LOCUS EDUCATION · QCE PHYSICS UNITS 3 AND 4

Physics *Masterclass.*

Physics · Units 3 and 4 · Final revision workbook · Technology-active (calculator allowed)

Saturday 7 November 2026, 12 to 3pm
UQ St Lucia, room 24-S304, and on Zoom
Your external exam: Monday 9 November. Paper 1 at 9am, Paper 2 at 12:30pm.
Free tutoring and future sessions: **locuseducation.com** · Instagram **@locustutoring**

How to use this book

1. Every question has a time slot. Try it on your own for about half the slot, then watch the tutor work it out live on the slides.
2. Question numbers here match the slides. Each section starts with three key ideas: read them before the block starts.
3. Level 1 is a warm-up, Level 2 is exam standard and Level 3 is the hardest: a new context that mixes several ideas. Each block starts easy and finishes hard.
4. Show every step. QCAA gives marks for recognising the physics, for the working, and for the answer. Write the formula before you substitute.
5. When you lose a mark, circle the step. Those circles are your revision list for Sunday.

Time	Block	Questions	Pages
12:05	Gravity and motion	1 to 3	2 to 4
12:30	Electromagnetism	4 to 10	5 to 9
1:20	*Break*		
1:30	Special relativity	11 to 13	10 to 11
1:55	Quantum theory	14 to 16	12 to 13
2:20	*Break*		
2:30	Standard Model	17 to 19	14
2:45	Exam technique + FAQs	20 to 21	15 to 16

Data used in this book (from the QCAA formula and data book)

$g = 9.8\ \text{m s}^{-2}$ $G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$ $h = 6.626 \times 10^{-34}\ \text{J s}$ $e = 1.60 \times 10^{-19}\ \text{C}$ 1 eV $= 1.60 \times 10^{-19}\ \text{J}$

$m_e = 9.11 \times 10^{-31}\ \text{kg}$ $\mu_0 = 4\pi \times 10^{-7}\ \text{T m A}^{-1}$ $1/(4\pi\varepsilon_0) = 8.99 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$ $b = 2.898 \times 10^{-3}\ \text{m K}$

Give answers to three significant figures unless the question says otherwise. Ignore air resistance throughout.

Aligned to the QCAA Physics General Senior Syllabus 2025, Unit 3: Gravity and electromagnetism (Topic 1 Gravity and motion; Topic 2 Electromagnetism) and Unit 4: Revolutions in modern physics (Topic 1 Special relativity; Topic 2 Quantum theory; Topic 3 The Standard Model). Questions written in the style of QCAA Physics external assessments 2020 to 2025. Prepared by Locus Education. Not an official QCAA publication.

Gravity and motion in *three ideas.*

1. Two motions, one clock. Horizontal velocity never changes. Vertical has a = −9.8 m s^{-2}. Time is the only thing they share. A height that is not zero gives a quadratic: pick the root that matches the physics.

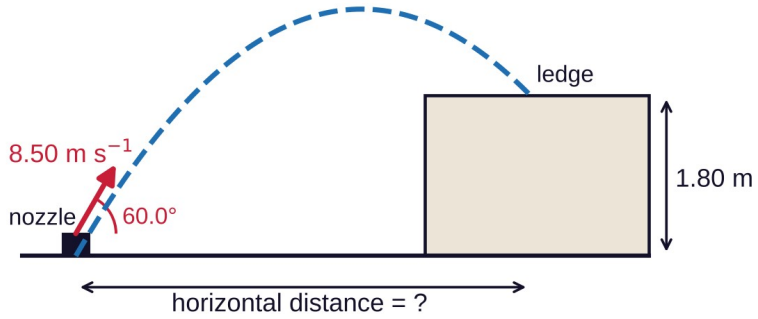
2. On a slope, resolve the weight. Along the slope: mg sin θ. Into the slope: mg cos θ, balanced by the normal force. For masses joined by a string, a = net force ÷ total mass, then find tension from one mass.

3. Circles, orbits and Kepler. Fnet = mv^2/r is supplied by a real force. In orbit $GMm/r^2 = mv^2/r$, so $v = \sqrt{(GM/r)}$ and $T^2/r^3 = 4\pi^2/GM$ (Kepler's third law). r is from the centre of the planet. Kepler: elliptical orbits, equal areas in equal times, $T^2 \propto r^3$.

