

Specification

Focus Questions

Every line of the Eduqas A Level Physics specification, rewritten as a question with the answer directly underneath. This free sample shows seven real pages from the full pack.

What's in this sample

- 1.6 Vibrations — simple harmonic motion, straight from the specification
- 1.6 — SHM calculations worked step by step, with exam tips
- 2.4 Capacitance — exponential discharge and the log graph method
- 2.5 Solids under stress — with the stress-strain diagram and its labelled points
- 3.4 Photons — the photoelectric effect and Einstein's equation
- 3.7 Particles — quark compositions and conservation laws
- Option B Medical Physics — dose, imaging and attenuation

The full pack: 30 booklets, 233 pages

730 questions & answers · 214 worked examples · 204 exam tips

Every practical · mixed exam practice · 12 six-mark mark schemes

1.6(a) Simple harmonic motion

Q1. Define simple harmonic motion.

Motion in which the acceleration is directly proportional to the displacement from a fixed equilibrium position and is always directed towards that position: $a = -\omega^2 x$.

Q2. Explain the significance of the minus sign in $a = -\omega^2 x$.

It shows that the acceleration is always in the opposite direction to the displacement, so the resultant force is a restoring force directed back towards equilibrium. Omitting it is treated as an incomplete definition.

Q3. State the defining condition in terms of force.

The restoring force is proportional to the displacement and acts towards equilibrium, $F = -kx$. This follows from $a = -\omega^2 x$ with $F = ma$.

Q4. Write the displacement equations for an oscillator released from maximum displacement and one starting at the centre.

From maximum displacement: $x = A \cos \omega t$. From the equilibrium position moving at maximum speed: $x = A \sin \omega t$.

Q5. Write the expressions for velocity and acceleration as functions of time, starting from $x = A \cos \omega t$.

$v = -A\omega \sin \omega t$ and $a = -A\omega^2 \cos \omega t = -\omega^2 x$. Velocity is $\pi/2$ out of phase with displacement, and acceleration is π out of phase with it.

Q6. Write the expression for velocity in terms of displacement.

$v = \pm \omega \sqrt{A^2 - x^2}$. The speed is a maximum of ωA at the centre, where $x = 0$, and zero at the extremes, where $x = \pm A$.

Q7. State the maximum speed and maximum acceleration of an oscillator of amplitude A .

$v_{\max} = \omega A$, occurring at the equilibrium position. $a_{\max} = \omega^2 A$, occurring at maximum displacement.

Q8. Describe the shapes of the displacement, velocity and acceleration graphs against time.

All three are sinusoidal with the same period. If displacement is a cosine, velocity is a negative sine, and acceleration is a negative cosine. Velocity leads displacement by a quarter of a cycle, and acceleration is exactly antiphase with displacement.

Q9. State what the gradient of each graph represents. [Maths skill]

The gradient of the displacement-time graph is the velocity, and the gradient of the velocity-time graph is the acceleration.

Q10. Describe the graph of acceleration against displacement for SHM, and state what the gradient gives. [Maths skill]

A straight line through the origin with a negative gradient. The gradient is $-\omega^2$, so ω is the square root of the magnitude of the gradient, and the period follows from $T = 2\pi/\omega$.

Q15. Show how a graph can be used to find g from a pendulum experiment. ☐☐☐

[Maths skill]

Square the period formula: $T^2 = 4\pi^2 l/g$. Plot T^2 against l ; the line should pass through the origin with gradient $4\pi^2/g$, so $g = 4\pi^2 \div \text{gradient}$.

Q16. Describe how the period of a mass-spring system is measured accurately. ☐☐☐

Time 20 complete oscillations and divide by 20, starting and stopping as the mass passes the equilibrium position where it moves fastest. Use a fiducial marker at that point, repeat three times and take a mean.

Q17. Explain why timing is started at the centre rather than at maximum displacement. ☐☐☐

The oscillator moves fastest at the centre and is momentarily at rest at the extremes, so the position changes most rapidly at the centre. The timing is therefore least affected by judging the exact moment of passing.

Q18. Describe how the kinetic and potential energies vary during one oscillation. ☐☐☐

Kinetic energy is a maximum at the centre and zero at the extremes. Potential energy is zero at the centre and a maximum at the extremes. Each completes two full cycles per oscillation, and their sum is constant for undamped SHM.

Q19. Give the expressions for total energy, kinetic energy and potential energy in SHM. ☐☐☐

Total $E = \frac{1}{2}m\omega^2 A^2$. Kinetic $E_k = \frac{1}{2}m\omega^2 (A^2 - x^2)$. Potential $E_p = \frac{1}{2}m\omega^2 x^2$.

Q20. State how the total energy of an oscillator depends on amplitude and frequency. ☐☐☐

It is proportional to the square of the amplitude and to the square of the angular frequency. Doubling the amplitude therefore gives four times the energy.

