1. Physical quantities and units

Weeks 1–3

物理量与单位

They should be able to

1. understand that all **physical quantities** consist of a **numerical magnitude** and a **unit**
2. make reasonable estimates of **physical quantities** included within the syllabus
3. recall the following **SI base quantities** and their units: **mass** (kg), **length** (m), **time** (s), **current** (A), **temperature** (K)
4. express **derived units** as products or quotients of the **SI base units** and use the derived units for quantities listed in this syllabus as appropriate
5. use SI base units to check the **homogeneity** of physical equations
6. recall and use the following **prefixes** and their symbols to indicate decimal submultiples or multiples of both base and derived units: pico (p), nano (n), micro (\mu), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)
7. understand and explain the effects of **systematic errors** (including **zero errors**) and **random errors** in measurements
8. understand the distinction between **precision** and **accuracy**
9. assess the **uncertainty** in a **derived quantity** by simple addition of **absolute** or **percentage** uncertainties
10. understand the difference between **scalar** and **vector** quantities and give examples of scalar and vector quantities included in the syllabus
11. add and subtract **coplanar vectors**
12. represent a vector as two **perpendicular components**

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 01 (10 questions, answers on sheet 2) Starter quiz 1 — past-paper questions	
Teach the new content	Handout 01 Slide deck 01 (+ notes handout, 6-up) Vocabulary list 01	
Practice guided then independent	Exercise sheets 1.1, 1.2, 1.3, 1.4 Past-paper sheets 1.1, 1.2, 1.3, 1.4	
Check before they leave	Unit test 1 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

2. Kinematics

Weeks 4

运动学

They should be able to

1. define and use **distance**, **displacement**, **speed**, **velocity** and **acceleration**
2. use **graphical methods** to represent distance, displacement, speed, velocity and acceleration
3. determine **displacement** from the area under a **velocity–time graph**
4. determine **velocity** using the gradient of a **displacement–time graph**
5. determine **acceleration** using the gradient of a **velocity–time graph**
6. derive, from the definitions of velocity and acceleration, equations that represent **uniformly accelerated motion** in a straight line
7. solve problems using equations that represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a **uniform gravitational field** without **air resistance**
8. describe an experiment to determine the **acceleration of free fall** using a falling object
9. describe and explain motion due to a **uniform velocity** in one direction and a **uniform acceleration** in a perpendicular direction

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 02 (10 questions, answers on sheet 2) Starter quiz 2 — past-paper questions	
Teach the new content	Handout 02 Slide deck 02 (+ notes handout, 6-up) Vocabulary list 02	
Practice guided then independent	Exercise sheets 2.1 Past-paper sheets 2.1	
Check before they leave	Unit test 2 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

3. Dynamics

Weeks 5–6

动力学

They should be able to

1. understand that **mass** is the property of an object that resists change in motion
2. recall $F = ma$ and solve problems using it, understanding that **acceleration** and **resultant force** are always in the same direction
3. define and use **linear momentum** as the product of mass and velocity
4. define and use **force** as **rate of change of momentum**
5. state and apply each of **Newton’s laws of motion**
6. describe and use the concept of **weight** as the effect of a **gravitational field** on a mass and recall that the weight of an object is equal to the product of its mass and the **acceleration of free fall**
7. show a qualitative understanding of **frictional forces** and **viscous/drag forces** including **air resistance** (no treatment of the coefficients of friction and viscosity is required, and a simple model of drag force increasing as speed increases is sufficient)
8. describe and explain qualitatively the motion of objects in a **uniform gravitational field** with **air resistance**
9. understand that objects moving against a **resistive force** may reach a **terminal (constant) velocity**
10. state the principle of **conservation of momentum**
11. apply the principle of conservation of momentum to solve simple problems, including **elastic** and **inelastic** interactions between objects in both one and two dimensions (knowledge of the concept of coefficient of restitution is not required)
12. recall that, for an **elastic collision**, total **kinetic energy** is conserved and the **relative speed of approach** is equal to the **relative speed of separation**
13. understand that, while **momentum** of a system is always conserved in interactions between objects, some change in **kinetic energy** may take place

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 03 (10 questions, answers on sheet 2) Starter quiz 3 — past-paper questions	
Teach the new content	Handout 03 Slide deck 03 (+ notes handout, 6-up) Vocabulary list 03	
Practice guided then independent	Exercise sheets 3.1, 3.2, 3.3 Past-paper sheets 3.1, 3.2, 3.3	
Check before they leave	Unit test 3 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

4. Forces, density and pressure

Weeks 7–8

力、密度与压强

They should be able to

1. understand that the **weight** of an object may be taken as acting at a single point known as its **centre of gravity**
2. define and apply the **moment of a force**
3. understand that a **couple** is a pair of forces that acts to produce rotation only
4. define and apply the **torque of a couple**
5. state and apply the **principle of moments**
6. understand that, when there is no **resultant force** and no **resultant torque**, a system is in **equilibrium**
7. use a **vector triangle** to represent **coplanar forces** in equilibrium
8. define and use **density**
9. define and use **pressure**
10. derive, from the definitions of pressure and density, the equation for **hydrostatic pressure** $\Delta p = \rho g \Delta h$
11. use the equation $\Delta p = \rho g \Delta h$
12. understand that the **upthrust** acting on an object in a fluid is due to a difference in hydrostatic pressure
13. calculate the upthrust acting on an object in a fluid using the equation $F = \rho g V$ (**Archimedes' principle**)

