INTO QUALIFICATIONS

IQM3013 Physics

Assessment 3 Paper 2

Candidate question paper

Duration: 2 hours

Total marks: 85

Do not open this paper until instructed. Record every answer in the separate answer booklet.

Instructions

- Answer all questions.
- Section A multiple-choice questions come first. Record the selected option in the separate answer booklet.
- Write all extended responses in the separate answer booklet and identify each question clearly.
- A scientific, non-programmable, non-graphing calculator may be used.
- Use the supplied Physics Data and Formulae Booklet.
- Show all working where relevant.
- No AI is permitted.
- The mark allocation is shown beside each question.

Answer all 25 Section A multiple-choice questions and all six Section B questions.
Record answers in the separate answer booklet, identifying A1–A25 and every Section B part clearly.
Choose one option A–D for each multiple-choice question.
Use the supplied Physics Data and Formulae Booklet and a permitted non-programmable, non-graphing scientific calculator.
No candidate-provided materials, AI, internet or unauthorised electronic assistance are permitted.
Show relevant working, units and suitable significant figures.

Section A • Multiple-choice questions

Answer all 25 multiple-choice questions. 25 marks.

Question A1: Two positive point charges are isolated in vacuum. Their separation doubles. What happens to the magnitude of the force between them? 1
A. It doubles.
B. It halves.
C. It becomes one quarter.
D. It becomes four times larger.

Question A2: Which statement describes the electric field lines around an isolated negative point charge? 1
A. They point radially inwards.
B. They form closed circles.
C. They point radially outwards.
D. They are parallel and equally spaced everywhere.

Question A3: A positive charge of 2.0 μC experiences a force of 0.012 N in a uniform electric field. What is the field strength? 1
A. 2.4×10^{-8} N C^{-1}
B. 6.0×10^{-5} N C^{-1}
C. 1.7×10^{-4} N C^{-1}
D. 6.0×10^{3} N C^{-1}

Question A4: An electron enters a uniform electric field with initial velocity perpendicular to the field. Ignoring gravity, what is its path within the field? 1
A. A straight line parallel to the field
B. A parabola
C. A circle at constant speed
D. A straight line opposite to the field

Question A5: A plane coil is in a uniform magnetic field. When is the magnitude of flux through the coil greatest? 1
A. The field is parallel to the plane.
B. The normal makes 45° with the field.
C. The normal is perpendicular to the field.
D. The field is perpendicular to the plane.

Question A6: A charged particle moves parallel to a uniform magnetic field. What is the magnetic force on it? 1
A. Bqv
B. Zero
C. Bqv^2
D. Bq/v

Question A7: A proton moves to the right in a magnetic field directed into the page. What is the direction of the magnetic force? 1
A. Up the page
B. Down the page
C. Out of the page
D. To the left

Question A8: Viewed from above, conventional current in a straight vertical wire flows towards the observer. What is the field direction around the wire? 1
A. Radially away from the wire
B. Clockwise
C. Anticlockwise
D. Parallel to the current

Question A9: Why does an ideal transformer require a changing primary current? 1
A. A changing current produces changing magnetic flux linking the secondary.
B. A constant current has no magnetic field.
C. Electrons must cross from the primary wire to the secondary wire.
D. A changing current eliminates all resistance.

Question A10: An ideal transformer has 500 primary turns and 100 secondary turns. The primary rms voltage is 20 V. What is the secondary rms voltage? 1
A. 100 V
B. 0.20 V
C. 10 V
D. 4.0 V

Question A11: Lenz’s law states that the direction of an induced current is such that its magnetic effect does what? 1
A. Always increases the original field
B. Opposes the change producing it
C. Always cancels the original field completely
D. Always points north

Question A12: A stationary coil is in a uniform magnetic field that remains constant in magnitude and direction. Its area and orientation are fixed. What is the induced emf? 1
A. It rises with time.
B. It equals BA.
C. It is zero.
D. It equals the number of turns.

