0 s

42. 2.0 s

43. +4.0 m s^{-1}

44. A curve with an increasing gradient (a parabola opening upwards).

45. Air resistance has a negligible effect on the motion of the dense steel sphere, ensuring the acceleration is that of free fall.

46. 2.5 m s^{-1}

47. 50 m

48. 1.5 m s^{-2}

49. 63 m

50. 45.3 m s^{-1}

Practice

1. (a) Rate of change of velocity. (b) 7.5 s

2. (a) 18 m s^{-1} (b) 1.0×10^3 m

3. (a) 50 m (b) 31 m s^{-1} downwards

4. (a) 16.5 m (b) 3.26 s

5. (a) 0.46 s (b) 1.1 m

6. (a) 4.2 s (b) 1.0×10^2 m

7. (a) 9.73 m s^{-2} (b) Air resistance acting on the falling ball reduces its downward acceleration.

8. (a) 1.3 m s^{-2} (b) -2.0 m s^{-2}

9. (a) 5.0 m s^{-1} (b) -10 m s^{-1}

10. The ball reaches a height of 8.1 m at the horizontal distance of 25 m, which is greater than 4.5 m, so it passes over the wall.

11. (a) 9.0 s (b) 1.6×10^2 m

12. 80 m

13. (a) 63 m s^{-1} (b) 3.1×10^2 m

14. (a) 1.8 m s^{-2} (b) 37 s

15. Rate of change of displacement.

16. 15 m s^{-1}

17. (a) 4.7 m s^{-1} (b) 3.3 m s^{-1}

18. 35.6 m

19. (a) -2.5 m s^{-2} (b) 0 m

20. 32°

21. 27.4 m

22. 1.8×10^3 m

23. (a) 2.5 m s^{-2} (b) 4.0 m s^{-1}

24. (a) 3.57 m s^{-1} (b) 9.82 m s^{-2}

25. (a) 2.0 s (b) 20 m

Advanced Practice

1. (a) Displacement s is the area under a velocity-time graph. For uniform acceleration, the graph is a straight line from velocity u to v in time t. The area is a rectangle plus a triangle: $s = ut + \frac{1}{2}(v - u)t$. From the definition of acceleration, $(v - u) = at$. Substituting this gives $s = ut + \frac{1}{2}(at)t = ut + \frac{1}{2}at^2$. (b) $u = 15$ m s^{-1}, $a = 5.0$ m s^{-2}

2. (a) $T = 100$ s (b) 30 m s^{-1}

3. (a) 3.03 s (b) 22.0 m s^{-1}

4. (a) 2.7 s (b) Magnitude: 32 m s^{-1}, Direction: 55° below the horizontal

5. (a) Horizontal velocity $v_x = 25.0 \cos 40.0° = 19.15$ m s^{-1}. Time to reach wall $t = 45.0/19.15 = 2.350$ s. Vertical position $y = (25.0 \sin 40.0°)(2.350) - 0.5(9.81)(2.350)^2 = 37.76 - 27.09 = 10.7$ m. (b) 34.0 m

6. (a) From definitions, $s = \frac{1}{2}(u+v)t$ and $a = \frac{v-u}{t}$. Substituting $t = \frac{v-u}{a}$ into the first equation gives $s = \frac{(v+u)(v-u)}{2a}$. Rearranging yields $2as = v^2 - u^2$, so $v^2 = u^2 + 2as$. (b) 77 m

7. (a) The true time of fall is $(t - \Delta t)$. Substituting this into the standard kinematic equation $s = ut + \frac{1}{2}at^2$ with $u = 0$ gives $h = \frac{1}{2}g(t - \Delta t)^2$. (b) Gradient $= \sqrt{\frac{g}{2}}$, y-intercept $= -\sqrt{\frac{g}{2}}\Delta t$

8. (a) 12 s (b) 288 m (c) 48 m s^{-1}

9. (a) 4.49 m (b) 1.40 s (c) 2.86 m (d) 12.8 m s^{-1}

10. (a) 5.0 m s^{-1} upwards (b) 61 m (c) 4.0 s

11. (a) Height of ball at net is 1.37 m, which is greater than 0.91 m (clears by 0.46 m) (b)

18.2 m (c) 26.9 m s^{-1}

12. (a) The horizontal component of velocity is constant, and the horizontal distances for both intervals are equal (12.0 m each). (b) 12.5 m s^{-1} (c) 37.0°

13. (a) 16.0 s (b) 288 m (c) 6.20 s (d) 22.9 m s^{-1}

14. (a) 2.00 s (b) 22.5 m s^{-1}

15. (a) Both objects fall with the same constant acceleration g, so their relative acceleration is zero and their relative velocity remains constant. (b) 2.72 s (c) 36.4 m

16. (a) $d = \frac{1}{2}gt_1^2$ (b) 51.7 m

17. (a) 2.27 s (b) 18.0 m (c) $v_y = -3.24$ m s^{-1}; the vertical component of velocity is negative, so the ball is travelling downwards.

18. (a) At maximum height $v_y = 0$, so $0 = (u\sin 30.0°)^2 - 2(9.81)(4.60)$. Rearranging gives $u^2(0.25) = 90.25 \implies u =$ 19.0 m s^{-1}. (b) 3.95 s (c) 39.0 m (d) 75.8 m

19. (a) $x = 15.0t$ and $y = 4.905t^2$ (b) 1.76 s (c) 30.6 m

20. (a) First gate: 2.00 m s^{-1}, Second gate: 4.05 m s^{-1} (b) 9.54 m s^{-2}

3 Dynamics（动力学）

Basic Drill

1. The product of an object's mass and its velocity.

2. 2.0 kg m s^{-1}

3. The total linear momentum of an isolated system remains constant, provided no resultant external force acts on it.

4. 24.5 N

5. 2.5 m s^{-1}

6. 1.5 m s^{-1}

7. The acceleration decreases because the upward drag force increases with speed, reducing the resultant downward force.

8. A collision in which the total kinetic energy of the system is conserved.

9. 2.3 m s^{-1}

10. The drag force increases as the speed increases.

11. −2.0 m s^{-1}

12. 0 N

13. 0 kg m s^{-1}

14. 0.06 N

15. 12 m s^{-1}

16. 20 m s^{-1} east

17. 4.0 m s^{-1}

18. The gradient of the graph becomes zero (the line becomes horizontal).

19. $-p$ along the x-axis

20. Total momentum is conserved; total kinetic energy is not conserved.

21. 3.6 kg m s^{-1}

22. 0 m s^{-2}

23. −3.0 kg m s^{-1}

24. 0 N

25. $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

26. 5.4×10^5 kg m s^{-1}

27. 0 N

28. 4.0 m s^{-1}

29. +1.5 m s^{-1}

30. −1.6 kg m s^{-1}

31. Yes, total kinetic energy is conserved.

32. 1.5 m s^{-1}

33. Vertically upwards

34. 1.0 kg m s^{-1}

35. Total kinetic energy is conserved in an elastic collision, but it decreases (is not conserved) in an inelastic collision.

36. As speed increases, the upward drag force increases until it equals the downward weight, so the resultant force becomes zero and acceleration ceases.

37. 4.0 m s^{-1} due South

38. 4.0 m s^{-1}

39. The acceleration decreases continuously until it becomes zero.

40. 4.5 m s^{-1} in the original direction of block X

41. No net external force acts on the system (the system is isolated).

42. The solid metal sphere

43. 12 kg m s^{-1}

44. Total momentum is conserved; total kinetic energy decreases.

45. Downward force: weight (gravitational force); Upward force: viscous drag (drag force).

46. 6.0 m s^{-1}

47. 8.0 m s^{-1}

48. Increases

49. +2.0 m s^{-1}

50. A collision in which total kinetic energy is not conserved.

Practice

1. Initially, the acceleration is at a maximum as the only downward force is weight. As speed increases, the upward viscous drag force increases. The resultant downward force decreases, causing acceleration to decrease. When the drag force equals the weight, the resultant force is zero, so acceleration becomes zero and terminal velocity is reached.

2. 1.0 m s^{-1}

3. Relative speed of approach is $3.0 - 0 = 3.0$ m s^{-1}. Relative speed of separation is $2.4 - (-0.60) = 3.0$ m s^{-1}. Since the relative speed of approach equals the relative speed of separation, the collision is perfectly elastic.

4. (a) 3.0 m s^{-1} (b) $v_P = 0.40$ m s^{-1}, $v_Q = 3.4$ m s^{-1}

5. 0.17 kg m s^{-1}

6. Opening the parachute increases the surface area, which increases the air resistance at any given speed. The new drag force equals the weight at a much lower speed, hence $v_2 < v_1$.

7. 30 m s^{-1} to the right

8. (a) 1.7 m s^{-1} (b) 15 J

9. (a) 5.2 kg m s^{-1} (b) 9.0 kg m s^{-1}

10. $k = 0.082$; units: kg s^{-1}

11. (a) 8.0 m s^{-1} (b) 2.4 kg m s^{-1}

12. 0.27 kg

13. The time taken to fall is greater than the time to rise. During the upward motion, air resistance and weight both act downwards, producing a larger deceleration. During the downward motion, air resistance acts upwards against weight, producing a smaller acceleration, resulting in a lower average speed.

14. 1.8 m s^{-1}

15. Initial kinetic energy is $\frac{1}{2}m(5.0)^2 = 12.5m$. Final total kinetic energy is $\frac{1}{2}m(3.0)^2 + \frac{1}{2}m(4.0)^2 = 4.5m + 8.0m = 12.5m$. Since total kinetic energy is conserved, the collision is perfectly elastic.

16. 6.9 m s^{-1}

17. 0.75 m s^{-1}

18. 3.3 m s^{-1}

19. 5.0 m s^{-1}

20. The rate of change of momentum decreases. The rate of change of momentum is equal to the resultant downward force. As air resistance increases, the resultant downward force (weight minus air resistance) decreases.

21. 0.18 kg

22. (a) 6780 m s^{-1} (b) The booster continues to move in the original forward direction of the spacecraft.

23. Final velocity is $0.25v$. Final kinetic energy is $\frac{1}{2}(4m)(0.25v)^2 = 0.125mv^2$, which is 25% of the initial kinetic energy ($\frac{1}{2}mv^2$). Thus 75% is lost.

24. 3.6 kg m s^{-1}

25. 0.67 N

Advanced Practice

1. (a) A collision in which total kinetic energy is conserved. (b) Relative speed of approach = 3.0 m s^{-1}. Relative speed of separation = $v_B - v_A$ = 3.0 m s^{-1}. By conservation of momentum: $0.40(5.0) + 0.60(2.0) = 0.40v_A + 0.60v_B \Rightarrow 3.2 = 0.4v_A + 0.6(v_A + 3.0) \Rightarrow v_A = 1.4$ m s^{-1}. $v_B = 4.4$ m s^{-1}.

2. (a) Magnitude of momentum = $\sqrt{(1200 \times 15)^2 + (3000 \times 10)^2} = 34986$ kg m s^{-1}. Velocity = 34986/4200 = 8.33 m s^{-1}. Direction: $\tan\theta = 18000/30000 = 0.60 \Rightarrow$ 31° North of East. (b) Initial KE = $0.5 \times 1200 \times 15^2 + 0.5 \times 3000 \times 10^2 = 285000$ J. Final KE = $0.5 \times 4200 \times 8.33^2 = 145714$ J. Loss in KE = 1.4×10^5 J.

3. (a) Initially, acceleration is g as air resistance is zero. As speed increases, air resistance increases, reducing the net downward force, so acceleration decreases. When air resistance equals weight, net force is zero and acceleration is zero (terminal velocity). (b) The air resistance becomes much greater than the weight, resulting in a net upward force. This causes a large upward acceleration (deceleration), which decreases as the skydiver slows down.