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 04 (10 questions, answers on sheet 2) Starter quiz 4 — past-paper questions	
Teach the new content	Handout 04 Slide deck 04 (+ notes handout, 6-up) Vocabulary list 04	
Practice guided then independent	Exercise sheets 4.1, 4.2, 4.3 Past-paper sheets 4.1, 4.2, 4.3	
Check before they leave	Unit test 4 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

5. Work, energy and power

Weeks 9–10

功、能量与功率

They should be able to

1. understand the concept of **work**, and recall and use $\text{work done} = \text{force} \times \text{displacement in the direction of the force}$
2. recall and apply the principle of **conservation of energy**
3. recall and understand that the **efficiency** of a system is the ratio of useful energy output from the system to the total energy input
4. use the concept of efficiency to solve problems
5. define **power** as work done per unit time
6. solve problems using $P = W/t$
7. derive $P = Fv$ and use it to solve problems
8. derive, using $W = Fs$, the formula $\Delta E_{\text{P}} = mg\Delta h$ for **gravitational potential energy** changes in a **uniform gravitational field**
9. recall and use the formula $\Delta E_{\text{P}} = mg\Delta h$ for gravitational potential energy changes in a uniform gravitational field
10. derive, using the equations of motion, the formula for **kinetic energy** $E_{\text{K}} = \frac{1}{2}mv^2$
11. recall and use $E_{\text{K}} = \frac{1}{2}mv^2$

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 05 (10 questions, answers on sheet 2) Starter quiz 5 — past-paper questions	
Teach the new content	Handout 05 Slide deck 05 (+ notes handout, 6-up) Vocabulary list 05	
Practice guided then independent	Exercise sheets 5.1, 5.2 Past-paper sheets 5.1, 5.2	
Check before they leave	Unit test 5 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

6. Deformation of solids

Weeks 11–12

固体的形变

They should be able to

1. understand that **deformation** is caused by **tensile** or **compressive forces** (forces and deformations will be assumed to be in one dimension only)
2. understand and use the terms **load**, **extension**, **compression** and **limit of proportionality**
3. recall and use **Hooke's law**
4. recall and use the formula for the **spring constant** $k = F/x$
5. define and use the terms **stress**, **strain** and the **Young modulus**
6. describe an experiment to determine the Young modulus of a metal in the form of a wire
7. understand and use the terms **elastic deformation**, **plastic deformation** and **elastic limit**
8. understand that the area under the **force–extension graph** represents the **work done**
9. determine the **elastic potential energy** of a material deformed within its **limit of proportionality** from the area under the force–extension graph
10. recall and use $E_p = \frac{1}{2}Fx = \frac{1}{2}kx^2$ for a material deformed within its limit of proportionality

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 06 (10 questions, answers on sheet 2) Starter quiz 6 — past-paper questions	
Teach the new content	Handout 06 Slide deck 06 (+ notes handout, 6-up) Vocabulary list 06	
Practice guided then independent	Exercise sheets 6.1, 6.2 Past-paper sheets 6.1, 6.2	
Check before they leave	Unit test 6 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

7. Waves

Weeks 13–15

波

They should be able to

1. describe what is meant by **wave motion** as illustrated by vibration in ropes, springs and ripple tanks
2. understand and use the terms **displacement**, **amplitude**, **phase difference**, **period**, **frequency**, **wavelength** and **speed**
3. understand the use of the **time-base** and y-gain of a **cathode-ray oscilloscope (CRO)** to determine frequency and amplitude
4. derive, using the definitions of speed, frequency and wavelength, the **wave equation** $v = f\lambda$
5. recall and use $v = f\lambda$
6. understand that energy is transferred by a **progressive wave**
7. recall and use $\text{intensity} = \text{power}/\text{area}$ and $\text{intensity} \propto (\text{amplitude})^2$ for a progressive wave
8. compare **transverse** and **longitudinal waves**
9. analyse and interpret graphical representations of transverse and longitudinal waves
10. understand that when a source of **sound waves** moves relative to a stationary observer, the **observed frequency** is different from the **source frequency** (understanding of the Doppler effect for a stationary source and a moving observer is not required)
11. use the expression $f_{\text{o}} = f_{\text{s}} v / (v \pm v_{\text{s}})$ for the observed frequency when a source of sound waves moves relative to a stationary observer
12. state that all **electromagnetic waves** are **transverse waves** that travel with the same speed c in free space
13. recall the approximate range of wavelengths in free space of the principal regions of the **electromagnetic spectrum** from **radio waves** to γ-rays
14. recall that wavelengths in the range 400–700 nm in free space are **visible** to the human eye
15. understand that **polarisation** is a phenomenon associated with **transverse waves**
16. recall and use **Malus's law** ($I = I_0 \cos^2\theta$) to calculate the **intensity** of a **plane-polarised** electromagnetic wave after transmission through a **polarising filter** or a series of polarising filters (calculation of the effect of a polarising filter on the intensity of an unpolarised wave is not required)