Question A13: Which pair correctly describes an alpha particle? 1
A. Charge −e; mass approximately one electron mass
B. No charge; zero rest mass
C. Charge +e; mass approximately one nucleon mass
D. Charge +2e; mass approximately four nucleon masses

Question A14: Which interaction provides the short-range attraction that binds protons and neutrons in a nucleus? 1
A. The strong nuclear interaction
B. Electrostatic repulsion
C. Friction
D. The magnetic force on moving electrons

Question A15: A sample initially contains N radioactive nuclei. After three half-lives, how many of these nuclei remain undecayed on average? 1
A. N/3
B. N/6
C. N/8
D. 7N/8

Question A16: A sample contains 2.0×10^{8} radioactive nuclei with decay constant 3.0×10^{-5} s^{-1}. What is its activity? 1
A. 1.5×10^{-13} Bq
B. 6.0×10^{3} Bq
C. 6.7×10^{12} Bq
D. 6.0×10^{-3} Bq

Question A17: What is nuclear mass defect? 1
A. The mass of electrons removed from an atom
B. The mass lost because a nucleus is moving
C. The difference between proton mass and neutron mass
D. The sum of the free constituent nucleon masses minus the nuclear mass

Question A18: A fusion reaction produces nuclei with greater binding energy per nucleon than the reactants. Which statement explains the energy released? 1
A. The products have a greater total rest mass.
B. Electric charge is destroyed.
C. The products have a smaller total rest mass.
D. The nucleons cease to exist.

Question A19: In beta-minus decay, what happens to the parent nucleus's proton number Z and nucleon number A? 1
A. Z increases by 1; A is unchanged.
B. Z decreases by 1; A is unchanged.
C. Z increases by 1; A increases by 1.
D. Z is unchanged; A decreases by 1.

Question A20: Which property is unchanged when an excited nucleus emits a gamma photon? 1
A. Its internal energy
B. Its proton number and nucleon number
C. Its total energy
D. Its excitation state

Question A21: Two photons have frequencies f and 2f. What is the ratio of their energies E(2f)/E(f)? 1
A. 1/2
B. 1
C. 2
D. 4

Question A22: What is one electron volt? 1
A. The energy gained by an electron moving through a potential difference of one volt
B. The charge on an electron
C. One volt per electron
D. The energy of every visible photon

Question A23: Light below the threshold frequency shines on a clean metal surface. Within the single-photon model, what happens if only the intensity increases? 1
A. Electrons are emitted after enough energy accumulates.
B. The work function decreases.
C. Maximum electron kinetic energy increases.
D. No photoelectrons are emitted.

Question A24: At fixed frequency above threshold, light intensity increases. The collection potential is sufficient to collect every emitted photoelectron. What increases? 1
A. The work function
B. The saturation photocurrent
C. The maximum photoelectron kinetic energy
D. The threshold frequency

Question A25: Why does an isolated gas of one element produce discrete emission lines? 1
A. Its electrons may have every possible energy.
B. All transitions emit the same photon energy.
C. Its allowed electronic energy differences are discrete.
D. Its photons slow down by different amounts.

Section B · Extended-response questions

Answer all 6 extended-response questions. 60 marks.

Question B1: Electric forces and acceleration — 10

Two positive point charges, +2.0 nC and +3.0 nC, are separated by 0.10 m in vacuum. Use Coulomb constant $k = 8.99 \times 10^{9}$ N m² C⁻². In a separate apparatus, parallel plates have a potential difference of 600 V and separation 0.020 m. Ignore edge effects. An electron is released from rest at the negative plate and reaches the positive plate without collision. Use elementary charge $e = 1.60 \times 10^{-19}$ C and electron mass $m = 9.11 \times 10^{-31}$ kg.