4. Mass of C = $3.8 \times 10^{-25} - 2(6.6 \times 10^{-27}) = 3.668 \times 10^{-25}$ kg. Momentum of A = 9.9×10^{-20} kg m s^{-1}. Momentum of B = 9.9×10^{-20} kg m s^{-1}. Resultant momentum of A and B = $\sqrt{2} \times 9.9 \times 10^{-20} = 1.40 \times 10^{-19}$ kg m s^{-1}. By conservation of momentum, momentum of C = 1.40×10^{-19} kg m s^{-1}. Velocity of C = $1.40 \times 10^{-19}/3.668 \times 10^{-25} = 3.8 \times 10^5$ m s^{-1}.

5. (a) Momentum: $mv = mv_P + 3mv_Q \Rightarrow v = v_P + 3v_Q$. Elastic: $v = v_Q - v_P \Rightarrow v_Q = v + v_P$. Substitute: $v = v_P + 3(v + v_P) \Rightarrow -2v = 4v_P \Rightarrow v_P = -0.5v$. The speed is $0.5v$ and the direction is opposite to its initial direction. (b) $v_Q = v - 0.5v = 0.5v$. Final KE of Q = $0.5(3m)(0.5v)^2 = 0.375mv^2$. Initial KE of P = $0.5mv^2$. Fraction = 0.375/0.5 = 0.75.

6. (a) The acceleration is the gradient of the velocity-time graph. (b) As velocity increases, the viscous drag force increases. The net downward force (weight minus drag and upthrust) decreases, so acceleration decreases. When drag plus upthrust equals weight, the net force is zero, making the acceleration and thus the gradient zero.

7. For an elastic collision between equal masses where one is stationary, they move off at 90° to each other, so B moves at 60°. By conservation of momentum in the original direction: $2.0(4.0) = 2.0v_A\cos 30° + 2.0v_B\cos 60°$. $v_A = 4.0\cos 30° = 3.5$ m s^{-1}. $v_B = 4.0\sin 30° = 2.0$ m s^{-1}.

8. (a) $4500 \times 2.4 = 4500 \times 1.2 + 2500v_Y \Rightarrow 10800 = 5400 + 2500v_Y \Rightarrow v_Y = 2.16$ m s^{-1}. (b) Relative speed of approach = 2.4 m s^{-1}. Relative speed of separation = $2.16 - 1.2 = 0.96$ m s^{-1}. Since relative speed of approach $\neq$ relative speed of separation, the collision is inelastic.

9. Initial momentum = $0.80 \times 12 = 9.6$ kg m s^{-1} East. M1 momentum = $0.30 \times 25 = 7.5$ kg m s^{-1} North. M2 must have momentum 7.5 kg m s^{-1} South and 9.6 kg m s^{-1} East. Total M2 momentum = $\sqrt{7.5^2 + 9.6^2} = 12.18$ kg m s^{-1}. $v_{M2} = 12.18/0.50 = 24.36 \approx 24$ m s^{-1}. Direction = $\tan^{-1}(7.5/9.6) = 38°$ South of East.

10. (a) At terminal velocity, D = 60 N. $0.24v^2 = 60 \Rightarrow v = \sqrt{250} \approx 16$ m s^{-1}. (b) Total forward force = 100 N. $0.24v^2 = 100 \Rightarrow v = \sqrt{416.7} \approx 20$ m s^{-1}.

11. (a) Since the collision is elastic and masses

are identical, they swap velocities. Speed of A is 0 m s^{-1}, speed of B is 6.0 m s^{-1}. (b) $m \times 6.0 = 2m \times v \Rightarrow v = 3.0$ m s^{-1}. (c) Initial KE $= 0.5m(6.0)^2 = 18m$. Final KE $= 0.5(2m)(3.0)^2 = 9m$. Energy lost $= 9m$. Percentage lost $= (9m/18m) \times 100\% = 50\%$.

12. (a) Just after projection, air resistance acts downwards in the same direction as weight, making the net force and acceleration greater than g. At the highest point, speed is zero, so air resistance is zero; the only force is weight, making acceleration equal to g. Thus, the initial acceleration is greater. (b) The time taken to rise is less. Energy is lost to air resistance, so the object falls back at lower speeds; a lower average speed over the same distance means the fall takes more time.

13. Initial KE $= 0.5 \times 65 \times 4.0^2 + 0.5 \times 55 \times 5.0^2 = 520 + 687.5 = 1207.5$ J. Momentum East $= 260$ kg m s^{-1}, North $= 275$ kg m s^{-1}. Total momentum squared $= 260^2 + 275^2 = 143225$. Final KE $= p^2/(2m) = 143225/(2 \times 120) = 596.8$ J. Loss in KE $= 1207.5 - 596.8 \approx 610$ J.

14. (a) Relative speed of approach $= 1.8$ m s^{-1}. Relative speed of separation $= v_M - (-0.6) = v_M + 0.6$. $v_M + 0.6 = 1.8 \Rightarrow v_M = 1.2$ m s^{-1}. (b) Momentum conservation: $m(1.8) = m(-0.6) + M(1.2) \Rightarrow 2.4m = 1.2M \Rightarrow M/m = 2.0$.

15. (a) At terminal velocity, $D = mg = 0.15 \times 9.81 = 1.4715$ N. $c = 1.4715/2.5 = 0.59$ kg s^{-1}. (b) At rest, $v = 0$ so $D = 0$. Acceleration $= g = 9.81$ m s^{-2}. (c) Net force $F = mg - cv = 1.4715 - 0.5886 \times 1.5 = 0.5886$ N. Acceleration $a = F/m = 0.5886/0.15 = 3.9$ m s^{-2}.

16. (a) $75v_P = 90 \times 1.2 \Rightarrow v_P = 1.44 \approx 1.4$ m s^{-1}. (b) Total KE $= 0.5 \times 75 \times 1.44^2 + 0.5 \times 90 \times 1.2^2 = 77.76 + 64.8 = 143$ J. (c) The internal (chemical) energy of astronaut P's muscles.

17. (a) y-momentum: $0 = 0.20 \times 3.0\sin(53.1°) + 0.30v_{By} \Rightarrow 0 = 0.48 + 0.30v_{By} \Rightarrow v_{By} = -1.6$ m s^{-1}. (b) x-momentum: $0.20 \times 5.0 = 0.20 \times 3.0\cos(53.1°) + 0.30v_{Bx} \Rightarrow 1.0 = 0.36 + 0.30v_{Bx} \Rightarrow v_{Bx} = 2.13$ m s^{-1}. (c) Initial KE $= 0.5 \times 0.20 \times 25 = 2.5$ J. Final KE $= 0.5 \times 0.20 \times 9.0 + 0.5 \times 0.30 \times ((-1.6)^2 + 2.133^2) = 0.90 + 1.07 = 1.97$ J. Since $1.97 \text{ J} < 2.5$ J, the collision is inelastic.

18. (a) $0.5 \times 0.40 \times v_X^2 = 0.45 \Rightarrow v_X^2 = 2.25 \Rightarrow v_X = 1.5$ m s^{-1}. (b) $p_X = 0.40 \times 1.5 = 0.60$ kg m s^{-1}. (c) By conservation of momentum, $p_Y = 0.60$ kg m s^{-1}. KE of Y $= p_Y^2/(2m_Y) = 0.60^2/1.2 = 0.30$ J.

19. (a) $\frac{1}{2}mv_0^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 \Rightarrow v_0^2 = v_1^2 + v_2^2$. (b) By conservation of momentum, $\vec{p}_0 = \vec{p}_1 + \vec{p}_2$. From (a), $p_0^2 = p_1^2 + p_2^2$. The momentum vectors form a triangle that satisfies Pythagoras' theorem, meaning the angle between $\vec{p}_1$ and $\vec{p}_2$ is 90°.

20. (a) $mg = kv^2 \Rightarrow 3.4 \times 10^{-6} \times 9.81 = 1.2 \times 10^{-6} \times v^2 \Rightarrow v^2 = 27.8 \Rightarrow v = 5.3$ m s^{-1}. (b) New mass $= 1.7 \times 10^{-6}$ kg. $1.7 \times 10^{-6} \times 9.81 = 1.2 \times 10^{-6}v^2 \Rightarrow v^2 = 13.9 \Rightarrow v = 3.7$ m s^{-1}. (c) As mass decreases, weight becomes less than air resistance. The resulting net upward force causes the raindrop to decelerate until the air resistance equals the new, smaller weight, reaching a lower terminal velocity.

4 Forces, density and pressure（力、密度与压强）

Basic Drill

1. The point at which the entire weight of the object may be considered to act.

2. 27 N m

3. 9.8 N m

4. The resultant force acting on the body must be zero, and the resultant torque (or moment) about any point must be zero.

5. 0.30 m

6. The product of one of the forces and the perpendicular distance between the lines of action of the forces.

7. 3.6×10^3 kg m^{-3}

8. 2.4×10^3 Pa

9. 1.5×10^5 Pa

10. 1.3×10^5 N

11. The difference in hydrostatic pressure between the bottom and the top of the object.

12. 3.4 N

13. 3.6 N

14. 2.7×10^3 kg m^{-3}

15. A closed triangle (or closed vector triangle).

16. 13 N m

17. 6.7×10^3 Pa

18. For an object in equilibrium, the sum of the clockwise moments about any point is equal to the sum of the anticlockwise moments about the same point.

19. 1.2 kg

20. 20 N

21. 9.8 N

22. Force acting normally (perpendicularly) per unit area.

23. 60 N

24. 89.8%

25. 1.7×10^5 Pa

26. The product of the force and the perpendicular distance from the line of action of the force to the pivot.

27. Directly vertically below the pin

28. 11 N m

29. 26 N m

30. A pair of equal and opposite parallel forces whose lines of action do not coincide, acting to produce rotation only.

31. 0.12 m

32. 6.8 N m

33. 15 N

34. The resultant force is zero and the resultant torque (resultant moment about any point) is zero.

35. 2.5 N

36. 360 N

37. 6.9 N

38. The resultant force is zero, so the vector sum of the three forces forms a closed loop when drawn end-to-tail.

39. Mass per unit volume.

40. 8.5×10^3 kg m^{-3}

41. 2.7×10^3 kg m^{-3}

42. Force per unit area, where the force acts normal to the area.

43. 1.5×10^3 Pa

44. 2.5×10^5 Pa

45. 6.0 m

46. The hydrostatic pressure at the bottom of the object is greater than at the top,

creating a net upward force on the object.