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 07 (10 questions, answers on sheet 2) Starter quiz 7 — past-paper questions	
Teach the new content	Handout 07 Slide deck 07 (+ notes handout, 6-up) Vocabulary list 07	
Practice guided then independent	Exercise sheets 7.1, 7.2, 7.3, 7.4, 7.5 Past-paper sheets 7.1, 7.2, 7.3, 7.4, 7.5	
Check before they leave	Unit test 7 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

8. Superposition

Weeks 16–18

叠加

They should be able to

1. explain and use the **principle of superposition**
2. show an understanding of experiments that demonstrate **stationary waves** using microwaves, stretched strings and air columns (it will be assumed that end corrections are negligible; knowledge of the concept of end corrections is not required)
3. explain the formation of a stationary wave using a graphical method, and identify **nodes** and **antinodes**
4. understand how **wavelength** may be determined from the positions of nodes or antinodes of a stationary wave
5. explain the meaning of the term **diffraction**
6. show an understanding of experiments that demonstrate diffraction including the qualitative effect of the **gap width** relative to the **wavelength** of the wave; for example diffraction of water waves in a ripple tank
7. understand the terms **interference** and **coherence**
8. show an understanding of experiments that demonstrate **two-source interference** using water waves in a ripple tank, sound, light and microwaves
9. understand the conditions required if two-source **interference fringes** are to be observed
10. recall and use $\lambda = ax / D$ for **double-slit interference** using light
11. recall and use $d \sin \theta = n\lambda$
12. describe the use of a **diffraction grating** to determine the **wavelength** of light (the structure and use of the spectrometer are not included)

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 08 (10 questions, answers on sheet 2) Starter quiz 8 — past-paper questions	
Teach the new content	Handout 08 Slide deck 08 (+ notes handout, 6-up) Vocabulary list 08	
Practice guided then independent	Exercise sheets 8.1, 8.2, 8.3, 8.4 Past-paper sheets 8.1, 8.2, 8.3, 8.4	
Check before they leave	Unit test 8 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

9. Electricity

Weeks 19–20

电学

They should be able to

1. understand that an **electric current** is a flow of **charge carriers**
2. understand that the charge on charge carriers is **quantised**
3. recall and use $Q = It$
4. use, for a current-carrying conductor, the expression $I = Anvq$, where n is the **number density** of charge carriers
5. define the **potential difference** across a component as the energy transferred per unit charge
6. recall and use $V = W/Q$
7. recall and use $P = VI$, $P = I^2R$ and $P = V^2/R$
8. define **resistance**
9. recall and use $V = IR$
10. sketch the $I\text{–}V$ characteristics of a **metallic conductor** at constant temperature, a **semiconductor diode** and a **filament lamp**
11. explain that the resistance of a filament lamp increases as current increases because its temperature increases
12. state **Ohm's law**
13. recall and use $R = \rho L/A$
14. understand that the resistance of a **light-dependent resistor (LDR)** decreases as the light intensity increases
15. understand that the resistance of a **thermistor** decreases as the temperature increases (it will be assumed that thermistors have a negative temperature coefficient)

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 09 (10 questions, answers on sheet 2) Starter quiz 9 — past-paper questions	
Teach the new content	Handout 09 Slide deck 09 (+ notes handout, 6-up) Vocabulary list 09	
Practice guided then independent	Exercise sheets 9.1, 9.2, 9.3 Past-paper sheets 9.1, 9.2, 9.3	
Check before they leave	Unit test 9 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

10. D.C. circuits

Weeks 21–22

直流电路

They should be able to

1. recall and use the **circuit symbols** shown in section 6 of this syllabus
2. draw and interpret **circuit diagrams** containing the circuit symbols shown in section 6 of this syllabus
3. define and use the **electromotive force (e.m.f.)** of a source as energy transferred per unit charge in driving charge around a complete circuit
4. distinguish between e.m.f. and **potential difference (p.d.)** in terms of energy considerations
5. understand the effects of the **internal resistance** of a source of e.m.f. on the **terminal potential difference**
6. recall **Kirchhoff's first law** and understand that it is a consequence of **conservation of charge**
7. recall **Kirchhoff's second law** and understand that it is a consequence of **conservation of energy**
8. derive, using Kirchhoff's laws, a formula for the **combined resistance** of two or more resistors in **series**
9. use the formula for the combined resistance of two or more resistors in series
10. derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in **parallel**
11. use the formula for the combined resistance of two or more resistors in parallel
12. use **Kirchhoff's laws** to solve simple circuit problems
13. understand the principle of a **potential divider circuit**
14. recall and use the principle of the **potentiometer** as a means of comparing **potential differences**
15. understand the use of a **galvanometer** in **null methods**
16. explain the use of **thermistors** and **light-dependent resistors** in potential dividers to provide a potential difference that is dependent on temperature and light intensity