(a) Calculate the magnitude of the force between the point charges and state whether it is attractive or repulsive. [3]

(b) Calculate the electric field strength between the plates and state its direction. [2]

(c) Calculate the electron’s kinetic energy on arrival, in joules, and its speed. Assume non-relativistic motion. [3]

(d) A learner says that the electron accelerates in the direction of the electric field because F = qE. Evaluate this statement. [2]

Question B2: Motion in a magnetic field — 10

A proton enters a uniform magnetic field of flux density 0.20 T with speed 3.0×10^{6} m s⁻¹ perpendicular to the field. Use proton mass 1.67×10^{-27} kg and charge $+1.60 \times 10^{-19}$ C. Ignore gravity and electric fields.

(a) Calculate the magnitude of the magnetic force. [2]

(b) Explain why the proton follows a circular path at constant speed. [3]

(c) Calculate the radius of the path. [3]

(d) A second proton enters the same field at twice the speed, still perpendicular to it. Determine the new radius and explain your result. [2]

Question B3: Flux linkage and a transformer 10

A coil has 200 turns, each of area 4.0×10^{-4} m². A uniform field is perpendicular to the plane of the coil and decreases uniformly from 0.50 T to zero in 0.020 s. Separately, an ideal transformer has 1000 primary turns and 100 secondary turns. Its primary rms voltage is 120 V and its secondary rms current is 2.0 A.

(a) Calculate the initial magnetic flux through one turn and the initial flux linkage of the coil. [3]

(b) Calculate the magnitude of the induced emf during the field decrease. [2]

(c) Explain the direction of the magnetic field produced by the induced current if the coil forms a closed conducting circuit. [2]

(d) Calculate the transformer’s secondary rms voltage and primary rms current. [3]

Question B4: Radioactive decay measurements 10

A detector measures an initial total count rate of 820 counts per minute from a fixed radioactive source and background. The background alone is 20 counts per minute and is constant. After 18.0 minutes the total count rate is 120 counts per minute. Detector geometry and efficiency are unchanged. The source contains one radioactive isotope. Treat the stated rates as mean rates and neglect dead time.

(a) Define half-life. [1]

(b) Use the count rates to calculate the half-life of the isotope. [3]

(c) Calculate the decay constant in s^{-1}. [2]

(d) Evaluate a proposal to estimate the half-life directly from the uncorrected total rates. State the direction of the resulting error. [2]

(e) State two measures that reduce external radiation exposure when handling a sealed source. [2]

Question B5: Nuclear binding and decay 10

For a helium-4 nucleus use proton mass 1.00728 u, neutron mass 1.00866 u and nuclear mass 4.00151 u. Use 1 u = 1.66054×10^{-27} kg, c = 3.00×10^{8} m s^{-1} and 1 MeV = 1.60×10^{-13} J. A separate nucleus of uranium-238 has proton number 92 and undergoes alpha decay.

(a) Calculate the helium-4 nucleus's mass defect in u and in kg. [3]

(b) Calculate its total binding energy in MeV and binding energy per nucleon in MeV. [3]

(c) State the proton number and nucleon number of the daughter nucleus produced by the uranium alpha decay. [2]

(d) A learner claims that a nucleus with greater binding energy per nucleon can never decay. Evaluate the claim. [2]

Question B6: Photoelectrons and discrete energy levels 10

Light of frequency 8.0×10^{14} Hz illuminates a metal of work function 2.0 eV. Use h = 6.63×10^{-34} J s, 1 eV = 1.60×10^{-19} J and c = 3.00×10^{8} m s^{-1}. In a separate isolated atom, two permitted electron energy levels are −2.0 eV and −5.0 eV.

(a) Calculate the incident photon energy in joules and the maximum photoelectron kinetic energy in joules. [3]

(b) Calculate the threshold frequency of the metal. [2]

(c) An electron in the atom moves from −2.0 eV to −5.0 eV. State whether a photon is emitted or absorbed and calculate its wavelength. [3]

(d) Explain why the observation of a threshold frequency supports the photon model of light. [2]