Question 1 · Fountain jet onto a ledge — Level 2 · 4 marks

A fountain nozzle at ground level fires a jet of water at 8.50 m s^{-1} at 60.0° above the horizontal. The water lands on a flat ledge 1.80 m above the nozzle, while it is moving downwards. Ignore air resistance.

Q1 Not to scale



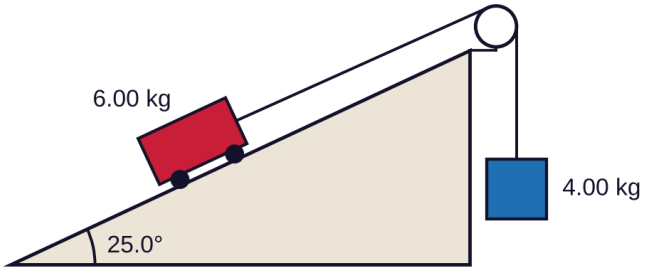
Determine the horizontal distance from the nozzle to where the water lands on the ledge. Show your working. **[4 marks]**

Horizontal distance = _____ m (to three significant figures)

Question 2 · Trolley, ramp and pulley — Level 2 · 4 marks

A 6.00 kg trolley sits on a frictionless ramp inclined at 25.0° to the horizontal. A light string runs from the trolley, parallel to the ramp, over a frictionless pulley at the top, to a hanging 4.00 kg mass. The system is released from rest.

Q2 Frictionless ramp and pulley



a) Determine the magnitude of the acceleration of the system. Show your working. **[3 marks]**

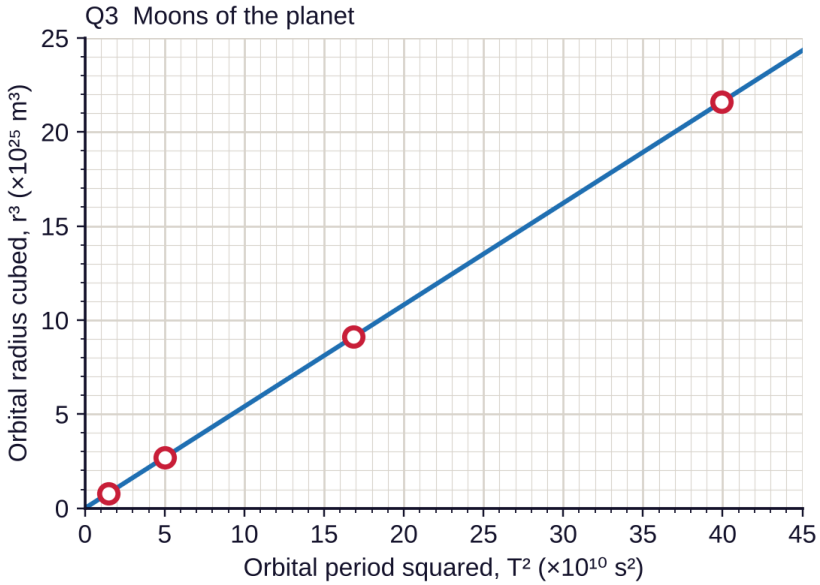
Acceleration = _____ m s^{-2} (to three significant figures)

b) Determine the tension in the string. **[1 mark]**

Tension = _____ N (to three significant figures)

Question 3 · Weighing a planet with its moons — Level 3 · 6 marks

An astronomer measures the orbital radius r and period T of four moons of a gas giant planet. The graph shows r^3 against T^2 for the moons. The planet has a radius of 5.80×10^7 m and rotates once every 11.0 h.



a) Use the graph to determine the mass of the planet. Show your working. **[4 marks]**

Mass = _____ kg (to three significant figures)

b) A satellite is to stay above the same point on the planet's equator. Determine its altitude above the planet's surface. **[2 marks]**

Altitude = _____ m (to three significant figures)

Electromagnetism in *three ideas.*

1. Electric vs magnetic fields. An electric field acts on any charge, moving or not ($F = qE$, $E = V/d$ between plates, field lines from + to −). A magnetic field acts only on moving charges and currents ($F = qvB \sin\theta$, $F = BIL \sin\theta$), and its field lines are closed loops, out of N and into S.