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 10 (10 questions, answers on sheet 2) Starter quiz 10 — past-paper questions	
Teach the new content	Handout 10 Slide deck 10 (+ notes handout, 6-up) Vocabulary list 10	
Practice guided then independent	Exercise sheets 10.1, 10.2, 10.3 Past-paper sheets 10.1, 10.2, 10.3	
Check before they leave	Unit test 10 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

11. Particle physics

Weeks 23–24

粒子物理

They should be able to

1. infer from the results of the α-particle scattering experiment the existence and small size of the **nucleus**
2. describe a simple model for the **nuclear atom** to include **protons**, **neutrons** and **orbital electrons**
3. distinguish between **nucleon number** and **proton number**
4. understand that **isotopes** are forms of the same element with different numbers of neutrons in their nuclei
5. understand and use the notation $_Z^A\text{X}$ for the representation of **nuclides**
6. understand that nucleon number and charge are conserved in nuclear processes
7. describe the composition, mass and charge of α-, β- and γ-radiations (both β^- (**electrons**) and β^+ (**positrons**) are included)
8. understand that an **antiparticle** has the same mass but opposite charge to the corresponding particle, and that a positron is the antiparticle of an electron
9. state that (electron) **antineutrinos** are produced during β^- decay and (electron) **neutrinos** are produced during β^+ decay
10. understand that α-particles have **discrete energies** but that β-particles have a **continuous range of energies** because (anti)neutrinos are emitted in β-decay
11. represent α- and β-decay by a **radioactive decay equation** of the form $^{238}_{92}\text{U} \rightarrow ^{234}_{90}\text{Th} + ^4_2\alpha$
12. use the **unified atomic mass unit (u)** as a unit of mass
13. understand that a **quark** is a **fundamental particle** and that there are six flavours (types) of quark: **up**, **down**, **strange**, **charm**, **top** and **bottom**
14. recall and use the charge of each flavour of quark and understand that its respective antiquark has the opposite charge (no knowledge of any other properties of quarks is required)
15. recall that **protons** and **neutrons** are not fundamental particles and describe protons and neutrons in terms of their **quark composition**
16. understand that a **hadron** may be either a **baryon** (consisting of three quarks) or a **meson** (consisting of one quark and one antiquark)
17. describe the changes to quark composition that take place during β^- and β^+ decay
18. recall that electrons and neutrinos are fundamental particles called **leptons**

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 11 (10 questions, answers on sheet 2) Starter quiz 11 — past-paper questions	
Teach the new content	Handout 11 Slide deck 11 (+ notes handout, 6-up) Vocabulary list 11	
Practice guided then independent	Exercise sheets 11.1, 11.2 Past-paper sheets 11.1, 11.2	
Check before they leave	Unit test 11 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

12. Motion in a circle

Weeks 25–26

圆周运动

They should be able to

1. define the **radian** and express **angular displacement** in radians
2. understand and use the concept of **angular speed**
3. recall and use $\omega = 2\pi / T$ and $v = r\omega$
4. understand that a force of constant magnitude that is always perpendicular to the direction of motion causes **centripetal acceleration**
5. understand that centripetal acceleration causes **circular motion** with a constant **angular speed**
6. recall and use $a = r\omega^2$ and $a = v^2 / r$
7. recall and use $F = mr\omega^2$ and $F = mv^2 / r$

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 12 (10 questions, answers on sheet 2)	
Teach the new content	Handout 12 Slide deck 12 (+ notes handout, 6-up) Vocabulary list 12	
Practice guided then independent	Exercise sheets 12.1, 12.2 Past-paper sheets 12.1, 12.2	
Check before they leave	Unit test 12 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

13. Gravitational fields

Weeks 27–29

引力场

They should be able to

1. understand that a **gravitational field** is an example of a **field of force** and define gravitational field as force per unit mass
2. represent a gravitational field by means of **field lines**
3. understand that, for a point outside a **uniform sphere**, the mass of the sphere may be considered to be a **point mass** at its centre
4. recall and use **Newton's law of gravitation** $F = Gm_1m_2 / r^2$ for the force between two point masses
5. analyse **circular orbits** in gravitational fields by relating the **gravitational force** to the **centripetal acceleration** it causes
6. understand that a **satellite** in a **geostationary orbit** remains at the same point above the Earth's surface, with an **orbital period** of 24 hours, orbiting from west to east, directly above the Equator
7. derive, from Newton's law of gravitation and the definition of gravitational field, the equation $g = GM/r^2$ for the **gravitational field strength** due to a point mass
8. recall and use $g = GM/r^2$
9. understand why g is approximately constant for small changes in height near the Earth's surface
10. define **gravitational potential** at a point as the work done per unit mass in bringing a small **test mass** from infinity to the point
11. use $\phi = -GM/r$ for the gravitational potential in the field due to a point mass
12. understand how the concept of gravitational potential leads to the **gravitational potential energy** of two point masses and use $E_P = -GMm/r$