47. 4.6×10^{-4} m^3

48. 900 kg m^{-3}

49. 2.5 N

50. Weight $W = mg = \rho Vg = \rho Ahg$; pressure $p = \frac{W}{A} = \frac{\rho Ahg}{A} = \rho gh$.

Practice

1. (a) The resultant force is zero and the resultant torque (or moment) is zero. (b) 108 N (c) 187 N

2. (a) 2.75×10^5 N (b) 0.506 m (c) 0.0126 m

3. (a) The resultant force acting on the object is zero, and the resultant torque about any point is zero. (b) 2.9 N

4. (a) 4000 kg m^{-3} (b) 7800 Pa

5. (a) Pressure $p = \frac{F}{A}$. The force F is the weight of a fluid column of height Δh and area A, so $F = mg$. Density $\rho = \frac{m}{V} = \frac{m}{A\Delta h}$, so $m = \rho A\Delta h$. Substituting gives $p = \frac{\rho A\Delta hg}{A} = \rho g\Delta h$. (b) 2.5×10^5 Pa

6. (a) The hydrostatic pressure increases with depth. Therefore, the pressure at the bottom of the sphere is greater than at the top, creating a resultant upward force. (b) 5.1 N

7. (a) For a system in equilibrium, the sum of clockwise moments about any point equals the sum of anticlockwise moments about the same point. (b) 60 N

8. 19 N

9. (a) 400 N (b) 1.1 m

10. 1220 kg m^{-3}

11. (a) 8.6×10^{-4} m^3 (b) 13 N

12. 144 N

13. 8220 kg m^{-3}

14. 3.0×10^5 Pa

15. 3.7×10^4 N

16. (a) 5.56×10^5 Pa (b) 1.3×10^5 N

17. 0.078 m

18. 1800 N

19. (a) Weight, normal contact force, and tension. (b) 15 N

20. (a) 3.0×10^4 N (b) 1.04 kg m^{-3}

21. (a) A pair of equal and opposite forces that act along different lines of action to produce rotation only. (b) 9.5 N m

22. (a) 4.9×10^6 Pa (b) 7.4×10^4 Pa

23. 0.39 N

24. 0.24 kg

25. 76.3 m

Advanced Practice

1. (a) The product of the force and the perpendicular distance from the pivot to the line of action of the force. (b) 482 N (c) 401 N

2. (a) The resultant force is zero and the resultant torque is zero. (b) 35 N (c) The tension increases, because the vertical component of the tension must remain constant to balance the weight, so a smaller angle requires a larger tension magnitude.

3. (a) A pair of forces of equal magnitude and opposite direction, whose lines of action do not coincide, that act to produce rotation only. (b) 34 N m (c) 113 N

4. (a) Pressure $p = \frac{F}{A}$. The force is the weight of the fluid column, $F = mg = \rho V g$. The volume is $V = A\Delta h$. Substituting gives $p = \frac{\rho A \Delta h g}{A} = \rho g \Delta h$. (b) 800 kg m^{-3}

5. (a) The upthrust acting on an object in a fluid is equal to the weight of the fluid displaced by the object. (b) 8.98 N (c) 14.4 cm (or 0.144 m)

6. (a) 2.70×10^3 N (b) 1.74×10^3 N (c) 29.2°

7. (a) The point at which the entire weight of an object may be considered to act. (b) 3.23 m (c) 43.1 kg

8. (a) Force per unit normal area. (b) 4.55×10^6 Pa (c) 3.21×10^5 N

9. (a) Weight, normal reaction force, and the applied horizontal force F. (b) 45.3 N (c) 90.6 N

10. (a) 785 Pa (b) 2960 Pa (c) 9.80 N (d) 925 kg m^{-3}

11. (a) For a body in rotational equilibrium, the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about that same point. (b) 80 N (c) 144 N

12. (a) 313 N (b) 8.65 kg (c) The pressure required to open the valve increases. The counterweight is further from the pivot, increasing its clockwise moment, which requires a larger anticlockwise moment (and thus greater upward force and pressure) to open the valve.

13. (a) The sum of the reaction forces at A and B is equal to the sum of the weight of the beam and the load W. (b) 240 N

14. (a) The resultant force acting on the object is zero. (b) 52.9 N (c) 139°

15. (a) 19.9 N (b) 1140 kg m^{-3}

16. (a) Equating clockwise and anticlockwise moments: $W \times \frac{L}{2}\sin 60° = T \times L\cos 60°$, which rearranges to $T = \frac{W}{2}\tan 60°$. (b) 59.5 N (c) 49.1°

17. (a) $p_1 = \rho g x$, $p_2 = \rho g(x + h)$. (b) $F = (p_2 - p_1)A = (\rho g(x + h) - \rho g x)A = \rho g h A$. Since $V = hA$, $F = \rho g V$. (c) The upthrust acting on an object in a fluid is equal to the weight of the fluid displaced by the object.

18. (a) 127 N (b) The maximum upthrust if fully submerged is $\rho_w g V_{ext} = 71.0$ N. Since the weight (127 N) is greater than the maximum upthrust, the sphere will sink.

19. (a) 0.373 m (b) 0.311 m

20. (a) 125 N (b) 108 N

5 Work, energy and power（功、能与功率）

Basic Drill

1. Work done per unit time (or rate of energy transfer).

2. 360 J

3. 3.8×10^5 J (or 375 kJ)

4. 590 J (or 589 J)

5. 400 W

6. 0.65 (or 65%)

7. 1.7×10^3 J (or 1660 J)

8. 1.4×10^4 W (or 14.3 kW)

9. Energy cannot be created or destroyed, only transformed from one form to another.

10. 16 J

11. 9.9 m s^{-1}

12. 5.9×10^3 W (or 5.89 kW)

13. 6.0 kJ (or 6.0×10^3 J)

14. 1.0×10^7 m s^{-1} (or 1.03×10^7 m s^{-1})

15. $P = \frac{W}{t} = \frac{Fs}{t} = F\left(\frac{s}{t}\right) = Fv$ as velocity $v = \frac{s}{t}$.

16. 3.2 m

17. 100 J

18. 1.3×10^4 J (or 13.5 kJ)

19. 400 W (or 0.40 kW)

20. $W = Fs = (ma)s = m(as)$; since $v^2 = 2as \Rightarrow as = \frac{1}{2}v^2$, $W = \frac{1}{2}mv^2 = E_K$.

21. 350 W (or 353 W)

22. 2.4×10^5 J (or 243 kJ)

23. 2.5×10^3 N (or 2.5 kN)

24. The upward force to lift the mass at constant speed is $F = mg$; work done is $W = F\Delta h = mg\Delta h$, so $\Delta E_P = mg\Delta h$.

25. 2.1×10^3 W (or 2.1 kW)

26. Work done per unit time (or rate of doing work)

27. 360 J

28. 300 J

29. 7.3×10^{-18} J

30. 6380 J

31. 280 W

32. 75% (or 0.75)

33. 20 m s^{-1}

34. 1.4×10^5 J (or 135 kJ)

35. 30 m s^{-1} (or 29.7 m s^{-1})

36. 3.6×10^5 J

37. 750 W

38. 740 J (or 736 J)

39. $v^2 = u^2 + 2as$ (or $v^2 = 2as$)

40. 45 m

41. 7.1×10^9 J

42. 4.5 (or $\frac{9}{2}$)

43. 820 W

44. 1500 N (or 1.5 kN)

45. 64% (or 0.64)

46. 100 J

47. 20 m (or 20.4 m)

48. 59 N

49. 9.8×10^4 W (or 98.1 kW)

50. 5.9 m s^{-1}

Practice

1. (a) Work done is the product of a force and the displacement in the direction of the force. (b) 310 J

2. (a) Energy cannot be created or destroyed; it can only be transferred from one form to another. (b)(i) 11 J (ii) 7.3 m

3. (a) Work done $W = Fs$. The force required to lift the mass at a constant speed is its weight $F = mg$. The displacement is $s = \Delta h$. Therefore, work done $W = mg\Delta h$, which equals the change in gravitational potential energy ΔE_P. (b) 6.6×10^4 J

4. (a) For an object accelerating from rest ($u = 0$) to speed v over distance s, $v^2 = 2as$. Work done $W = Fs$ and $F = ma$, so $W = mas = m(\frac{1}{2}v^2) = \frac{1}{2}mv^2$. This work done is transferred to the kinetic energy E_K. (b) 3.8×10^5 J

5. (a) Power is the work done per unit time. (b)(i) 2.1×10^4 J (ii) 2000 J (iii) 380 W

6. (a) Power $P = \frac{W}{t}$. Work done $W = Fs$, where s is displacement. So $P = \frac{Fs}{t}$. Since constant speed $v = \frac{s}{t}$, substituting gives $P = Fv$. (b) 2.1×10^4 W

7. (a) 780 W (b) 1.1 m s^{-1}

8. (a) 310 W (b) 250 W (c) 560 W

9. (a) 91 J (b) 78 m s^{-1} (c) 310 m

10. (a) Mass per second = density × area × speed = $1.2 \times 1500 \times 9.5 = 17100$ kg s^{-1}. (b) 7.7×10^5 J (c) 41%

11. (a) 150 J (b) 8.7 m s^{-1}

12. (a) 2.1×10^5 J (b) 5.4×10^4 J (c) 16 m s^{-1}

13. (a) 12 m s^{-1} (b) 7.3 m

14. (a) 7.2×10^4 N (b) 9.6 m s^{-1}

15. (a) 1.6×10^4 J (b) 4.1×10^4 J

16. (a) 5.3×10^5 J (b) 1.9×10^4 W

17. (a) 620 J (b) It is transferred to the thermal energy of the slide and the child.

18. (a) Efficiency is the ratio of useful energy output to the total energy input. (b)(i) 6.9×10^4 W (ii) 32%

19. (a) 3.7×10^5 J (b) 4.4×10^4 W (c) Power is required to overcome air resistance (or friction) during the acceleration.

20. (a) 1.8×10^5 J (b) 4.7×10^3 J (c) 4.6 kW

21. (a) 3.5×10^7 W (b) 79%

22. (a) 810 J (b) 6800 N

23. (a) 6000 N (b) The driving force (6000 N) is greater than the resistive force (1800 N), so there is a resultant forward force. (c) 8.4×10^4 W

24. (a) 4.4×10^5 N (b) 1.3×10^8 J (c) 610 m

25. (a) 78 J (b) 6.0 J (c) 18 m s^{-1}

Advanced Practice

1. (a) $W = Fs = (ma)s$. From $v^2 = u^2 + 2as$, we have $as = \frac{1}{2}(v^2 - u^2)$. Substituting gives $W = m(\frac{1}{2}(v^2 - u^2)) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$. (b) 2.4×10^5 J

2. (a) 3.5×10^7 J (b) 4.2×10^6 J (c) 1.3×10^5 W

3. (a) 53 J (b) 22 J (c) 2.1 N

4. (a) 3.3×10^3 W (b) 16 W (c) 67%

5. (a) 340 J (b) 340 J (c) 6.7 m s^{-1}

6. (a) Work done $W = Fs$. To lift an object at constant velocity, the lifting force $F = mg$. The displacement $s = \Delta h$. Therefore $W = mg\Delta h$, which is the energy transferred to gravitational potential energy. (b) 3.4×10^4 J

7. (a) 6.3×10^5 J (b) 7.5×10^3 N (c) 21 m

8. (a) Volume per second = $Av = \pi(25)^2 \times 12 = 23562$ $m^3 s^{-1}$. Mass per second = ρ × Volume per second = $1.2 \times 23562 =$

28274 $\approx 2.8 \times 10^4$ kg s^{-1}. (b) 2.0×10^6 J (c) 8.1×10^5 W

9. (a) 1.3×10^4 J (b) 3.8×10^3 J (c) 16 m s^{-1}

10. (a) $P = \frac{W}{t}$. Since work done $W = Fs$, $P = \frac{Fs}{t}$. As velocity $v = \frac{s}{t}$, substituting gives $P = Fv$. (b) 29 N (c) 230 W (d) On an incline, the cyclist must also do work against gravity, increasing the total opposing force. Since power $P = Fv$ is constant and F increases, v must decrease.

11. (a) 48 J (b) 0.59 J (c) 1.2×10^3 N

12. (a) 63 N (b) 750 W (c) 330 W

13. (a) 120 J (b) 37 J (c) 49 m

14. (a) 2.3×10^4 J (b) 30 m (c) 2.8×10^4 J

15. (a) 49 kW (b) 0.42 kW (c) 76%

16. (a) 6.4 J (b) 69 J (c) 27 m s^{-1}

17. (a) 3.8×10^5 J (b) 6.8×10^3 W (c) 210 N

18. (a) 0 J (b) 50 N (c) 300 W

19. (a) 650 J (b) 8.1×10^3 N (c) The work required to pass through the block is 1200 J, which is greater than the initial kinetic energy of 735 J, so the bullet will not pass completely through.