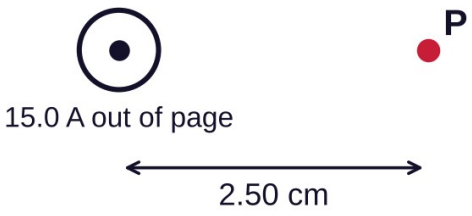
2. Two hand rules, two jobs. Grip rule (thumb along current, fingers curl) gives the field of a wire or solenoid. Palm rule (fingers along B, thumb along I or v of a positive charge, palm pushes) gives the force. Negative charge: reverse it. Angles: θ is between v (or I) and B; flux uses B perpendicular to the coil.

3. Faraday then Lenz, and watch n vs N. $\varepsilon = -N\Delta\Phi/\Delta t$, where N is the number of turns. In a solenoid, $B = \mu_0 nI$, where n is turns PER METRE. The induced current always opposes the change in flux.

Question 4 · Field near a straight wire — Level 1 · 2 marks

A long straight wire carries a current of 15.0 A directly out of the page. Point P is 2.50 cm to the right of the wire.

Q4 View from above, looking at the page



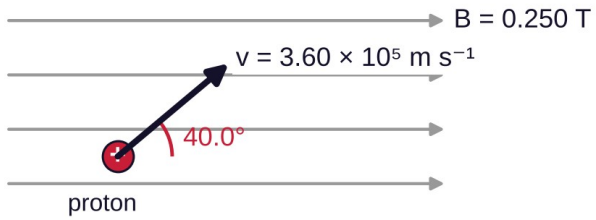
Determine the magnitude and direction of the magnetic field at P. **[2 marks]**

B = _____ T (to three significant figures) Direction: _____

Question 5 · Proton crossing a field at an angle — Level 2 · 4 marks

A proton moves in the plane of the page at 3.60×10^5 m s^{-1}. Its velocity is at 40.0° to a uniform 0.250 T magnetic field, which points to the right in the plane of the page.

Q5 All vectors in the plane of the page



a) Calculate the magnitude of the magnetic force on the proton. **[2 marks]**

Force = _____ N (to three significant figures)

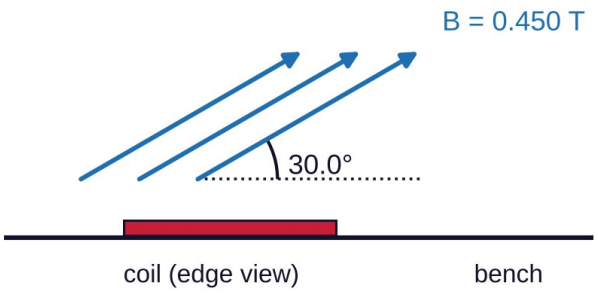
b) Determine the direction of the force at this instant. **[1 mark]**

c) An electron moves with the same velocity. State how the force on it compares with the force on the proton. **[1 mark]**

Question 6 · Tilting a coil: the angle trap — Level 2 · 4 marks

A square coil of 80 turns and side length 6.00 cm lies flat on a horizontal bench. A uniform 0.450 T magnetic field is directed at 30.0° above the horizontal. In 0.120 s the coil is rotated until its plane is perpendicular to the field.

Q6 Side view



a) Calculate the initial magnetic flux through one turn of the coil. **[2 marks]**

Flux = _____ Wb (to three significant figures)

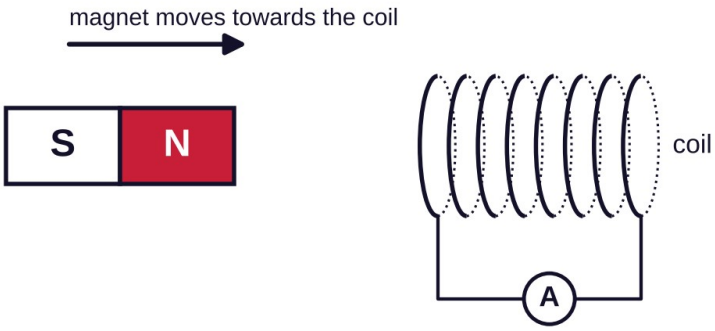
b) Calculate the magnitude of the average emf induced in the coil during the rotation. **[2 marks]**

emf = _____ V (to three significant figures)

Question 7 · Bar magnet into a coil — Level 2 · 5 marks

The north pole of a bar magnet is pushed towards one end of a coil. The coil is connected to a sensitive ammeter.