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 13 (10 questions, answers on sheet 2)	
Teach the new content	Handout 13 Slide deck 13 (+ notes handout, 6-up) Vocabulary list 13	
Practice guided then independent	Exercise sheets 13.1, 13.2, 13.3, 13.4 Past-paper sheets 13.1, 13.2, 13.3, 13.4	
Check before they leave	Unit test 13 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

14. Temperature

Weeks 30–31

温度

They should be able to

1. understand that (thermal) energy is transferred from a region of **higher temperature** to a region of **lower temperature**
2. understand that regions of equal temperature are in **thermal equilibrium**
3. understand that a **physical property** that varies with temperature may be used for the measurement of temperature and state examples of such properties, including the density of a liquid, volume of a gas at constant pressure, resistance of a metal, e.m.f. of a **thermocouple**
4. understand that the scale of **thermodynamic temperature** does not depend on the property of any particular substance
5. convert temperatures between **kelvin** and **degrees Celsius** and recall that $T/\text{K} = \theta/\text{ }^{\circ}\text{C} + 273.15$
6. understand that the lowest possible temperature is zero kelvin on the thermodynamic temperature scale and that this is known as **absolute zero**
7. define and use **specific heat capacity**
8. define and use **specific latent heat** and distinguish between **specific latent heat of fusion** and **specific latent heat of vaporisation**

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 14 (10 questions, answers on sheet 2)	
Teach the new content	Handout 14 Slide deck 14 (+ notes handout, 6-up) Vocabulary list 14	
Practice guided then independent	Exercise sheets 14.1, 14.2, 14.3 Past-paper sheets 14.1, 14.2, 14.3	
Check before they leave	Unit test 14 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

15. Ideal gases

Weeks 32–33

理想气体

They should be able to

1. understand that **amount of substance** is an **SI base quantity** with the base unit **mol**
2. use molar quantities where one **mole** of any substance is the amount containing a number of particles of that substance equal to the **Avogadro constant** N_{A}
3. understand that a gas obeying $pV \propto T$, where T is the **thermodynamic temperature**, is known as an **ideal gas**
4. recall and use the **equation of state** for an ideal gas expressed as $pV = nRT$, where $n = $ amount of substance (number of moles) and as $pV = NkT$, where $N = $ number of molecules
5. recall that the **Boltzmann constant** k is given by $k = R/N_{\text{A}}$
6. state the basic assumptions of the **kinetic theory of gases**
7. explain how molecular movement causes the **pressure** exerted by a gas and derive and use the relationship $pV = \frac{1}{3}Nm\langle c^2 \rangle$, where $\langle c^2 \rangle$ is the **mean-square speed** (a simple model considering one-dimensional collisions and then extending to three dimensions using $\frac{1}{3}\langle c^2 \rangle = \langle c_x^2 \rangle$ is sufficient)
8. understand that the **root-mean-square speed** $c_{\text{r.m.s.}}$ is given by $\sqrt{\langle c^2 \rangle}$
9. compare $pV = \frac{1}{3}Nm\langle c^2 \rangle$ with $pV = NkT$ to deduce that the **average translational kinetic energy** of a molecule is $\frac{3}{2}kT$, and recall and use this expression

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 15 (10 questions, answers on sheet 2)	
Teach the new content	Handout 15 Slide deck 15 (+ notes handout, 6-up) Vocabulary list 15	
Practice guided then independent	Exercise sheets 15.1, 15.2, 15.3 Past-paper sheets 15.1, 15.2, 15.3	
Check before they leave	Unit test 15 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

16. Thermodynamics

Weeks 34–35

热力学

They should be able to

1. understand that **internal energy** is determined by the state of the system and that it can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system
2. relate a rise in temperature of an object to an increase in its internal energy
3. recall and use $W = p\Delta V$ for the **work done** when the volume of a gas changes at **constant pressure** and understand the difference between the work done by the gas and the work done on the gas
4. recall and use the **first law of thermodynamics** $\Delta U = q + W$ expressed in terms of the increase in **internal energy**, the heating of the system (energy transferred to the system by heating) and the work done on the system

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 16 (10 questions, answers on sheet 2)	
Teach the new content	Handout 16 Slide deck 16 (+ notes handout, 6-up) Vocabulary list 16	
Practice guided then independent	Exercise sheets 16.1, 16.2 Past-paper sheets 16.1, 16.2	
Check before they leave	Unit test 16 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