20. (a) 2.4×10^8 W (b) 1.9×10^7 W (c) Net rate = 2.2×10^8 W, Efficiency = 80%

6 Deformation of solids（固体的形变）

Basic Drill

1. Force per unit cross-sectional area

2. 1.5×10^{-3}

3. 300 N m^{-1}

4. Extension is directly proportional to the applied force, provided the limit of proportionality is not exceeded.

5. 8.0×10^{7} Pa

6. 0.16 m

7. 1.2×10^{11} Pa

8. 0.080 J

9. Micrometer screw gauge

10. 12 N

11. The maximum stress or force beyond which the material undergoes permanent (plastic) deformation and does not return to its original length when the load is removed.

12. 0.020

13. 0.12 J

14. In elastic deformation the material returns to its original dimensions when the load is removed, whereas in plastic deformation there is a permanent deformation.

15. 1.3×10^{-7} m^2

16. 2.1×10^{11} Pa

17. Work done (or elastic potential energy stored)

18. 0.036 J

19. 0.050 m

20. 1.5×10^{-5} m^2

21. The point beyond which force is no longer directly proportional to extension (Hooke's law is no longer obeyed).

22. $4E$

23. 8.0×10^{-4} m

24. 2.0×10^{5} Pa

25. To compensate for changes in temperature (thermal expansion) and sagging of the main support.

26. Extension is directly proportional to the applied force, provided the limit of proportionality is not exceeded.

27. 0.15 m

28. 3.0×10^{3} N

29. 400 N m^{-1}

30. 5.0×10^{7} Pa

31. 6.0×10^{-4}

32. kg $m^{-1}s^{-2}$

33. The ratio of tensile stress to tensile strain.

34. 4.50×10^{11} Pa

35. Deformation in which the material does not return to its original length or shape when the deforming force is removed.

36. Work done on the material (or elastic potential energy stored).

37. 0.45 J

38. 0.18 J

39. To calculate an average diameter and account for any non-uniformity in the wire's cross-section.

40. Thermal energy dissipated (or work converted into heat).

41. 5.0×10^{-7} m^2

42. 0.030

43. Up to the limit of proportionality, force is proportional to extension; beyond the elastic limit, permanent (plastic) deformation occurs.

44. 8.0×10^{-4}

45. 240 N m^{-1}

46. 1.6×10^{-3} m

47. $9E_p$

48. To produce a larger extension for a given load, which reduces the percentage uncertainty in the extension measurement.

49. 7.0×10^{7} Pa

50. 0.080 J

Practice

1. $F = 2.50 \times 9.81 = 24.5$ N $x = 0.580 - 0.450 = 0.130$ m $k = \frac{F}{x} = \frac{24.525}{0.130} = 189$ N m^{-1}

2. $x = \frac{FL}{AE} = \frac{4.20\times10^5\times2.40}{0.0550\times3.80\times10^{10}} = 4.83 \times 10^{-4}$ m

3. (a) The extension of a material is directly proportional to the applied force, provided the limit of proportionality is not exceeded. (b) The point beyond which the applied force is no longer directly proportional to the extension.

4. $E_P = \frac{1}{2}Fx = 0.5\times45\times3.0\times10^{-3} = 0.068$ J

5. (a) Area $= \pi \times (0.40 \times 10^{-3})^2 = 5.03 \times 10^{-7}$ m^2 Stress $= \frac{65}{5.03\times10^{-7}} = 1.29\times10^8$ Pa (b) Strain $= \frac{\text{Stress}}{E} = \frac{1.29\times10^8}{2.1\times10^{11}} = 6.14\times10^{-4}$

6. (a) Area $= \pi \times (0.28 \times 10^{-3})^2 = 2.46 \times 10^{-7}$ m^2 $E = \frac{FL}{Ax} = \frac{30.0\times2.500}{2.46\times10^{-7}\times1.8\times10^{-3}} = 1.69\times10^{11}$ Pa (b) Micrometer screw gauge

7. (a) 45.0 N (b) 1.25×10^4 N m^{-1} (c) 0.300 J

8. For a material obeying Hooke's law, $E_P \propto x^2$. Since the extension is 3 times greater, the energy stored is $3^2 = 9$ times greater. $E_P = 0.15 \times 9 = 1.35$ J

9. Work done $= \frac{1}{2}kx_2^2 - \frac{1}{2}kx_1^2 = \frac{1}{2} \times 450 \times (0.050^2 - 0.020^2) = 225 \times (0.0025 - 0.0004) = 0.473$ J

10. $x = \frac{FL}{AE}$. Wire A has 2× length and $\frac{1}{4}$× cross-sectional area compared to B. $x_A = \frac{F(2L_B)}{(\frac{1}{4}A_B)E} = 8\frac{FL_B}{A_BE} = 8x_B$ Ratio = 8

11. Area $= \pi\times(0.60\times10^{-2})^2 = 1.13\times10^{-4}$ m^2 Maximum load = breaking stress × A = $7.5 \times 10^7 \times 1.13 \times 10^{-4} = 8480$ N

12. (a) Gradient of linear section $= \frac{32}{4.0\times10^{-3}} = 8000$ N m^{-1} (b) 4.0 mm

13. $F = 4.00 \times 9.81 = 39.24$ N $x = \frac{FL}{AE} = \frac{39.24\times1.80}{3.20\times10^{-7}\times1.30\times10^{11}} = 1.70 \times 10^{-3}$ m $E_P = \frac{1}{2}Fx = 0.5\times39.24\times1.70\times10^{-3} = 0.0334$ J

14. (a) The total work done in stretching the rubber cord. (b) Energy dissipated $= 0.85 - 0.60 = 0.25$ J

15. $E = \frac{\text{Stress}}{\text{Strain}} = \frac{1.5\times10^8}{0.0012} = 1.25 \times 10^{11}$ Pa

16. Area $= \pi\times(0.50\times10^{-3})^2 = 7.85\times10^{-7}$ m^2 $x_{\text{al}} = \frac{150\times2.00}{7.85\times10^{-7}\times7.0\times10^{10}} = 5.46 \times 10^{-3}$ m $x_{\text{st}} = \frac{150\times3.00}{7.85\times10^{-7}\times2.1\times10^{11}} = 2.73 \times 10^{-3}$ m Total extension $= 5.46 + 2.73 = 8.19 \times 10^{-3}$ m

17. $E_P = \frac{1}{2}Fx = \frac{1}{2}(\text{stress} \times A)(\text{strain} \times L) = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{Volume}$ $E_P = 0.5 \times 8.0\times10^7 \times 4.0\times10^{-4} \times 4.5\times10^{-5} = 0.72$ J

18. (a) $F = 0.80 \times 9.81 = 7.85$ N $k = \frac{7.848}{0.045} = 174$ N m^{-1} (b) $E_P = \frac{1}{2}Fx = 0.5 \times 7.848 \times 0.045 = 0.177$ J

19. $L = \frac{EAx}{F} = \frac{1.1\times10^{11}\times2.4\times10^{-6}\times0.45\times10^{-3}}{180} = 0.66$ m

20. (a) 1250 N m^{-1} (b) 0.120 m (c) 9.00 J

21. Gradient of linear region $= \frac{40}{4.0} = 10$ N mm^{-1} Elastic recovery upon unloading $= \frac{55}{10} = 5.5$ mm Permanent extension $= 7.0 - 5.5 = 1.5$ mm

22. $F = 2.50 \times 9.81 = 24.53$ N Area $= \pi \times (1.50 \times 10^{-2})^2 = 7.07 \times 10^{-4}$ m^2 Stress $= \frac{24.53}{7.07\times10^{-4}} = 3.47 \times 10^4$ Pa Strain $= \frac{\text{Stress}}{E} = \frac{3.47\times10^4}{1.50\times10^6} = 0.0231$

23. Work done = Area under graph = Area of triangle + Area of rectangle Area $= (\frac{1}{2} \times 2.0 \times 10^{-3} \times 20) + (3.0 \times 10^{-3} \times 20) = 0.020 + 0.060 = 0.080$ J

24. (a) Original length of the wire, diameter of the wire, applied force (or load), and the corresponding extension. (b) Young modulus = gradient of the linear section of the graph$\times \frac{\text{original length}}{\text{cross-sectional area}}$.

25. (a) $E_P = \frac{1}{2}Fx \rightarrow 1.2 = 0.5 \times 50 \times x \rightarrow x = \frac{1.2}{25} = 0.048$ m (b) $k = \frac{F}{x} = \frac{50}{0.048} = 1040$ N m^{-1}

Advanced Practice

1. (a) 7.1×10^{-3} m (b) 1.6 J

2. (a) $E_P = \frac{1}{2}Fx$, substitute $F = \frac{EAx}{L}$ to give $E_P = \frac{EAx^2}{2L}$. (b) 3.1×10^4 J m^{-3}

3. (a) 1.3 mm (b) 0.093 J

4. (a) 5.0×10^2 N (b) 3.0

5. (a) Piece A: 450 N m^{-1}, Piece B: 225 N m^{-1} (b) 0.067 m

6. (a) 0.48 J (b) 0.15 J

7. (a) 2.1×10^{11} Pa (b) The gradient would increase by a factor of 8 (to 1.1×10^5 N m^{-1}).

8. (a) 57 N (b) 1.6 J

9. (a) 0.50 m (b) $E_P \propto x$ for constant F. Since $x \propto 1/k$, $E_{P1}/E_{P2} = k_2/k_1 = 300/200 = 1.5$.

10. (a) Stress: 5.7×10^6 Pa, Strain: 1.9×10^{-4} (b) 7.6×10^{-4} m

11. (a) 0.26 J (b) 0.14 J

12. (a) 1.3 (or 4/3) (b) 4.0

13. (a) 150 J (b) The large amount of stored elastic potential energy is rapidly converted into kinetic energy of the rope.

14. (a) 1.6×10^4 N m^{-1} (b) 0.071 J

15. (a) Steel: 2.8×10^{-3} m^2, Concrete: 5.0×10^{-3} m^2 (b) 4.1×10^5 N

16. (a) 0.75 mm (b) The total energy is 0.045 J, which is half the energy stored in the single wire.

17. (a) The graph is a straight line passing through the origin, indicating force is directly proportional to extension. (b) Energy is the area under the graph, which is a triangle of area $\frac{1}{2}Fx$. Since $F = kx$, Area $= \frac{1}{2}kx^2$. (c) 0.89 J

18. (a) 1.5×10^{-3} m (b) 3.3×10^{-3} m

19. (a) Total extension $x = x_1 + x_2 = \frac{F}{k} + \frac{F}{k} = \frac{2F}{k}$. Therefore, effective $k = \frac{F}{x} = \frac{k}{2}$. (b) 1200 N m^{-1}

20. (a) 1.3×10^{11} Pa (b) 6.4×10^{-3} m

7 Waves（波）

Basic Drill

1. 0.75 m

2. 20 m s^{-1}

3. 500 Hz

4. 6.0 V

5. 9.0

6. 0.16 W m^{-2}

7. 135°

8. In a transverse wave, oscillations are perpendicular to the direction of energy propagation; in a longitudinal wave, oscillations are parallel to the direction of energy propagation.

9. (a) longitudinal (b) transverse

10. 25 Hz

11. Period = 0.080 s; frequency = 12.5 Hz

12. 785 Hz

13. 425 Hz

14. 19 m s^{-1}

15. 3.00 m

16. Visible light

17. 400 nm to 700 nm

18. Region: Microwave; frequency: 1.0×10^{10} Hz

19. Sound waves are longitudinal, so oscillations are parallel to the direction of wave propagation.

20. 45 W m^{-2}

21. 60°

22. 5.0×10^3 W m^{-2}

23. The forward motion of the source compresses the wavefronts, shortening the observed wavelength while the wave speed remains constant.