Q7 Sketch the field on this diagram



a) On the diagram, sketch the magnetic field around the bar magnet. Show at least six field lines with their direction. **[2 marks]**

b) Use Lenz's law to determine whether the end of the coil nearest the magnet becomes a north or a south pole while the magnet approaches. Justify your answer. **[2 marks]**

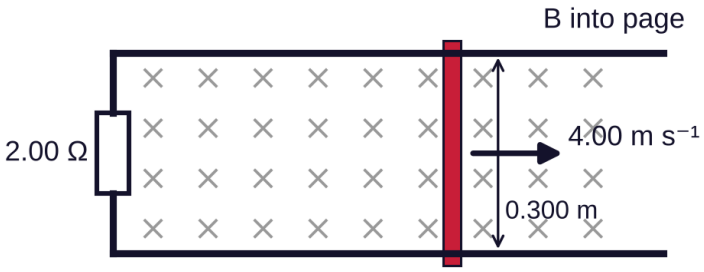
Pole: _____

c) State one change that would produce a larger induced current, and explain why it works. **[1 mark]**

Question 8 · Rod sliding on rails — Level 3 · 6 marks

A metal rod of length 0.300 m slides to the right at a constant 4.00 m s^{-1} along two horizontal conducting rails. The rails are joined on the left by a 2.00 Ω resistor. A uniform magnetic field points into the page. A voltmeter across the rod reads 0.180 V. Ignore the resistance of the rod and rails.

Q8 View from above



a) Determine the magnetic field strength. **[2 marks]**

B = _____ T (to three significant figures)

b) Use Lenz's law to determine the direction of the current in the rod (towards the top or bottom of the page). Justify your answer. **[2 marks]**

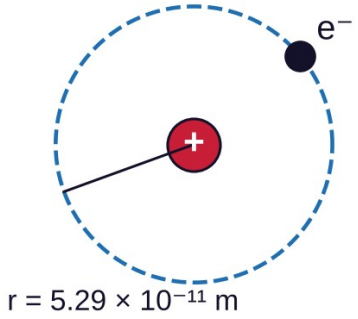
c) Determine the force needed to keep the rod moving at constant speed. **[2 marks]**

Force = _____ N (to three significant figures)

Question 9 · Inside a hydrogen atom — Level 3 · 5 marks

In the Bohr model, the electron in a hydrogen atom's ground state moves in a circle of radius 5.29×10^{-11} m around the proton. The electrostatic attraction provides the centripetal force. Use $1/(4\pi\varepsilon_0) = 8.99 \times 10^{9}$ N m^2 C^{-2}.

Q9 Not to scale



a) Show that the speed of the electron is about 2.2×10^{6} m s^{-1}. **[3 marks]**

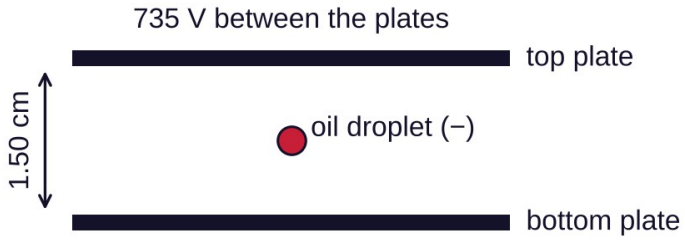
b) Hence calculate the kinetic energy of the electron, in eV. **[2 marks]**

Kinetic energy = _____ eV (to three significant figures)

Question 10 · Holding a droplet with an electric field — Level 3 · 7 marks

A tiny negatively charged oil droplet of mass 3.20×10^{-15} kg floats at rest between two horizontal metal plates 1.50 cm apart when the potential difference between them is 735 V.

Q10 Not to scale



a) Determine the magnitude of the charge on the droplet, and the number of excess electrons it carries. **[3 marks]**

Charge = _____ C Electrons = _____

b) Determine which plate is positive. Justify your answer. **[1 mark]**

c) The potential difference is increased to 980 V. Determine the magnitude and direction of the droplet's acceleration. **[2 marks]**

Acceleration = _____ m s^{-2} (to three significant figures)

d) Explain why a magnetic field could not hold this droplet at rest. **[1 mark]**

Special relativity in *three ideas.*

1. Two postulates. The laws of physics are the same in every inertial frame of reference. The speed of light in a vacuum, $c = 3.00 \times 10^8$ m s^{-1}, is the same for every observer. Everything else in this topic follows from these two.