17. Oscillations

Weeks 36–37

振动

They should be able to

1. understand and use the terms **displacement**, **amplitude**, **period**, **frequency**, **angular frequency** and **phase difference** in the context of oscillations, and express the period in terms of both frequency and angular frequency
2. understand that **simple harmonic motion** occurs when **acceleration** is proportional to **displacement** from a fixed point and in the opposite direction
3. use $a = -\omega^2 x$ and recall and use, as a solution to this equation, $x = x_0 \sin \omega t$
4. use the equations $v = v_0 \cos \omega t$ and $v = \pm \omega \sqrt{x_0^2 - x^2}$
5. analyse and interpret graphical representations of the variations of displacement, velocity and acceleration for simple harmonic motion
6. describe the interchange between **kinetic** and **potential energy** during simple harmonic motion
7. recall and use $E = \frac{1}{2}m\omega^2x_0^2$ for the **total energy** of a system undergoing simple harmonic motion
8. understand that a **resistive force** acting on an oscillating system causes **damping**
9. understand and use the terms **light**, **critical** and **heavy damping** and sketch displacement–time graphs illustrating these types of damping
10. understand that **resonance** involves a maximum amplitude of oscillations and that this occurs when an oscillating system is forced to oscillate at its **natural frequency**

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 17 (10 questions, answers on sheet 2)	
Teach the new content	Handout 17 Slide deck 17 (+ notes handout, 6-up) Vocabulary list 17	
Practice guided then independent	Exercise sheets 17.1, 17.2, 17.3 Past-paper sheets 17.1, 17.2, 17.3	
Check before they leave	Unit test 17 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

18. Electric fields

Weeks 38–40

电场

They should be able to

1. understand that an **electric field** is an example of a **field of force** and define electric field as force per unit positive charge
2. recall and use $F = qE$ for the force on a charge in an electric field
3. represent an electric field by means of **field lines**
4. recall and use $E = \Delta V / \Delta d$ to calculate the **field strength** of the uniform field between charged **parallel plates**
5. describe the effect of a **uniform electric field** on the motion of **charged particles**
6. understand that, for a point outside a **spherical conductor**, the charge on the sphere may be considered to be a **point charge** at its centre
7. recall and use **Coulomb's law** $F = Q_1Q_2 / (4\pi\varepsilon_0 r^2)$ for the force between two point charges in free space
8. recall and use $E = Q / (4\pi\varepsilon_0 r^2)$ for the **electric field strength** due to a point charge in free space
9. define **electric potential** at a point as the work done per unit positive charge in bringing a small **test charge** from infinity to the point
10. recall and use the fact that the electric field at a point is equal to the negative of **potential gradient** at that point
11. use $V = Q / (4\pi\varepsilon_0 r)$ for the electric potential in the field due to a point charge
12. understand how the concept of electric potential leads to the **electric potential energy** of two point charges and use $E_P = Qq / (4\pi\varepsilon_0 r)$

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 18 (10 questions, answers on sheet 2)	
Teach the new content	Handout 18 Slide deck 18 (+ notes handout, 6-up) Vocabulary list 18	
Practice guided then independent	Exercise sheets 18.1, 18.2, 18.3, 18.4, 18.5 Past-paper sheets 18.1, 18.2, 18.3, 18.4, 18.5	
Check before they leave	Unit test 18 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

19. Capacitance

Weeks 41–42

电容

They should be able to

1. define **capacitance**, as applied to both isolated spherical conductors and to **parallel plate capacitors**
2. recall and use $C = Q/V$
3. derive, using $C = Q/V$, formulae for the **combined capacitance** of capacitors in **series** and in **parallel**
4. use the capacitance formulae for capacitors in series and in parallel
5. determine the **electric potential energy** stored in a capacitor from the area under the **potential–charge graph**
6. recall and use $W = \frac{1}{2}QV = \frac{1}{2}CV^2$
7. analyse graphs of the variation with time of potential difference, charge and current for a capacitor discharging through a resistor
8. recall and use $\tau = RC$ for the **time constant** for a capacitor discharging through a resistor
9. use equations of the form $x = x_0 e^{-(t/RC)}$ where x could represent current, charge or potential difference for a capacitor discharging through a resistor

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 19 (10 questions, answers on sheet 2)	
Teach the new content	Handout 19 Slide deck 19 (+ notes handout, 6-up) Vocabulary list 19	
Practice guided then independent	Exercise sheets 19.1, 19.2, 19.3 Past-paper sheets 19.1, 19.2, 19.3	
Check before they leave	Unit test 19 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

20. Magnetic fields

Weeks 43–45

磁场

They should be able to

1. understand that a **magnetic field** is an example of a **field of force** produced either by moving charges or by **permanent magnets**
2. represent a magnetic field by **field lines**
3. understand that a force might act on a **current-carrying conductor** placed in a **magnetic field**
4. recall and use the equation $F = BIL \sin \theta$, with directions as interpreted by **Fleming's left-hand rule**
5. define **magnetic flux density** as the force acting per unit current per unit length on a wire placed at right-angles to the magnetic field
6. determine the direction of the force on a charge moving in a **magnetic field**
7. recall and use $F = BQv \sin \theta$
8. understand the origin of the **Hall voltage** and derive and use the expression $V_{\text{H}} = BI / (ntq)$, where $t = \text{thickness}$
9. understand the use of a **Hall probe** to measure **magnetic flux density**
10. describe the motion of a **charged particle** moving in a **uniform magnetic field** perpendicular to the direction of motion of the particle
11. explain how electric and magnetic fields can be used in **velocity selection**
12. sketch magnetic field patterns due to the currents in a **long straight wire**, a **flat circular coil** and a long **solenoid**
13. understand that the magnetic field due to the current in a solenoid is increased by a **ferrous core**
14. explain the origin of the forces between **current-carrying conductors** and determine the direction of the forces
15. define **magnetic flux** as the product of the **magnetic flux density** and the cross-sectional area perpendicular to the direction of the magnetic flux density
16. recall and use $\Phi = BA$
17. understand and use the concept of **magnetic flux linkage**
18. understand and explain experiments that demonstrate: • that a **changing magnetic flux** can induce an e.m.f. in a circuit • that the **induced e.m.f.** is in such a direction as to oppose the change producing it • the factors affecting the magnitude of the induced e.m.f.
19. recall and use **Faraday's and Lenz's laws** of electromagnetic induction