24. 0 W m^{-2}

25. 1.57 rad (or $\frac{\pi}{2}$ rad)

26. 6.0×10^{-4} m

27. 12 W m^{-2}

28. 1.0 V

29. Parallel to the direction of energy propagation.

30. 628 Hz

31. 5.56×10^{14} Hz

32. $6.25I$

33. 90° (or $\frac{\pi}{2}$ rad)

34. 45°

35. 21.3 m s^{-1}

36. Energy

37. 0.159 W m^{-2}

38. 100 Hz

39. X-rays

40. 0.020 s

41. Sound waves in air are longitudinal waves, and polarisation is a phenomenon that only occurs for transverse waves.

42. 0.612 m

43. 6.0 Hz

44. $\frac{1}{9}I_0$ (or $0.11I_0$)

45. $0.75I_0$

46. 0.40 m

47. 2500 s

48. 8.0 cm

49. 407 Hz

50. 400 nm to 700 nm (or 4.0×10^{-7} m to 7.0×10^{-7} m)

Practice

1. (a) Wave motion is the transfer of energy from one point to another without the net transfer of matter. (b) Speed $v = \frac{\text{distance}}{\text{time}}$. In one period T, the wave travels a distance of one wavelength λ, so $v = \frac{\lambda}{T}$. Since frequency $f = \frac{1}{T}$, substituting this gives $v = f\lambda$.

2. (a) 2.5 ms (b) 0.625 ms div^{-1} (or 0.63 ms div^{-1})

3. (a) 7.5×10^{-3} W m^{-2} (b) 8.0 m

4. (a) In a transverse wave, particle oscillations are perpendicular to the direction of wave travel (energy transfer). In a longitudinal wave, particle oscillations are parallel to the direction of wave travel. (b) Transverse: electromagnetic waves (or waves on a string/water). Longitudinal: sound waves.

5. (a) 15 Hz (b) 135° (or $\frac{3\pi}{4}$ rad)

6. (a) Amplitude = 2 mm, Wavelength = 0.40 m (b) $x = 0.20$ m (or 0.60 m) (c) $x = 0.40$ m (or 0.80 m)

7. 486 Hz

8. (a) 560 Hz (b) The observed frequency decreases further, because the denominator $(v + v_s)$ in the Doppler equation increases as the source speed increases.

9. (a) They are all transverse waves and they all travel at the same speed (3.0×10^8 m s^{-1}) in a vacuum. (b) 10^{-12} m to 10^{-8} m (c) Wavelength $\lambda = \frac{c}{f} = \frac{3.0\times10^8}{4.5\times10^{14}} = 6.7 \times 10^{-7}$ m = 670 nm. This is within the visible range of 400-700 nm.

10. (a) Polarisation is the restriction of the oscillations of a transverse wave to a single plane. (b) 2.8 W m^{-2}

11. (a) 60° (b) Polarisation requires oscillations to be restricted to one plane perpendicular to the direction of energy transfer. Longitudinal waves oscillate parallel to the direction of energy transfer, so they only have one direction of oscillation and cannot be polarised.

12. (a) 0.30 m (b) 144° (or 2.5 rad)

13. (a) 10 mV (b) 100 Hz

14. 3.0 mm

15. (a) 785 Hz (b) 141 Hz

16. (a) Away from the observer. (b) 14 m s^{-1}

17. (a) Microwaves (b) 1.5×10^{10} Hz (c) 4.3×10^{14} Hz to 7.5×10^{14} Hz

18. (a) $I = I_0 \cos^2\theta$ (b) $0.64A_0$

19. (a) 0.40 m s^{-1} (b) The leaf oscillates vertically up and down about its equilibrium position. (c) The leaf does not move horizontally in the direction of the wave, showing matter is not transferred, but the leaf gains kinetic and potential energy, showing energy is transferred.

20. (a) 208 Hz (b) 90° (or $\frac{\pi}{2}$ rad) (c) 349 m s^{-1}

21. (a) 1645 Hz (b) 1378 Hz (c) As the car passes, the relative velocity changes from moving towards the observer to moving away, changing the denominator in the Doppler equation from $(v - v_s)$ to $(v + v_s)$.

22. (a) 0.033 s (b) 0.80 m (c) 14 mm

23. (a) 60° (b) 2.25 W m^{-2}

24. (a) Gamma rays: $\leq 10^{-11}$ m. Radio waves: $\geq 10^{-1}$ m. (b) 1.0×10^{15}

25. 24 m s^{-1}

Advanced Practice

1. (a) Speed is distance divided by time. In one period T, the wave travels one wavelength λ, so $v = \lambda/T$. Since $f = 1/T$, $v = f\lambda$. (b)(i) 7.5 m s^{-1} (b)(ii) 8000 W m^{-2}

2. (a) 62.5 Hz (b) 0.0115 V (c) 6.5 divisions

3. (a) In a transverse wave, particles oscillate perpendicular to the direction of energy transfer. In a longitudinal wave, particles oscillate parallel to the direction of energy transfer. (b)(i) 200 Hz (b)(ii) 1.4π rad (or 4.4 rad)

4. (a) 30 m s^{-1} (b) 413 Hz

5. (a) 3.00×10^8 m s^{-1} (b) 5.4×10^{-7} m (c) Visible light (d) Yes, because its wavelength of 540 nm falls within the visible range of 400 nm to 700 nm.

6. (a) 67° (b) $0.13I_0$

7. (a) Amplitude = 2.5 mm, Frequency = 250 Hz (b) 6.0 m (c) 120° (or $2\pi/3$ rad)

8. (a) 22.4 m s^{-1} (b) 87 Hz

9. (a) Microwaves (b) They can travel through a vacuum (or they are transverse waves / can be polarised). (c) 0.71

10. (a) 90° (or $\pi/2$ rad) (b) 1.78×10^{-4} W m^{-2}

11. (a) The source moves away during the emission of the wave, increasing the distance between adjacent wavefronts. This increases the observed wavelength, and since wave speed is constant, the observed frequency decreases. (b) 0.304 m

12. (a) 4.0 m s^{-1} (b) 0 mm

13. (a) 1100 W m^{-2} (b) 2.0

14. $0.39I_0$

15. (a) 1.2×10^{18} Hz (b) 400 nm to 700 nm (c) 0.054 J

16. (a) 862 Hz (b) 16.7 m s^{-1}

17. (a) 2.0×10^{-4} s (b) $0.25I$

18. (a) 500 Hz (b) 0.30π rad (or 0.94 rad) (c) 0.099 m

19. (a) 3.16 m (b) Wavelength of red light is approx 700 nm. Ratio = 4.5×10^6.

20. (a) 54.7° (b) 90° (c) 2.89 V m^{-1}

8 Superposition（波的叠加）

Basic Drill

1. When two or more waves meet at a point, the resultant displacement is equal to the vector sum of the individual displacements of the waves.

2. 0.50 m

3. 1.0×10^{10} Hz

4. A point on a stationary wave where the amplitude of vibration is always zero.

5. 0.72 m

6. 0° (or 0 rad, in phase)

7. 0.40 m

8. The spreading of a wave as it passes through a gap or around an obstacle.

9. The width of the gap is approximately equal to the wavelength of the waves.

10. Diffraction is reduced (less spreading of the wavefronts occurs).

11. The wavelength of sound waves is of a similar order of magnitude to the doorway width, whereas the wavelength of visible light is much smaller than the doorway width.

12. Sources that emit waves with a constant phase difference.

13. Path difference $= n\lambda$, where n is an integer $(0, 1, 2, \dots)$.

14. Destructive interference

15. 6.0×10^{-7} m (or 600 nm)

16. 4 (increases by a factor of 4)

17. 250 nm (or 2.5×10^{-7} m)

18. The fringe separation increases because red light has a longer wavelength than blue light.

19. 2.00×10^{-6} m

20. 17.5°

21. 3

22. 5.87×10^{-7} m (or 587 nm)

23. Red light

24. The order of the diffraction maximum (or order number)

25. The maxima are much sharper (brighter/more widely spaced), allowing angles to be measured with greater precision.

26. 5.0 mm

27. 0.36 m

28. 3.0 cm

29. 0.80 m

30. 1.0 m

31. The waves must travel in opposite directions and have the same frequency (or wavelength).

32. At a node the amplitude of vibration is zero, whereas at an antinode the amplitude is a maximum.

33. The spreading of a wave into its geometrical shadow as it passes through a gap or past an edge.

34. Diffraction increases and the transmitted wavefronts become semi-circular.

35. The gap width is approximately equal to (or less than) the wavelength of the waves.

36. The sources emit waves that have a constant phase difference.

37. Constructive interference

38. 300 nm

39. 6.4×10^{-7} m

40. 2.95 mm

41. 0.25 m

42. 5.6 cm

43. A bright white fringe

44. 2.0×10^{-6} m

45. 3.00×10^{-6} m

46. 6.11×10^{-7} m

47. 7

48. 7.05°

49. 0.84 m

50. 3.9×10^{-4} m

Practice

1. (a) 1.25 cm (or 0.0125 m) (b) The intensity at the minimum increases; the reflected wave now has a smaller amplitude than the incident wave, so the waves no longer completely cancel out (destructive interference is incomplete).

2. +2.3 cm

3. (a) 180° (or π rad) (b) 0.80 m

4. (a) The transmitted wave reflects off the metal plate. The incident and reflected waves, which have the same frequency and speed, travel in opposite directions and superpose. (b) 2.8 cm

5. (a) Node at the water surface, antinode at the open end. (b) 64.8 cm (c) 48.6 cm

6. (a) 0.80 m (b) 0 mm

7. (a) 1 node, 2 antinodes. (b) 1.3 m

8. (a) The spreading of a wave as it passes through a gap or past an edge. (b) When $d = 10.0$ cm, there is little diffraction (waves remain mostly straight). When $d =$ 2.5 cm, the diffraction is maximum, and the waves spread out significantly to form roughly semicircular wavefronts.

9. Significant diffraction occurs because the wavelength (0.40 m) is comparable in magnitude to the gap width (0.90 m).

10. The wavelength of sound is comparable to the width of the window, causing significant diffraction. The wavelength of light is much smaller than the window width, so its diffraction is negligible.

11. (a) The detected intensity varies, spreading over a wide angle with a central maximum. (b) The waves spread out less (diffraction is reduced) and the central maximum becomes narrower.

12. (a) Two waves are coherent if they have a constant phase difference. (b) Light from two separate bulbs is emitted randomly, so there is no constant phase difference between them (they are incoherent).

13. (a) 4.5 cm (b) The path difference is 3λ (an integer number of wavelengths), so constructive interference occurs.

14. (a) Waves from S_1 and S_2 meet and superpose at the microphone. At minima, the path difference is an odd number of half-wavelengths, causing destructive interference. (b) The distance between adjacent minima decreases.

15. 4.2×10^{-3} m

16. (a) 3.5×10^{-3} m (b) 4.5×10^{-4} m

17. (a) The fringe separation increases because it is directly proportional to the distance to the screen ($x \propto D$). (b) The fringe separation decreases because it is inversely proportional to the slit separation ($x \propto 1/a$).

18. 1. The waves must be coherent (have a constant phase difference). 2. The waves must have roughly equal amplitudes. 3. The waves must be unpolarised or polarised

in the same plane.