2. Proper time: same place. Proper length: at rest. Proper time t_0 is measured in the frame where both events happen at the same location. Proper length L_0 is measured in the frame at rest relative to both ends. Dilated time > proper time and contracted length < proper length, because $\gamma = 1/\sqrt{(1 - v^2/c^2)}$ is always ≥ 1: $t = \gamma t_0$ and $L = L_0/\gamma$.

3. Simultaneity is relative. Two events at the same time in one frame need not be at the same time in another. That resolves the paradoxes: the travelling twin's clock is the moving clock, so she ages less, and in the ladder and barn the two frames disagree about when the doors shut.

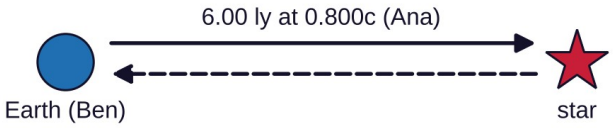
Question 11 · The speed limit — Level 1 · 2 marks

No spacecraft, however powerful, can be accelerated to the speed of light.

Explain why an object with mass cannot reach the speed of light. **[2 marks]**

Question 12 · The twins — Level 2 · 4 marks

Twins Ana and Ben are both 20 years old. Ana travels at 0.800c to a star 6.00 light-years from Earth (measured in Earth's frame), then immediately returns at the same speed. Ben stays on Earth.



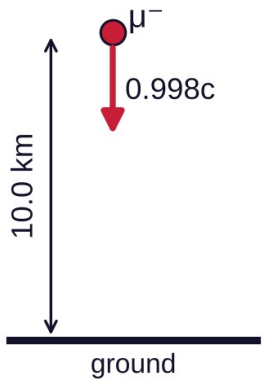
a) Calculate the time the round trip takes as measured by Ben, and as measured by Ana. **[2 marks]**

Ben: _____ years Ana: _____ years

b) Use special relativity to explain why the twins are no longer the same age when Ana returns, and state which twin is younger. **[2 marks]**

Question 13 · Muons that should not make it — Level 3 · 6 marks

Muons are created 10.0 km above the ground and travel straight down at 0.998c. The mean lifetime of a muon, measured at rest, is 2.20 μs.



a) Show that the Lorentz factor for these muons is about 15.8. **[1 mark]**

b) Using Earth's frame, determine whether a typical muon reaches the ground. **[2 marks]**

c) Using the muon's frame, determine the thickness of atmosphere the muon must cross, and explain why this frame reaches the same conclusion. **[3 marks]**

Quantum theory in *three ideas.*

1. Black bodies: hotter means higher and bluer. As T rises every wavelength gets brighter and the peak moves to shorter λ (λmax = b/T). Classical physics predicted infinite intensity at short λ. Planck's quanta (E = hf) fixed it.

2. Photoelectric effect: light as particles. One photon frees at most one electron: Ek(max) = hf − W, and Ek = qV_0 for the stopping voltage. Below the threshold frequency nothing is emitted, however bright the light. The double slit's interference pattern is the evidence for light as a wave.

3. Energy levels: photon energy = gap. Emission: electron drops, photon energy equals the difference between two levels. Each different gap gives a different line. Biggest gap, shortest wavelength.

Question 14 · Photoelectrons from potassium — Level 1 · 2 marks

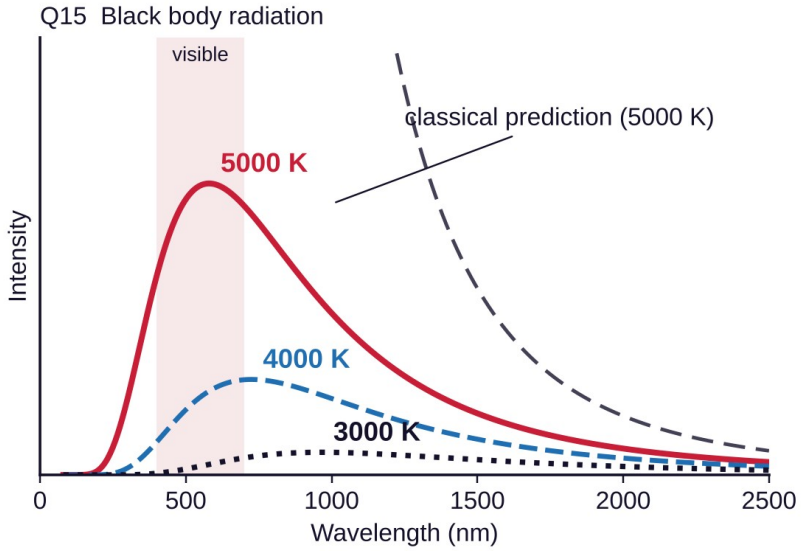
Photons of energy 3.20 eV strike a potassium surface, which has a work function of 2.30 eV.