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 20 (10 questions, answers on sheet 2)	
Teach the new content	Handout 20 Slide deck 20 (+ notes handout, 6-up) Vocabulary list 20	
Practice guided then independent	Exercise sheets 20.1, 20.2, 20.3, 20.4, 20.5 Past-paper sheets 20.1, 20.2, 20.3, 20.4, 20.5	
Check before they leave	Unit test 20 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

21. Alternating currents

Weeks 46–47

交流电

They should be able to

1. understand and use the terms **period**, **frequency** and **peak value** as applied to an **alternating current** or voltage
2. use equations of the form $x = x_0 \sin \omega t$ representing a sinusoidally alternating current or voltage
3. recall and use the fact that the **mean power** in a resistive load is half the maximum power for a sinusoidal alternating current
4. distinguish between **root-mean-square (r.m.s.)** and **peak values** and recall and use $I_{\text{r.m.s.}} = I_0 / \sqrt{2}$ and $V_{\text{r.m.s.}} = V_0 / \sqrt{2}$ for a sinusoidal alternating current
5. distinguish graphically between **half-wave** and **full-wave rectification**
6. explain the use of a single **diode** for the half-wave rectification of an alternating current
7. explain the use of four diodes (**bridge rectifier**) for the full-wave rectification of an alternating current
8. analyse the effect of a single capacitor in **smoothing**, including the effect of the values of capacitance and the **load resistance**

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 21 (10 questions, answers on sheet 2)	
Teach the new content	Handout 21 Slide deck 21 (+ notes handout, 6-up) Vocabulary list 21	
Practice guided then independent	Exercise sheets 21.1, 21.2 Past-paper sheets 21.1, 21.2	
Check before they leave	Unit test 21 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

22. Quantum physics

Weeks 48–50

量子物理

They should be able to

1. understand that **electromagnetic radiation** has a **particulate nature**
2. understand that a **photon** is a **quantum** of electromagnetic energy
3. recall and use $E = hf$
4. use the **electronvolt (eV)** as a unit of energy
5. understand that a photon has **momentum** and that the momentum is given by $p = E/c$
6. understand that **photoelectrons** may be emitted from a metal surface when it is illuminated by electromagnetic radiation
7. understand and use the terms **threshold frequency** and **threshold wavelength**
8. explain **photoelectric emission** in terms of photon energy and **work function energy**
9. recall and use $hf = \Phi + \frac{1}{2}m{v_{\text{max}}}^2$
10. explain why the **maximum kinetic energy** of photoelectrons is independent of intensity, whereas the photoelectric current is proportional to intensity
11. understand that the **photoelectric effect** provides evidence for a **particulate nature** of electromagnetic radiation while phenomena such as **interference** and **diffraction** provide evidence for a **wave nature**
12. describe and interpret qualitatively the evidence provided by **electron diffraction** for the wave nature of particles
13. understand the **de Broglie wavelength** as the wavelength associated with a moving particle
14. recall and use $\lambda = h/p$
15. understand that there are **discrete electron energy levels** in isolated atoms (e.g. atomic hydrogen)
16. understand the appearance and formation of **emission** and **absorption line spectra**
17. recall and use $hf = E_1 - E_2$

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 22 (10 questions, answers on sheet 2)	
Teach the new content	Handout 22 Slide deck 22 (+ notes handout, 6-up) Vocabulary list 22	
Practice guided then independent	Exercise sheets 22.1, 22.2, 22.3, 22.4 Past-paper sheets 22.1, 22.2, 22.3, 22.4	
Check before they leave	Unit test 22 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

23. Nuclear physics

Weeks 51–52

核物理

They should be able to

1. understand the **equivalence between energy and mass** as represented by $E = mc^2$ and recall and use this equation
2. represent simple **nuclear reactions** by **nuclear equations** of the form $^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{17}_{8}\text{O} + ^{1}_{1}\text{H}$
3. define and use the terms **mass defect** and **binding energy**
4. sketch the variation of **binding energy per nucleon** with **nucleon number**
5. explain what is meant by **nuclear fusion** and **nuclear fission**
6. explain the relevance of binding energy per nucleon to nuclear reactions, including nuclear fusion and nuclear fission
7. calculate the energy released in nuclear reactions using $E = c^2 \Delta m$
8. understand that fluctuations in count rate provide evidence for the **random nature** of **radioactive decay**
9. understand that radioactive decay is both **spontaneous** and **random**
10. define **activity** and **decay constant**, and recall and use $A = \lambda N$
11. define **half-life**
12. use $\lambda = 0.693 / t_{\frac{1}{2}}$
13. understand the **exponential nature** of radioactive decay, and sketch and use the relationship $x = x_0 e^{-\lambda t}$, where x could represent activity, number of undecayed nuclei or received count rate