19. 180° (or π rad)

20. 1.7×10^{-6} m

21. 18°

22. 3

23. (a) 1.60λ (b) 216° (or 1.2π rad) (c) 275 Hz

24. 1. The maxima are much sharper (narrower), allowing their angles to be measured more precisely. 2. The maxima are brighter, making them easier to observe.

25. 5.7×10^{-7} m

Advanced Practice

1. (a) The incident wave from the transmitter and the wave reflected from the plate travel in opposite directions and superpose to form a stationary wave. (b) 8.3×10^{9} Hz.

2. (a) 1.0λ. (b) Maximum intensity. The path difference is an integer number of wavelengths, so the waves arrive in phase and interfere constructively.

3. (a) A stationary wave is formed by the superposition of the incident wave and the wave reflected from the water surface. Resonance occurs when the natural frequency of the air column matches the tuning fork. (b) 500 Hz.

4. (a) 45°. (b) 2.

5. (a) The sources must be coherent (constant phase difference) and the waves must have approximately equal amplitudes. (b) 0.051 m.

6. (a) The incident sound wave and the wave reflected from the closed end have the same frequency and travel in opposite directions; they overlap and superpose to form the stationary wave. (b) 12.0 cm (c) 180° (or π rad) (d) 16.0 cm

7. 10.2°.

8. 0.47 m.

9. (a) The spreading of a wave as it passes through a gap or around an edge. (b) The spreading of the waves will decrease significantly because the gap width is now much larger than the wavelength.

10. (a) When two waves meet, the resultant displacement is the algebraic sum of their individual displacements. (b) 0.075 s. (c) A single triangular pulse with a peak displacement of 6.0 cm and a width of 10.0 cm.

11. (a) A constant phase difference between two waves. (b) Light from independent bulbs is emitted in random bursts. The phase difference changes rapidly and randomly, so the interference pattern shifts too quickly to be observed, resulting in uniform illumination.

12. (a) 487 lines per mm. (b) Yes, it can be observed. The calculated value for $\sin\theta$ is 0.949, which is less than or equal to 1.

13. (a) Node at the closed end, antinode at the open end. (b) $f_2 = 2f_1$.

14. (a) At the central maximum, the path difference is zero for all wavelengths, so all colours interfere constructively and combine to form white light. (b) Blue. The fringe spacing is directly proportional to wavelength, and blue light has a shorter wavelength than red light.

15. 100 nm.

16. (a) 60 cm. (b) 0° (or 0 rad).

17. (a) 6.0 cm. (b) Constructive interference. The path difference is exactly 2λ, so the waves arrive in phase.

18. (a) Increases. Fringe spacing is directly proportional to the distance D. (b) Increases. Fringe spacing is inversely proportional to the slit separation a.

19. $4\lambda \leq d < 5\lambda$.

20. (a) Diffraction is the spreading out of a wave as it passes through a gap or around an edge. (b) 420 nm (c) 30.3° (d) 3 (e) For the zero order, the path difference between waves from adjacent slits is zero for all wavelengths, so constructive interference occurs at $\theta = 0°$.

9 Electricity（电学）

Basic Drill

1. 81 C

2. 4.5×10^{10}

3. Quantisation of charge

4. 1.2×10^{-4} m s^{-1}

5. 0.25

6. Energy transferred from electrical energy to other forms of energy per unit charge

7. 4200 J

8. 36 W

9. 29 W

10. 2.6 Ω

11. 4.9 MJ

12. The ratio of potential difference across the conductor to the current in it

13. The current in a conductor is directly proportional to the potential difference across it, provided physical conditions such as temperature remain constant

14. 400 Ω

15. The temperature of the filament increases, increasing lattice vibrations and the collision frequency of conduction electrons

16. 0.7 V

17. 6.9 Ω

18. 4.6×10^{-7} Ω m

19. $9R$

20. Decreases

21. Increases

22. 4.0 Ω

23. 1.0×10^{29} m^{-3}

24. 5.6×10^{-19} C

25. 6.0 V

26. 2.3×10^{20}

27. 1.7×10^{-7} Ω m

28. 3.6×10^{5} J

29. 2.0 hours

30. 1.6×10^{-4} m s^{-1}

31. 1.2 A

32. $0.75R$

33. 10 m

34. 8.0×10^{-4} A

35. 30 W

36. The current in a conductor is directly proportional to the potential difference across it, provided physical conditions such as temperature remain constant.

37. 2.4×10^{-4} A

38. 0.25

39. 12 V

40. 3.0 Ω

41. Electric charge only exists in discrete amounts that are integer multiples of the elementary charge e.

42. 2.0×10^{-7} Ω m

43. 30 V

44. Zero

45. Free electrons (or conduction electrons)

46. 9.6 A

47. The ratio of potential difference across a component to the current in it ($R = \frac{V}{I}$).

48. 1.8×10^{-4} m s^{-1}

49. Constant temperature

50. 830 J

Practice

1. (a) Charge can only exist in discrete amounts that are integer multiples of the elementary charge e. (b)(i) 960 C (b)(ii) 6.0×10^{21}

2. (a) 2.0×10^{-6} m^2 (b) 2.9×10^{-4} m s^{-1}

3. (a) The energy transferred per unit charge. (b)(i) 16 V (b)(ii) 16 s

4. (a) For a metallic conductor at constant temperature, the current is directly proportional to the potential difference across it. (b)(i) 15 Ω (b)(ii) 5.4 W

5. (a) 13 Ω (b) 11 W (c) 3.0×10^{-4} m s^{-1}

6. (a) 2.0 A (b) 12 Ω (c) As current increases, the power dissipated increases, raising the temperature of the filament. This causes the atoms to vibrate with greater amplitude, increasing the collision rate with electrons and thus increasing resistance.

7. (a) Semiconductor diode (b) 20 Ω (c) Infinite (or very high)

8. (a) The resistance decreases. (b) 0.040 W (c) 500 Ω

9. (a) The resistance increases. (b) 2.0×10^6 Ω (c) 0.030 A (d) 8.4×10^{18}

10. (a) 1/4 of the area of wire X (b) $16R$ (c) 40 Ω

11. (a) The rate of flow of charge carriers. (b) 2.8×10^{11}

12. (a) 1.6×10^{-7} m^2 (b) 5.5×10^{29} m^{-3}

13. (a) 21 Ω (b) 3.9 m

14. (a) 480 C (b) 6.8×10^{-4} Ω (c) 0.082 V (d) 9.8 W (e) 2.9×10^{-4} m s^{-1}

15. (a) Charge can only exist in discrete amounts that are integer multiples of the elementary charge e. (b) Drop B, because 4.0×10^{-19} C is not an integer multiple of 1.6×10^{-19} C ($2.5e$).

16. (a) 13 A (b) 2600 C (c) 1.6×10^{22} (d) The energy transferred per unit charge.

17. (a) 1.6 (b) 1.3

18. (a) 0.019 W (b) 5.0×10^{-8} A

19. (a) 2.0 Ω (b) 3.0 Ω (c) At the higher potential difference, the power dissipated is greater, so the temperature of the filament is higher. This increases atomic vibrations, which increases the resistance.

20. (a) Charge only exists in discrete integer multiples of the elementary charge. (b) 470 s (c) 1.1×10^{15} m^{-3}

21. (a) 6.0×10^{-8} m^2 (b) 0.024 Ω

22. (a) 8.6×10^4 C (b) 5.4×10^{23} (c) 3.5×10^7 J (d) (i) 0.063 Ω (ii) 1.9×10^{-6} m^2

23. (a) Area is proportional to the square of the diameter ($A \propto D^2$). (b) $v/9$

24. (a) 7.7×10^{-6} m^2 (b) 3.1×10^{-3} m

25. (a) $Q = It$ (b)(i) 2.0 A (b)(ii) 360 C (b)(iii) 2.3×10^{21}

Advanced Practice

1. (a) Charge is conserved and there is no accumulation of charge carriers at the junction, so the rate of flow of charge must be the same throughout. (b) $I = Anvq$. Since I, n, and q are constant, $v \propto \frac{1}{A} \propto \frac{1}{d^2}$. The ratio is $\frac{(3d)^2}{d^2} = 9$.

2. (a) 3.0×10^{15} (b) 4.3 J

3. (a) 2.5 Ω (b) As current increases, the temperature of the filament increases. The lattice ions vibrate with greater amplitude,

increasing the frequency of collisions with free electrons and reducing their average drift speed for a given applied voltage. (c) 6.0

4. (a) Volume $V = AL$ is constant, so new area $A' = \frac{A}{2.5}$. New resistance $R' = \frac{\rho(2.5L)}{A/2.5} = 6.25\frac{\rho L}{A} = 6.25R$. (b) 4.0×10^{-8} Ω m

5. (a) As temperature increases, electrons are excited into the conduction band, significantly increasing the number density n of charge carriers. This massive increase in n outweighs the decrease in drift speed v due to increased lattice vibrations, resulting in a larger current I for the same V, and hence lower resistance. (b) 0.33

6. (a) 0.20 Ω (b) 3.6×10^{-3} Ω

7. (a) 1200 W (b) 4800 W

8. (a) 5.4×10^{4} Ω (b) 750 Ω (c) The number density of charge carriers increases.

9. (a) 2.3×10^{-4} m s^{-1} (b) 2.4×10^{23}

10. (a) 40 Ω (b) The resistance decreases. The ratio V/I becomes smaller because the current increases at a much greater rate than the potential difference.

11. (a) The energy transferred per unit charge. (b) 86 J

12. (a) For a metallic conductor at constant temperature, the current is directly proportional to the potential difference across it. (b) 3.0 V (c) As current increases, the temperature of the filament increases, which increases its resistance. Therefore, current is not directly proportional to potential difference.

13. (a) 6.3×10^{-5} m^2 (b) 3.2×10^{-4} Ω

14. (a) 7.2 Ω (b) 4.5×10^{5} W (c) 1.1×10^{5} W; the power loss is reduced by a factor of 4.

15. (a) 5.0 Ω (b) 1.4×10^{-7} Ω m

16. (a) 6.7×10^{-6} (b) 1.3×10^{4} C

17. (a) Substitute $I = \frac{V}{R}$ and $R = \frac{\rho L}{A}$ into $I = Anve$ to obtain $\frac{VA}{\rho L} = Anve$. Cancelling A on both sides gives $v = \frac{V}{\rho Lne}$. (b) 0.31 m s^{-1} (c) 5.0×10^{-8} m^2 (d) 0.31 m s^{-1}

18. (a) 4.0 Ω (b) 0.67 Ω (c) As current flows, the filament rapidly heats up. The increased temperature increases lattice vibrations, reducing electron drift speed for a given voltage, thus increasing the resistance and reducing the current.

19. (a) 1.1×10^{12} m^{-3} (b) 2.1×10^{5} s

20. (a) 7.5 Ω m^{-1} (b) 1.2×10^{-6} Ω m

10 D.C. circuits（直流电路）

Basic Drill

1. Energy transferred per unit charge in driving charge around a complete circuit.

2. E.m.f. is the transfer of chemical (or other non-electrical) energy to electrical energy per unit charge, whereas p.d. is the transfer of electrical energy to other forms of energy per unit charge.

3. 540 J

4. 5.0 V

5. 0.60 Ω

6. The sum of currents entering a junction is equal to the sum of currents leaving the junction; charge is conserved.

7. 2.4 A leaving the junction

8. In any closed loop of a circuit, the algebraic sum of the e.m.f.s is equal to the algebraic sum of the potential differences; energy is conserved.

9. 90 Ω

10. 10 Ω

11. 24 Ω

12. 5.0 A

13. 0.30 A

14. Current through the cell produces a potential drop across the internal resistance of the cell (lost volts), reducing the terminal potential difference below the e.m.f.