Calculate the maximum kinetic energy of the emitted photoelectrons in joules, and the stopping voltage. **[2 marks]**

Ek(max) = _____ J Stopping voltage = _____ V

Question 15 · Reading black body curves — Level 2 · 4 marks

The graph shows the measured intensity of radiation emitted by a black body at three temperatures. The dashed line shows the classical prediction for the 5000 K curve.



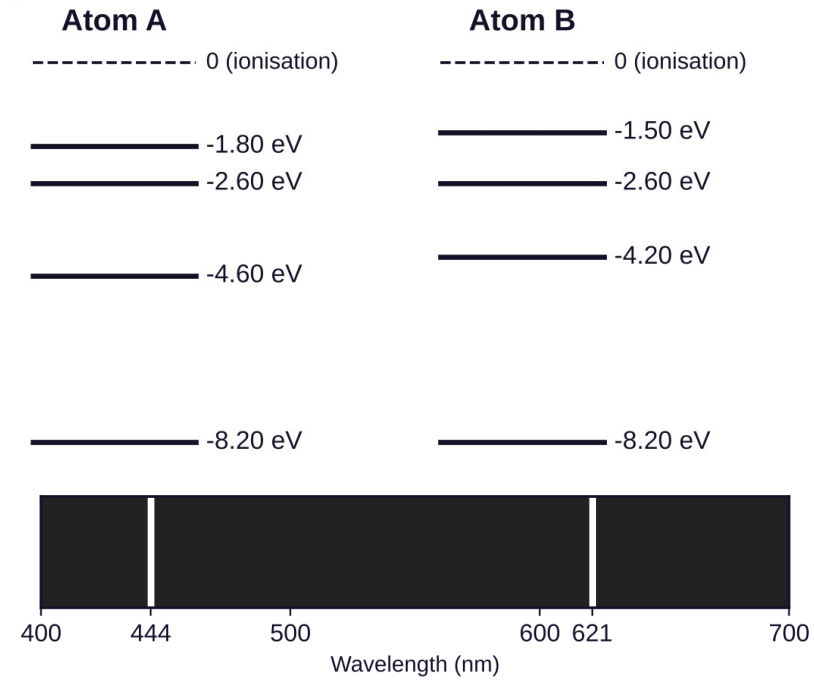
a) Describe how the shape of the curve changes as the temperature increases. **[2 marks]**

b) Explain how Planck's idea of quantised energy resolved the difference between the classical prediction and the measured curve at short wavelengths. **[2 marks]**

Question 16 · Which atom made this spectrum? Level 3 · 6 marks

A gas discharge tube produces a visible emission spectrum with lines at 444 nm and 621 nm only. The energy level diagrams for two possible atoms, A and B, are shown. Visible light is 400 nm to 700 nm.

Q16 Not to scale



a) Determine which atom is producing the spectrum. Show your working. **[4 marks]**

Atom = _____

b) Calculate the minimum frequency of a photon that could ionise this atom from its ground state. **[2 marks]**

Frequency = _____ Hz (to three significant figures)

Standard Model in *three ideas.*

1. Hadrons are made of quarks. Baryons: three quarks (baryon number +1). Mesons: a quark and an antiquark (baryon number 0). Add the quark charges to get the particle's charge.

2. Leptons never feel the strong force. Quarks feel strong, weak, electromagnetic and gravity. Charged leptons feel weak, electromagnetic and gravity. Neutrinos feel only weak and gravity.

3. Check every reaction three ways. Charge, baryon number and lepton number must all balance. Antileptons count −1. Only the weak interaction (W^+, W^-, Z) changes quark flavour. In reaction diagrams time runs left to right.

Question 17 · Reading quark content — Level 1 · 2 marks

The Ξ particle has quark content d s s. The K^0 particle has quark content d $\bar{s}$ (a down quark and an anti-strange quark). The down and strange quarks each have charge $-\frac{1}{3}e$.

