Mark schemes give "C1 M1 A1" and leave the reasoning to you. These are written the way you should write them: state the principle, write the equation, substitute with units, then evaluate – because the method marks are awarded before the answer is reached. 官方答案只给 C1 M1 A1; 这里按"原理 – 公式 – 代入 – 结果"完整写出。

Mechanics

A ball of mass 0.15 kg strikes a wall horizontally at 12 m/s and rebounds at 8.0 m/s. The contact lasts 0.020 s. Calculate the average force on the ball. [4]

Taking the initial direction as positive, the change in momentum is $\Delta p = mv_{\text{final}} - mv_{\text{initial}} = 0.15(-8.0) - 0.15(12) = -1.2 - 1.8 = -3.0$ N s. The average force is $F = \dfrac{\Delta p}{\Delta t} = \dfrac{-3.0}{0.020} = -150$ N, so a force of 150 N acts on the ball away from the wall.

Momentum is a VECTOR. The rebound velocity must be negative; treating both as positive gives 30 N s and 1500 N, a factor-of-five error that looks plausible.

Defining the positive direction in words is worth doing – it is where the sign marks are won.

A satellite orbits the Earth at radius $r = 7.0 \times 10^6$ m. Given $GM = 4.0 \times 10^{14}$ m^{3}s^{-2}, calculate its orbital speed and period. [5]

For a circular orbit the gravitational force provides the centripetal force: $\dfrac{GMm}{r^2} = \dfrac{mv^2}{r}$, so $v^2 = \dfrac{GM}{r}$ and $v = \sqrt{\dfrac{4.0 \times 10^{14}}{7.0 \times 10^6}} = \sqrt{5.71 \times 10^7} = 7.6 \times 10^3$ m/s. The period is $T = \dfrac{2\pi r}{v} = \dfrac{2\pi(7.0 \times 10^6)}{7.6 \times 10^3} = 5.8 \times 10^3$ s.

The first line – equating gravitational to centripetal force – is the method mark, and it is worth writing even if the algebra then fails.

The mass of the satellite cancels. Saying so shows why the orbit is independent of it.

Fields and circuits

A capacitor of 470 μF is charged to 12 V. Calculate the energy stored, and the charge on it. [4]

Energy: $E = \frac{1}{2}CV^2 = 0.5 \times 470 \times 10^{-6} \times 12^2 = 0.5 \times 470 \times 10^{-6} \times 144 = 3.4 \times 10^{-2}$ J. Charge: $Q = CV = 470 \times 10^{-6} \times 12 = 5.6 \times 10^{-3}$ C.

Convert μF to F before substituting. Leaving 470 in the formula gives 33 840 J, which should look absurd.

Note $E = \frac{1}{2}CV^2$, not CV^2 – the factor of a half is a mark on its own.

Explain why the resistance of a metallic conductor increases with temperature. [3]

In a metal the charge carriers are delocalised electrons. As temperature rises the positive ions vibrate with greater amplitude, so electrons collide with them more frequently. Each collision transfers energy from the electron, reducing the drift velocity for a given potential difference, so the current falls and the resistance rises.

The marks are for the ions vibrating MORE, more frequent collisions, and reduced drift velocity – three linked steps, not one assertion.

Saying 'the electrons move faster so there is more resistance' reverses the mechanism and scores nothing.

Quantum and nuclear

Light of wavelength 450 nm falls on a metal of work function 2.0 eV. Calculate the maximum kinetic energy of the emitted electrons. ($h = 6.63 \times 10^{-34}$ J s, $c = 3.00 \times 10^8$ m/s, 1 eV $= 1.60 \times 10^{-19}$ J) [5]

Photon energy: $E = \dfrac{hc}{\lambda} = \dfrac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{450 \times 10^{-9}} = 4.42 \times 10^{-19}$ J. Work function in joules: $2.0 \times 1.60 \times 10^{-19} = 3.20 \times 10^{-19}$ J. By Einstein's photoelectric equation, $E_{k,\max} = hf - \phi = 4.42 \times 10^{-19} - 3.20 \times 10^{-19} = 1.2 \times 10^{-19}$ J, which is 0.76 eV.

Convert the wavelength to metres and the work function to joules BEFORE subtracting. Mixing eV with joules is the standard failure here.

Quoting the answer in both joules and eV costs one line and protects against a units requirement in the mark scheme.

A wire of length 1.8 m and diameter 0.40 mm has resistance 3.6 Ω. Calculate the resistivity of the metal. [4]

The cross-sectional area is $A = \pi r^2 = \pi(0.20 \times 10^{-3})^2 = 1.26 \times 10^{-7}$ m^2. From $R = \dfrac{\rho L}{A}$, $\rho = \dfrac{RA}{L} = \dfrac{3.6 \times 1.26 \times 10^{-7}}{1.8} = 2.5 \times 10^{-7}$ Ω m.

The RADIUS is half the diameter. Using 0.40 mm as the radius makes the area four times too large and the answer four times too big.

Resistivity is a property of the material, so the length and thickness must divide out – which is why the units are ohm metres, not ohms.

Explain why the resistance of a thermistor falls as its temperature rises, while that of a metal wire increases. [4]

In a metal the number of charge carriers is fixed; raising the temperature makes the lattice ions vibrate more, so electrons collide with them more often, the drift velocity falls for a given p.d. and the resistance rises. In a semiconducting thermistor, heating releases many more charge carriers than it costs in extra collisions, so the number density rises sharply and the resistance falls.