15. 8.0 V

16. 240 Ω

17. The potential difference across the fixed resistor increases because the resistance of the NTC thermistor decreases, so the fixed resistor takes a greater fraction of the total supply voltage.

18. 2.0 V

19. A measurement technique in which the circuit condition is adjusted until the current passing through the detecting instrument (galvanometer) is zero.

20. 2.10 V

21. At the balance point, no current is drawn from the cell, so there is no potential drop across its internal resistance and the true e.m.f. is measured.

22. 0.30 Ω

23. $I = \frac{E}{R+r}$

24. 10 Ω

25. 1.5 V

26. 9.0 V

27. 10 Ω

28. 7.2 V

29. Conservation of energy

30. 270 J

31. 8.1 V

32. 7.5 A

33. 0.40 Ω

34. 0.72 m

35. 60 Ω

36. E.m.f. is the energy transferred from chemical (or other) energy to electrical energy per unit charge, whereas p.d. is the electrical energy transferred to other forms per unit charge.

37. The potential difference increases because the resistance of the thermistor decreases, so a larger fraction of the supply voltage drops across the fixed resistor.

38. 8.0 Ω

39. 2.0 V

40. A measurement method in which a circuit parameter is adjusted until a zero current reading (no deflection) is obtained on the galvanometer.

41. The algebraic sum of currents entering a junction is equal to the algebraic sum of currents leaving that junction.

42. 0.50 A

43. 1.44 V

44. 0.60 A

45. 75 Ω

46. The electromotive force (e.m.f.) of the cell

47. 8.0 Ω

48. The output potential difference increases

49. $V = E\left(\frac{R}{R+r}\right)$

50. 1.3 A

Practice

1. (a) Energy transferred per unit charge in driving charge around a complete circuit. (b) e.m.f. is the energy transferred from other forms to electrical energy per unit charge; p.d. is the energy transferred from electrical energy to other forms per unit charge.

2. (a) $V = 0.70 \times 12 = 8.4$ V (b) $9.0 = 8.4 + 0.70r \Rightarrow r = 0.86\ \Omega$

3. (a) The sum of currents entering a junction is equal to the sum of currents leaving the junction. (b) It is a consequence of the conservation of charge; charge cannot be created or destroyed at a junction. (c) 4.3 A flowing away from the junction.

4. (a) In any closed loop of a circuit, the sum of the electromotive forces is equal to the sum of the potential differences. (b) Energy. (c) $12 - 4.5 = 7.5$ V.

5. Current I is the same in all resistors (Kirchhoff's first law). By Kirchhoff's second law, the total p.d. $V = V_1 + V_2 + V_3$. Since $V = IR$, $IR = IR_1 + IR_2 + IR_3$. Dividing by I gives $R = R_1 + R_2 + R_3$.

6. The p.d. V across each resistor is the same (Kirchhoff's second law). By Kirchhoff's first law, the total current $I = I_1 + I_2 + I_3$. Since $I = \frac{V}{R}$, $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$. Dividing by V gives $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.

7. Resistance of B and C in parallel $= (\frac{1}{10} + \frac{1}{10})^{-1} = 5.0\ \Omega$. Total resistance $= 15 + 5.0 = 20\ \Omega$.

8. (a) $E = 0.50(8.0 + r)$ and $E = 1.0(3.0 + r)$. $4.0 + 0.50r = 3.0 + 1.0r \Rightarrow 0.50r = 1.0 \Rightarrow r = 2.0\ \Omega$. (b) $E = 1.0 \times (3.0 + 2.0) = 5.0$ V.

9. $V = \frac{33}{47+33} \times 9.0 = \frac{33}{80} \times 9.0 = 3.7$ V.

10. As light intensity increases, the resistance of the LDR decreases. The total resistance of the circuit decreases, so the current increases. The p.d. across the fixed resistor (voltmeter reading) increases since $V = IR$ and R is constant while I increases.

11. At 20 °C, $V_1 = \frac{2.0}{2.0+5.0} \times 6.0 = 1.71$ V. At 100 °C, $V_2 = \frac{2.0}{2.0+0.50} \times 6.0 = 4.80$ V. Change $= 4.80 - 1.71 = 3.1$ V.

12. (a) A uniform wire carrying a constant current has a constant potential gradient, so the p.d. across a section of the wire is proportional to its length. (b) The galvanometer detects the presence and direction of current. In a null method, the contact on the wire is adjusted until the galvanometer reads zero, indicating that the p.d. across the wire section exactly balances the unknown e.m.f. or p.d.

13. $\frac{E}{1.50} = \frac{0.76}{0.60} \Rightarrow E = 1.50 \times \frac{0.76}{0.60} = 1.9$ V.

14. (a) Net e.m.f. $= 6.0 - 2.0 = 4.0$ V. Total

resistance = 3.2 + 0.50 + 0.30 = 4.0 Ω. Current = $\frac{4.0}{4.0}$ = 1.0 A. (b) Terminal p.d. of A = $E - Ir = 6.0 - (1.0 \times 0.50) = 5.5$ V.

15. (a) Parallel part = $(\frac{1}{6.0} + \frac{1}{3.0})^{-1}$ = 2.0 Ω. Total = 4.0 + 2.0 = 6.0 Ω. (b) Current in $R_1 = \frac{12}{6.0}$ = 2.0 A. (c) p.d. across parallel part = $12 - (2.0 \times 4.0) = 4.0$ V. Current in $R_2 = \frac{4.0}{6.0} = 0.67$ A.

16. (a) $V = E - Ir$ (b) Gradient = $-r$. $r = \frac{4.1-3.2}{2.00-0.50} = \frac{0.9}{1.50} = 0.60$ Ω. (c) $4.1 = E - 0.50(0.60) \Rightarrow E = 4.1 + 0.3 = 4.4$ V.

17. (a) $R = (\frac{1}{80} + \frac{1}{240})^{-1}$ = 60 Ω. (b) Total resistance = 120 + 60 = 180 Ω. p.d. = $\frac{60}{180} \times 15 = 5.0$ V.

18. (a) $I = \frac{4.0}{14.0+2.0}$ = 0.25 A. (b) $V = 0.25 \times 14.0$ = 3.5 V. (c) Balance length $L = \frac{1.5}{3.5} \times 1.00 = 0.43$ m.

19. (a) Total e.m.f. = 3.0 V, total internal resistance = 0.80 Ω. $3.0 = 0.60(R + 0.80) \Rightarrow R = 5.0 - 0.80 = 4.2$ Ω. (b) Total e.m.f. = 1.5 V, total internal resistance = 0.20 Ω. $I = \frac{1.5}{4.2+0.20} = \frac{1.5}{4.4} = 0.34$ A.

20. (a) As temperature rises, the resistance of the NTC thermistor decreases. This causes the total circuit resistance to decrease and current to increase, increasing the p.d. across the fixed resistor to trigger the fan. (b) $3.6 = \frac{R}{R+1.5} \times 9.0 \Rightarrow 3.6R + 5.4 = 9.0R \Rightarrow 5.4R = 5.4 \Rightarrow R = 1.0$ kΩ.

21. (a) By Kirchhoff's first law at the top junction, current entering = current leaving. $I_{\text{left}} = 2.0 + 0.50 = 2.5$ A flowing upwards. (b) By Kirchhoff's second law for the left loop: $E_1 = (2.5 \times 4.0) + (2.0 \times 5.0) = 10 + 10 = 20$ V.

22. The total resistance in the primary circuit increases, so the current in the potentiometer wire decreases. The potential difference across the wire decreases, reducing the potential gradient. Therefore, a greater balance length is required to balance the same test cell e.m.f.

23. (a) $(\frac{1}{24} + \frac{1}{24} + \frac{1}{24})^{-1}$ = 8.0 Ω. (b) Parallel part = 12 Ω. Total = 12 + 24 = 36 Ω.

24. (a) $V = E - Ir \Rightarrow 10.5 = 12.0 - I(0.50) \Rightarrow I = 3.0$ A. (b) $R = \frac{V}{I} = \frac{10.5}{3.0} = 3.5$ Ω.

25. The potentials at the junctions are equal. $\frac{200}{300} = \frac{400}{R} \Rightarrow R = 600$ Ω.

Advanced Practice

1. (a) 2.0 A (b) 2.0 Ω (c) e.m.f. is the energy transferred from other forms to electrical energy per unit charge; p.d. is the energy transferred from electrical energy to other forms per unit charge.

2. (a) $E = 1.50$ V, $r = 0.30$ Ω (b) 1.9 W

3. (a) 1.0 A (b) 6.0 V

4. By Kirchhoff's first law, the total current I entering the parallel combination equals the sum of the currents in each branch: $I = I_1 + I_2 + I_3$. By Kirchhoff's second law, the potential difference V across each resistor is the same. Substituting $I = \frac{V}{R}$ for each component gives $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$. Dividing through by V yields $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.

5. (a) 3.0 A (b) 2.0 W

6. (a) 7.2 V (b) 6.0 V (c) 17%

7. (a) 0 A (b) 2.6 V (c) Current now flows through the test cell and the 2.0 Ω resistor, causing a potential drop across its internal resistance. The terminal p.d. measured by the potentiometer is therefore less than E_X, requiring a shorter balance length.

8. (a) 12.5 kΩ (b) 0.28 V (c) As light intensity increases, the resistance of the

LDR decreases. The total circuit resistance decreases, so the current increases. Since $V = IR$ for the fixed resistor, its potential difference increases.

9. (a) 1.8 kΩ (b) The p.d. increases. The resistance of the NTC thermistor decreases at higher temperatures, so it takes a smaller share of the 5.0 V supply, leaving a larger p.d. across the variable resistor. (c) To allow the threshold temperature at which the fan activates to be adjusted.

10. (a) 1.0 A (b) 4.8 V (c) 2.7 V

11. (a) 2.67 Ω (b) 3.0 A (c) 1.5 A from C to D

12. (a) The sum of the electromotive forces in any closed loop is equal to the sum of the potential differences in that loop. (b) 1.75 Ω (c) 11.5 W (d) 11.6 W. The power is slightly higher (this is the maximum power transfer point).

13. (a) 16.0 Ω (b) 1.5 A (c) 3600 J

14. (a) The potential difference across a uniform wire is directly proportional to the length of the wire. (b) 0.750 (c) 4.0 V (d) The driver cell has internal resistance, so there is a potential drop (lost volts) across it when current flows through the circuit.

15. By Kirchhoff's first law, the current I is the same in all three resistors. By Kirchhoff's second law, the total potential difference V across the combination is the sum of the individual potential differences: $V = V_1 + V_2 + V_3$. Substituting $V = IR$ for each component gives $IR = IR_1 + IR_2 + IR_3$. Cancelling the common current I yields $R = R_1 + R_2 + R_3$.