Determine the charge of each particle, and classify each as a baryon or a meson. **[2 marks]**

Ξ: charge _____ type _____ K^0: charge _____ type _____

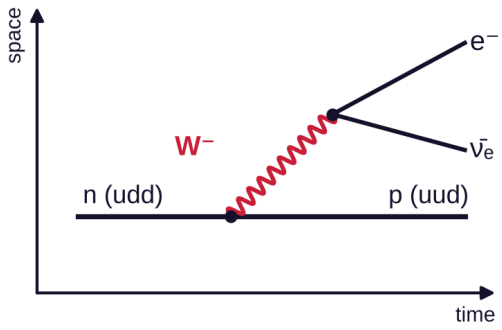
Question 18 · Contrast quarks and leptons — Level 2 · 3 marks

Quarks and leptons are both elementary particles in the Standard Model.

Contrast quarks and leptons in terms of the fundamental interactions each can experience. **[3 marks]**

Question 19 · Neutron decay diagram — Level 2 · 3 marks

The reaction diagram represents the decay of a free neutron into a proton, an electron and an electron antineutrino.



a) Describe the interaction shown, including the change at the quark level and the exchange particle. **[2 marks]**

b) Show that lepton number is conserved in this decay. **[1 mark]**

Exam technique in *three ideas.*

1. Marks follow a pattern. 1 mark for recognising the physics (name the law or write the formula), 1 or more for mathematical reasoning (substitution and rearranging), 1 for the answer with units.

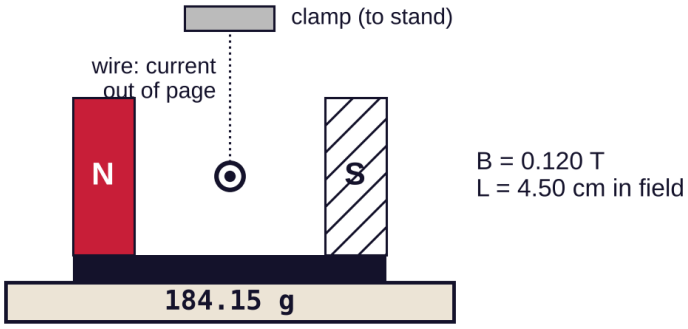
2. Explain = cause, physics, effect. Say what changes, name the law that links it, then state the result. One idea per sentence. A labelled diagram can earn marks too.

3. Unfamiliar? Break it into familiar steps. Write down every quantity given, decide which topic each one belongs to, and chain the formulas. The answer of one step is the input of the next.

Question 20 · Wire on a balance — Level 2 · 5 marks

A U-shaped magnet sits on an electronic balance. A horizontal straight wire, held by a clamp that does not touch the magnet, passes between the poles perpendicular to the field, with 4.50 cm of wire in the 0.120 T field. With no current, the balance reads 182.40 g. When a current flows, the reading rises to 184.15 g.

Q20 Not to scale



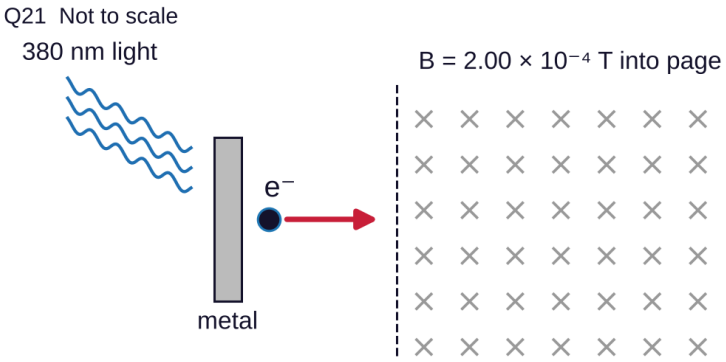
a) Explain why the balance reading increases when the current flows. **[2 marks]**

b) Determine the current in the wire. Show your working. **[3 marks]**

Current = _____ A (to three significant figures)

Question 21 · Photoelectron in a magnetic field — Level 3 · 7 marks

Light of wavelength 380 nm falls on a metal surface with a work function of 2.40 eV. The fastest photoelectrons emitted travel to the right into a uniform 2.00×10^{-4} T magnetic field directed into the page, perpendicular to their velocity.



a) Determine the maximum radius of the photoelectrons' circular path in the field. Show your working. **[5 marks]**

Radius = _____ m (to three significant figures)

b) Determine whether the photoelectrons curve towards the top or the bottom of the page. Justify your answer. **[2 marks]**