Q21. Sketch and describe graphs of energy against displacement for SHM. ☐☐☐

Potential energy is an upward parabola with its minimum at $x = 0$. Kinetic energy is an inverted parabola with its maximum at $x = 0$. The two add to a horizontal line at the total energy.

WORKED EXAMPLE 4 • Mass-spring period

Question: A 0.45 kg mass hangs from a spring of stiffness 28 N m^{-1} . Find the period and the frequency of oscillation.

Step 1: $T = 2\pi\sqrt{(m/k)} = 2\pi\sqrt{(0.45 \div 28)}$

Step 2: $= 2\pi\sqrt{0.01607} = 2\pi \times 0.1268$

Step 3: $f = 1/T$

Answer: $T = 0.797 \text{ s}$ and $f = 1.25 \text{ Hz}$

WORKED EXAMPLE 7 · Time to reach a given value [Maths skill]

Question: How long does it take a capacitor to discharge to 25% of its initial charge through a circuit of time constant 4.5 s?

Step 1: $0.25 = e^{(-t/\tau)}$

Step 2: $\ln 0.25 = -t/4.5$, and $\ln 0.25 = -1.386$

Step 3: $t = 1.386 \times 4.5$

Answer: 6.24 s

EXAM TIP

Check whether the question is about charging or discharging. Discharge decays as $e^{-t/RC}$; charging rises as $(1 - e^{-t/RC})$.

EXAM TIP

For a graph method, plot **ln V against t**, not V against t. The gradient is $-1/RC$.

EXAM TIP

Remember $e^{-1} = 0.37$, so one time constant leaves 37% on discharge and reaches 63% on charging. Quoting the wrong one of these loses the mark.

2.5(a) Stress, strain and the Young modulus

Q1. Define tensile stress and state its unit. □ □ □

The force applied per unit cross-sectional area, $\sigma = F/A$, measured in pascals or N m^{-2} .

Q2. Define tensile strain and state its unit. □ □ □

The extension divided by the original length, $\epsilon = \Delta L/L$. It is a ratio, so it has no units, and is often given as a percentage.

Q3. Define the Young modulus and state its unit. □ □ □

The ratio of tensile stress to tensile strain for a material in its linear region, $E = \sigma/\epsilon = FL/(A\Delta L)$, measured in pascals. It is a property of the material, not of the specimen.

Q4. Explain why the Young modulus is a property of the material while stiffness is a property of the sample. □ □ □

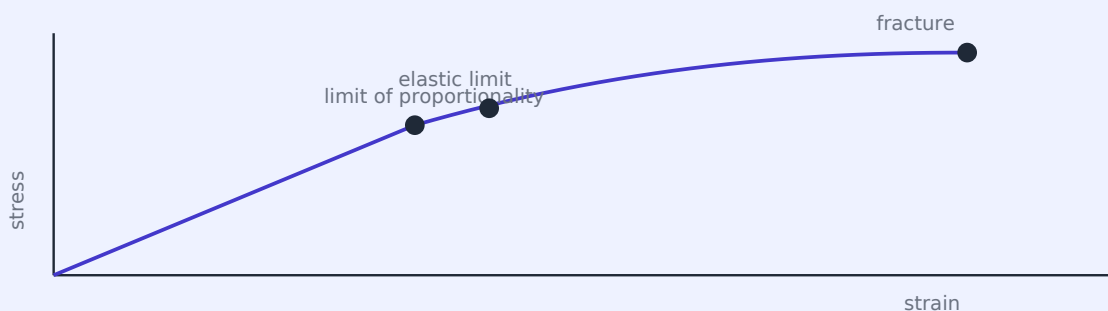
Stress and strain already allow for the cross-sectional area and the original length, so the ratio depends only on the material. The spring constant $k = F/\Delta L$ depends on the dimensions of the particular specimen as well.

Q5. State Hooke's law and the condition for it to apply. □ □ □

The extension is directly proportional to the applied force, provided the limit of proportionality is not exceeded.

Q6. Define the limit of proportionality and the elastic limit, and state which comes first. □ □ □

The limit of proportionality is the point beyond which stress is no longer proportional to strain — the graph stops being a straight line. The elastic limit, slightly beyond it, is the point beyond which the material no longer returns to its original length when the load is removed.



*A stress-strain curve for a ductile metal. Note the order: the limit of proportionality comes **first**, then the elastic limit just beyond it, then a long plastic region before fracture.*

Q7. Define the yield point and the ultimate tensile stress. □ □ □

The yield point is where the material suddenly extends greatly for little extra stress, as planes of atoms begin to slide. The ultimate tensile stress is the maximum stress the material can withstand before it breaks.

Q10. Define threshold frequency and relate it to the work function. □□□

The minimum frequency of radiation that will cause emission. At the threshold the electron just escapes with zero kinetic energy, so $\phi = hf_0$ and $f_0 = \phi/h$.

Q11. Describe how a graph is used to find h and ϕ from photoelectric data. □□□

[Maths skill]

Plot $E_{k(\max)}$ against f . Since $E_{k(\max)} = hf - \phi$, the line is straight with gradient h and intercept $-\phi$ on the energy axis. The intercept on the frequency axis is the threshold frequency.