16. (a) 6.25 Ω (b) 0.80 A (c) 0.10 A

17. (a) 2.0 kΩ (b) 5.3 V (c) 6.0 V

18. (a) 1.0 A (b) 0.50 A (c) 1.6 V

19. (a) The sum of currents entering a junction equals the sum of currents leaving the junction. It is based on the conservation of charge. (b) 3.0 A (c) 2.5 A entering the junction

20. (a) $P = \frac{E^2 R}{(R+r)^2}$ (b) 6.0 Ω (c) 18 V (d) 13.5 W

11 Particle physics（粒子物理）

Basic Drill

1. The nucleus is positively charged and contains most of the mass of the atom in a very small volume.

2. 146

3. They have the same number of protons (proton number) but different numbers of neutrons (nucleon number).

4. $+3.20 \times 10^{-19}$ C

5. 6.64×10^{-27} kg

6. $A = 222$, $Z = 86$

7. Electron antineutrino (or antineutrino)

8. $A = 22$, $Z = 10$

9. The decay energy in β-decay is shared randomly between the β-particle and the emitted (anti)neutrino.

10. Mass = m_e, charge = $+e$ (or $+1.60 \times 10^{-19}$ C)

11. Electron, up quark, neutrino

12. (a) $+\frac{2}{3}e$ (b) $-\frac{1}{3}e$

13. $+\frac{1}{3}e$

14. $A = 7$, $Z = 3$

15. 0

16. Charge $= +\frac{2}{3}e - \left(-\frac{1}{3}e\right) = +\frac{2}{3}e + \frac{1}{3}e = +e$

17. $+\frac{1}{3}e$

18. No change to nucleon number and no change to proton number

19. A baryon consists of three quarks, while a meson consists of one quark and one antiquark.

20. 18

21. $+4.80 \times 10^{-19}$ C

22. Photons (electromagnetic radiation) of zero mass and zero charge.

23. Quark composition: $\bar{u}\bar{u}\bar{d}$; net charge: $-e$

24. ${}^{234}_{90}\mathrm{Th} \rightarrow {}^{234}_{91}\mathrm{Pa} + {}^{0}_{-1}\beta + \bar{\nu}_e$

25. ${}^{17}_{8}\mathrm{O}$

26. udd

27. $+\frac{1}{3}e$

28. Nucleon number: 222, Proton number: 86

29. Meson

30. The total energy released is shared between the β-particle and an (anti)neutrino in varying proportions.

31. $-1e$

32. $+1e$

33. 143

34. Electron neutrino (or neutrino, ν_e)

35. Most of the mass and all the positive charge are concentrated in a very small, dense region called the nucleus.

36. $+1e$

37. 18 up quarks and 18 down quarks

38. 4 u

39. (a) No change (0) (b) Increases by 1 (+1)

40. Proton (${}^{1}_{1}\mathrm{p}$ or ${}^{1}_{1}\mathrm{H}$)

41. Charge: $+1.60 \times 10^{-19}$ C, Mass: 5.49×10^{-4} u (or same mass as an electron)

42. Up, down, strange, charm, top, bottom

43. Lepton; it is a fundamental particle.

44. 0

45. ${}^{22}_{10}\mathrm{Ne}$

46. Nuclei of the same element with the same number of protons but different numbers of neutrons.

47. $A = 14$, $Z = 7$, Y is an electron antineutrino ($\bar{\nu}_e$)

48. 1.28×10^{-18} C

49. $\bar{u}\bar{u}\bar{d}$ (two anti-up quarks and one anti-down quark)

50. The atom is mostly empty space.

Practice

1. (a) Most α-particles pass straight through the foil with little or no deflection. A very small proportion of α-particles are deflected by angles greater than 90°. (b) Most passing through implies the atom is mostly empty space. The large deflection of a few particles implies that the positive charge and most of the mass are concentrated in a very small central volume (the nucleus).

2. (a) Protons: 92; Neutrons: 143; Electrons: 92. (b) Charge = $92 \times 1.60 \times 10^{-19}$ = 1.47×10^{-17} C. (c) Isotopes are forms of the same element (same number of protons) with different numbers of neutrons in their nuclei.

3. (a) ${}^{239}_{94}\text{Pu} \rightarrow {}^{235}_{92}\text{U} + {}^{4}_{2}\alpha$ (b) Mass = 4 u; Charge = $+2e$. (c) Discrete energies mean that the α-particles are emitted with specific, fixed values of kinetic energy, rather than a continuous range.

4. (a) ${}^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\beta + \bar{\nu}_e$ (or electron antineutrino) (b) Electron antineutrino. (c) The total energy released in the decay is shared randomly between the β^- particle and the antineutrino, allowing the β^- particle to take any kinetic energy up to a maximum value.

5. (a) Proton: up, up, down (uud). Neutron: up, down, down (udd). (b) Charge of up quark = $+2/3e$; Charge of down quark = $-1/3e$. Total charge = $+2/3e - 1/3e - 1/3e = 0$. (c) Protons and neutrons are not fundamental particles (they are composed of quarks).

6. (a) Baryon: consists of three quarks. Meson: consists of one quark and one antiquark. (b) Charge of up quark = $+2/3e$. Charge of anti-down quark = $+1/3e$. Total charge = $+2/3e + 1/3e = +1e$.

7. (a) ${}^{18}_{9}\text{F} \rightarrow {}^{18}_{8}\text{O} + {}^{0}_{+1}\beta + \nu_e$ (b) A proton changes into a neutron. Therefore, an up quark changes into a down quark.

8. (a) Hadrons are not fundamental particles (they are composed of quarks), whereas leptons are fundamental particles. (b) Hadrons: neutron. Leptons: electron, positron, electron neutrino.

9. (a) Positron. (b) 9.11×10^{-31} kg. (c) Electron antineutrino.

10. (a) 1.66×10^{-27} kg. (b) Mass = $4.00 \times 1.66 \times 10^{-27} = 6.64 \times 10^{-27}$ kg. (c) Ratio = $\frac{6.64 \times 10^{-27}}{9.11 \times 10^{-31}} = 7290$ (to 3 s.f.).

11. (a) An α-particle consists of 2 protons and 2 neutrons, while a β^--particle consists of a single high-speed electron. (b) γ-radiation consists of high-energy electromagnetic waves (or photons). (c) γ-radiation.

12. (a) ${}^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\alpha$ (b) Initial charge is $95e$. Final charge is $93e$ (from Np) $+2e$ (from α) = $95e$. Thus, charge is conserved.

13. (a) Change in nucleon number = $232 - 208 = 24$. Number of α-particles = $24/4 = 6$. (b) Emission of 6 α-particles reduces the proton number by 12 (from 90 to 78). The final proton number is 82, requiring an increase of 4. Therefore, 4 β^--particles are emitted.

14. (a) Up, down, strange, charm, top, bottom. (b) Top quark: $+2/3e$; Bottom quark:

$-1/3e$. (c) $+2/3e$.

15. (a) $d \rightarrow u + {}^{0}_{-1}\beta + \bar{\nu}_e$ (b) The initial charge of the down quark is $-1/3e$. The final charge is $+2/3e$ (up quark) $+(-1e)$ (electron) $+0$ (antineutrino) $= -1/3e$. Thus, charge is conserved.

16. (a) The vast majority of α-particles pass straight through the foil with little or no deflection. (b) A deflection greater than 90° requires a massive, concentrated positive charge to provide a sufficiently strong electrostatic repulsive force. This supports a model with a small, dense, positive nucleus.

17. (a) ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\alpha$ (b) Nucleon number = 222; Proton number = 86.

18. (a) $+2/3e$. (b) The antiquark must have a charge of $+1/3e$ to make the total charge $+e$. This corresponds to an anti-down quark. (c) It is not a fundamental particle (it is a hadron made of quarks).

19. (a) Positron (or β^+ particle) and electron neutrino. (b) ${}^{11}_{6}\text{C} \rightarrow {}^{11}_{5}\text{B} + {}^{0}_{+1}\beta + \nu_e$

20. (a) Ratio $= \frac{2\times1.60\times10^{-19}}{4.00\times1.66\times10^{-27}} = 4.82 \times 10^7$ C kg^{-1}. (b) Ratio $= \frac{1.60\times10^{-19}}{9.11\times10^{-31}} = 1.76 \times 10^{11}$ C kg^{-1}.

21. (a) Similarity: All have exactly one proton in their nucleus. Difference: They have different numbers of neutrons (0, 1, and 2 respectively). (b) ${}^{3}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} + {}^{0}_{-1}\beta + \bar{\nu}_e$

22. (a) A continuous energy spectrum means the emitted particles can have any kinetic energy up to a certain maximum value, rather than only specific discrete values. (b) The total decay energy is shared between the β^- particle and the antineutrino. Since the energy can be shared in any proportion, the β^- particle can have a continuous range of energies.

23. (a) Three quarks. (b) To achieve a charge of $+2e$ using three quarks, all three must be up quarks (each with $+2/3e$). The composition is up, up, up (uuu).

24. (a) Charge of anti-up quark $= -2/3e$. Total charge $= -1/3e - 2/3e = -1e$. (b) Anti-strange quark ($\bar{s}$) and up quark (u). (c) $+e$.

25. (a) ${}^{23}_{12}\text{Mg} \rightarrow {}^{23}_{11}\text{Na} + {}^{0}_{+1}\beta + \nu_e$ (b) Leptons. (c) The nucleus has 12 protons and 11 neutrons. Up quarks $= (12\times2)+(11\times1) = 35$. Down quarks $= (12\times1)+(11\times2) = 34$.

Advanced Practice

1. 2.9×10^6 C kg^{-1}

2. (a) To prevent the α-particles from colliding with air molecules, which would absorb or scatter them. (b) A very small fraction of the α-particles are scattered through large angles (greater than 90°).

3. (a) Two protons and two neutrons. (b) α-decay produces only two particles (the daughter nucleus and the α-particle), so energy and momentum conservation dictate a single discrete energy for the α-particle. In β-decay, a third particle (an antineutrino or neutrino) is also emitted, which shares the available kinetic energy with the β-particle in a continuous range.

4. (a) $+e$ (Up $= +2/3e$, strange $= -1/3e$, top $= +2/3e$). (b) It is not a fundamental particle because it is composed of smaller constituent particles (quarks).

5. (a) $+e$ (Charm $= +2/3e$, anti-strange $= +1/3e$). (b) The positron belongs to the leptons. The other particle is an electron neutrino.

6. (a) ${}^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\beta + \bar{\nu}_\text{e}$ (b) A down quark

changes into an up quark ($d \to u$).

7. (a) Anti-up, anti-up, anti-down ($\bar{u}\bar{u}\bar{d}$). (b) 1.67×10^{-27} kg

8. (a) A β^+ particle has the exact same mass as an electron, but an equal and opposite (positive) charge of $+e$. (b) A β^+ particle is a fundamental particle with mass (a lepton/antimatter), whereas a γ-ray is a quantum of electromagnetic radiation (a photon) with zero rest mass.

9. Nucleon number: 207; Proton number: 82 (The isotope is ${}^{207}_{82}\mathrm{Pb}$).

10. 15 protons and 15 neutrons.

11. (a) ${}^{18}_{9}\mathrm{F} \to {}^{18}_{8}\mathrm{O} + {}^{0}_{+1}\beta + \nu_\mathrm{e}$ (b) 26 up quarks and 28 down quarks.

12. (a) Nucleon number = 7. (b) 4 neutrons.

13. (a) Down, strange, or bottom quark. (b) A baryon consists of three quarks, whereas a meson consists of one quark and one antiquark.

14. (a) 79 protons, 118 neutrons, 79 electrons. (b) The volume ratio is 10^{12}. This implies that the atom is mostly empty space, with almost all its mass concentrated in a very small central nucleus.

15. 6.4×10^{-19} C

16. (a) Electron antineutrino. (b) The total energy released in the decay is shared between the β^- particle and the antineutrino. Since the antineutrino can carry away any fraction of this energy, the β^- particle can have any kinetic energy up to a maximum value.

17. (a) A proton is composed of two up quarks and one down quark (uud). A positron is a lepton, which is a fundamental particle and therefore not made of quarks. (b) Antiproton, with a charge of $-e$.

18. (a) Nucleon number = $A - 4$; Proton number = P. (b) They are isotopes of the same element, as they have the same proton number but different nucleon numbers.

19. Mass of atom = 1.9926×10^{-26} kg; Mass of nucleus = 1.9921×10^{-26} kg

20. (a) Electron, electron antineutrino, and positron. (b) 1.76×10^{11} C kg^{-1}