Both halves turn on which effect wins: carrier number or collision frequency.

Saying 'the electrons move faster' reverses the mechanism and scores nothing.

A stationary wave on a string 1.2 m long, fixed at both ends, is vibrating in its third harmonic at 210 Hz. Determine the speed of the wave. [4]

The third harmonic fits three half-wavelengths into the string: $L = \dfrac{3\lambda}{2}$, so $\lambda = \dfrac{2 \times 1.2}{3} = 0.80$ m. Then $v = f\lambda = 210 \times 0.80 = 1.7 \times 10^2$ m s^{-1}.

Draw the shape first: nodes at both ends and two more inside, three loops in all.

The wave speed is a property of the string's tension and mass per unit length, so every harmonic on the same string travels at this speed.

Light of wavelength 590 nm falls normally on a grating with 400 lines per mm. Determine the highest order of maximum observable. [4]

The slit spacing is $d = \dfrac{1 \text{ mm}}{400} = 2.5 \times 10^{-6}$ m. From $n\lambda = d\sin\theta$, the largest possible angle is 90° where $\sin\theta = 1$, so $n_{\max} = \dfrac{d}{\lambda} = \dfrac{2.5 \times 10^{-6}}{590 \times 10^{-9}} = 4.24$. An order must be a whole number, so the highest observed is the 4th.

Round DOWN, always: $n = 5$ would need $\sin\theta > 1$, which is impossible.

The 4.24 is not the answer. The mark is for saying why it becomes 4.

A 2.0 kg trolley moving at 3.0 m/s collides with a stationary 4.0 kg trolley and they move off together. Determine their common velocity and the percentage of kinetic energy lost. [5]

Momentum is conserved: $(2.0)(3.0)+0 = (6.0)v$, so $v = 1.0\ \mathrm{m\ s^{-1}}$. Kinetic energy before is $\frac{1}{2}(2.0)(3.0)^2 = 9.0$ J; after is $\frac{1}{2}(6.0)(1.0)^2 = 3.0$ J. The fraction lost is $\dfrac{9.0-3.0}{9.0} = 67\%$.

Momentum is conserved in EVERY collision; kinetic energy only in an elastic one. Two thirds of it is gone here and the momentum is untouched.

Use the combined mass after the collision, not the moving trolley's mass.

An ideal gas of 0.25 mol occupies 6.0×10^{-3} m^3 at 320 K. Determine its pressure, and the mean kinetic energy of one molecule. [5]

From $pV = nRT$, $p = \dfrac{nRT}{V} = \dfrac{0.25 \times 8.31 \times 320}{6.0 \times 10^{-3}} = 1.1 \times 10^5$ Pa. The mean kinetic energy of one molecule depends only on temperature: $E_\mathrm{K} = \frac{3}{2}kT = 1.5 \times 1.38 \times 10^{-23} \times 320 = 6.6 \times 10^{-21}$ J.

R goes with moles and k with molecules. Mixing them is out by the Avogadro constant.

That pressure is close to atmospheric, which is a good sanity check for a laboratory sample.

A 470 µF capacitor charged to 9.0 V is discharged through a 22 kΩ resistor. Determine the time constant and the p.d. after 15 s. [5]

$\tau = RC = 22 \times 10^3 \times 470 \times 10^{-6} = 10.3$ s. Then $V = V_0 e^{-t/\tau} = 9.0 \times e^{-15/10.3} = 9.0 \times 0.233 = 2.1$ V.

15 s is about 1.5 time constants, so expect roughly a fifth of the starting p.d. – the arithmetic agrees.

The time constant has units of seconds: ohms times farads really does give seconds.

Explain, in terms of the photon model, why no electrons are emitted from a metal below a threshold frequency however intense the light. [4]

Light delivers its energy in whole photons of energy hf, and one electron absorbs one photon. If hf is less than the work function, no single photon can supply the energy needed to escape, so no electron is emitted. Increasing the intensity sends more photons per second, not more energetic ones, so it changes how many electrons could be freed but not whether any can be.

A wave model predicts that any frequency works if you wait long enough. Saying why it fails is what earns the marks.

'One electron, one photon' is the sentence the mark scheme wants.

A nucleus of iron-56 has mass 55.9349 u. Given the proton mass 1.00728 u and the neutron mass 1.00867 u, determine the binding energy per nucleon in MeV. [5]

Iron-56 has 26 protons and 30 neutrons. The total mass of the separate nucleons is $26(1.00728) + 30(1.00867) = 56.4499$ u. The mass defect is $56.4499 - 55.9349 = 0.5150$ u. Since 1 u = 931.5 MeV, the binding energy is 479.7 MeV, so per nucleon it is $\dfrac{479.7}{56} = 8.6$ MeV.

Count protons and neutrons separately; using 56 protons is the usual slip.

Iron sits at the peak of the binding-energy curve at about 8.8 MeV per nucleon, so 8.6 is right.

A star has luminosity 4.0×10^{26} W and surface temperature 5800 K. Determine its radius. [4]

From the Stefan-Boltzmann law $L = 4\pi r^2 \sigma T^4$, $r = \sqrt{\dfrac{L}{4\pi\sigma T^4}} = \sqrt{\dfrac{4.0 \times 10^{26}}{4\pi(5.67 \times 10^{-8})(5800)^4}} = 7.0 \times 10^8$ m.

Raise the temperature to the fourth power INSIDE the bracket before dividing.

This is the Sun's own radius, which is the check: those numbers are the Sun's.