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 23 (10 questions, answers on sheet 2)	
Teach the new content	Handout 23 Slide deck 23 (+ notes handout, 6-up) Vocabulary list 23	
Practice guided then independent	Exercise sheets 23.1, 23.2 Past-paper sheets 23.1, 23.2	
Check before they leave	Unit test 23 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

24. Medical physics

Weeks 53–54

医学物理

They should be able to

1. understand that a **piezo-electric crystal** changes shape when a p.d. is applied across it and that the crystal generates an e.m.f. when its shape changes
2. understand how **ultrasound** waves are generated and detected by a **piezoelectric transducer**
3. understand how the **reflection** of pulses of ultrasound at boundaries between tissues can be used to obtain diagnostic information about internal structures
4. define the **specific acoustic impedance** of a medium as $Z = \rho c$, where c is the speed of sound in the medium
5. use $I_{\text{R}} / I_0 = (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ for the **intensity reflection coefficient** of a boundary between two media
6. recall and use $I = I_0 e^{-\mu x}$ for the **attenuation** of ultrasound in matter
7. explain that **X-rays** are produced by electron bombardment of a metal target and calculate the **minimum wavelength** of X-rays produced from the accelerating p.d.
8. understand the use of X-rays in imaging internal body structures, including an understanding of the term **contrast** in X-ray imaging
9. recall and use $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter
10. understand that **computed tomography (CT) scanning** produces a 3D image of an internal structure by first combining multiple X-ray images taken in the same section from different angles to obtain a 2D image of the section, then repeating this process along an axis and combining 2D images of multiple sections
11. understand that a **tracer** is a substance containing radioactive nuclei that can be introduced into the body and is then absorbed by the tissue being studied
12. recall that a tracer that decays by β^+ decay is used in **positron emission tomography (PET scanning)**
13. understand that **annihilation** occurs when a particle interacts with its **antiparticle** and that mass–energy and momentum are conserved in the process
14. explain that, in PET scanning, positrons emitted by the decay of the tracer annihilate when they interact with electrons in the tissue, producing a pair of **gamma-ray photons** travelling in opposite directions
15. calculate the energy of the gamma-ray photons emitted during the annihilation of an **electron-positron pair**
16. understand that the gamma-ray photons from an annihilation event travel outside the body and can be detected, and an image of the tracer concentration in the tissue can be created by processing the arrival times of the gamma-ray photons

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 24 (10 questions, answers on sheet 2)	
Teach the new content	Handout 24 Slide deck 24 (+ notes handout, 6-up) Vocabulary list 24	
Practice guided then independent	Exercise sheets 24.1, 24.2, 24.3 Past-paper sheets 24.1, 24.2, 24.3	
Check before they leave	Unit test 24 (with mark scheme)	

Stage	Use	Your notes
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	

25. Astronomy and cosmology

Weeks 55–56

天文学与宇宙学

They should be able to

1. understand the term **luminosity** as the total power of radiation emitted by a star
2. recall and use the **inverse square law** for **radiant flux intensity** F in terms of the luminosity L of the source $F = L / (4\pi d^2)$
3. understand that an object of known luminosity is called a **standard candle**
4. understand the use of standard candles to determine distances to galaxies
5. recall and use **Wien's displacement law** $\lambda_{\text{max}} \propto 1/T$ to estimate the peak surface temperature of a star
6. use the **Stefan–Boltzmann law** $L = 4\pi\sigma r^2 T^4$
7. use Wien's displacement law and the Stefan–Boltzmann law to estimate the radius of a star
8. understand that the lines in the emission and absorption spectra from distant objects show an increase in wavelength from their known values
9. use $\Delta\lambda / \lambda \approx \Delta f / f \approx v / c$ for the **redshift** of electromagnetic radiation from a source moving relative to an observer
10. explain why redshift leads to the idea that the Universe is expanding
11. recall and use **Hubble's law** $v \approx H_0 d$ and explain how this leads to the **Big Bang theory** (candidates will only be required to use SI units)

Stage	Use	Your notes
Starter 10 min · retrieval practice	Topic quiz 25 (10 questions, answers on sheet 2)	
Teach the new content	Handout 25 Slide deck 25 (+ notes handout, 6-up) Vocabulary list 25	
Practice guided then independent	Exercise sheets 25.1, 25.2, 25.3 Past-paper sheets 25.1, 25.2, 25.3	
Check before they leave	Unit test 25 (with mark scheme)	
Homework set from the Library	Any unused exercise sheet above Holiday homework pack	