Q12. Define stopping potential and state its relationship to maximum kinetic energy. □□□

The reverse potential difference just sufficient to stop the most energetic electrons reaching the collector, so that the photocurrent falls to zero. $eV_s = E_{k(\max)}$.

WORKED EXAMPLE 1 · Photon energy [Maths skill]

Question: Find the energy of a photon of wavelength 450 nm, in joules and in electronvolts.

Step 1: $E = hc/\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) \div (450 \times 10^{-9})$

Step 2: $= 1.989 \times 10^{-25} \div 4.50 \times 10^{-7} = 4.42 \times 10^{-19} \text{ J}$

Step 3: In eV: divide by 1.60×10^{-19}

Answer: $4.42 \times 10^{-19} \text{ J}$, or **2.76 eV**

WORKED EXAMPLE 2 · Photoelectric calculation [Maths skill]

Question: Light of wavelength 380 nm falls on a metal of work function 2.1 eV. Find the maximum kinetic energy of the emitted electrons.

Step 1: Photon energy $= hc/\lambda = 1.989 \times 10^{-25} \div 3.80 \times 10^{-7} = 5.234 \times 10^{-19} \text{ J}$

Step 2: Work function in joules $= 2.1 \times 1.60 \times 10^{-19} = 3.36 \times 10^{-19} \text{ J}$

Step 3: $E_k = hf - \phi = 5.234 \times 10^{-19} - 3.36 \times 10^{-19}$

Answer: $1.87 \times 10^{-19} \text{ J}$, or **1.17 eV**

WORKED EXAMPLE 3 · Threshold wavelength

Question: Find the longest wavelength that will cause emission from a metal of work function 4.3 eV.

Step 1: At threshold the electron just escapes: $hf_0 = \phi$

Step 2: $\phi = 4.3 \times 1.60 \times 10^{-19} = 6.88 \times 10^{-19} \text{ J}$

Step 3: $\lambda_0 = hc/\phi = 1.989 \times 10^{-25} \div 6.88 \times 10^{-19}$

Answer: $2.89 \times 10^{-7} \text{ m}$, or **289 nm — in the ultraviolet**

Q25. Compare the four interactions by relative strength and range.

Strong is the most powerful but acts only over about 10^{-15} m. Electromagnetic is about a hundred times weaker but has infinite range. Weak is far weaker still and acts over about 10^{-18} m. Gravity is by far the weakest but has infinite range and, because mass is always positive, dominates on astronomical scales.

Q26. Explain why the weak interaction is the only one that can change quark flavour.

The W bosons couple quarks of different types, so an up quark can become a down quark and vice versa. The strong and electromagnetic interactions leave quark flavour unchanged, which is why beta decay is a weak process.

Q27. Explain why the strong nuclear force must be repulsive at very short range.

If it were attractive at all separations, the nucleus would collapse. It is repulsive below about 0.5 fm, attractive out to about 3 fm, and negligible beyond that, which gives the nucleus a stable size.

EXAM TIP

Work through the conservation laws **one at a time** in a list: charge, baryon number, each lepton number. Stating which one fails earns the mark.

EXAM TIP

Only the **weak** interaction changes quark flavour, which is why all beta decays are weak processes.

EXAM TIP

In an issues question where measurements disagree with theory, there are only two valid responses: carry out **further research or experiments**, or **modify the theory or model**.

EXAM TIP

In comprehension questions, **never quote the article directly** — direct quotes are awarded no marks.

Extended response practice

These are marked on the quality of the whole answer, not separate points. Plan 3–4 linked ideas, use the correct technical words, and answer every part of the question.

Question 1. Compare the use of X-rays and ultrasound for medical imaging, referring to how each image is formed, the information obtained and the risks involved. [6 marks]

MARK SCHEME — what a top-level answer includes

- X-rays are produced by accelerating electrons onto a metal target and are attenuated according to $I = I_0 e^{-\mu x}$ as they pass through the body.
- The attenuation coefficient rises steeply with atomic number, so bone containing calcium attenuates far more than soft tissue and appears white on the image.
- This gives excellent images of bone and, with a contrast medium, of hollow organs, and CT scanning extends it to cross-sectional and three-dimensional images.
- Ultrasound images are formed by reflection: a piezoelectric transducer sends a pulse and detects the echoes from boundaries where the acoustic impedance $Z = \rho c$ changes.
- The time of the echo gives the depth and its amplitude gives the size of the impedance mismatch, so ultrasound excels at soft-tissue boundaries and, using the Doppler shift, at blood flow.
- X-rays are ionising and so carry a risk of cell damage and cancer, which is why doses are minimised, lead shielding is used and repeat scans are limited — CT doses are considerably higher than a plain radiograph.
- Ultrasound at diagnostic intensities is considered non-ionising and safe enough for routine use in pregnancy, but it cannot image through bone or gas and gives lower resolution at depth, so the two techniques are complementary.

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