PRIFYSGOL ABERYSTWYTH UNIVERSITY

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DEPARTMENT OF PHYSICS

SEMESTER 2 EXAMINATIONS, MAY 2026

PH11120 – Electricity Magnetism and Matter

Time allowed – 3 hours

- **Full marks can be attained for complete answers to ALL eight questions in Section A and TWO questions from Section B**
- **The numbers in brackets after the questions indicate the allocation of marks for each question.**
- **Only calculators from the Casio FX83, FX85 or FX991 range may be used.**
- **A booklet of mathematical formulae and standard constants will be provided.**
- **MAE MODD I FYFYRWYR GYFLWYNO ATEBION I'R PAPUR HWN NAILL AI YN Y GYMRAEG NEU'R SAESNEG**
- **STUDENTS MAY SUBMIT ANSWERS TO THIS PAPER IN EITHER WELSH OR ENGLISH**

Once seated, students may complete the front cover of the answer book(s) and the attendance slip ONLY.

DO NOT TURN THE EXAMINATION QUESTION PAPER OVER UNTIL INSTRUCTED TO DO SO.

Section A

Attempt ALL questions in the booklet provided

1 For each of the five situations, state one material from the following list which would be most suitable: gold, germanium, plastic, iron, niobium. [5]

i. The core of an efficient transformer

ii. An insulated casing for an integrated circuit

iii. An electrical conductor in an integrated circuit

iv. A semiconductor for an integrated circuit

v. A superconductor to generate the magnetic field for a Tokamak reactor

2 Suggest arrangements for connecting four 2 kΩ resistors to give an equivalent resistance of 0.5 kΩ, 2 kΩ, and 5 kΩ. All four resistors must be used in each case. [5]

3 The mass of the Hubble spacecraft is 1.11 x 10^4 kg. Determine the weight of the spacecraft in an orbit which is 560 km above the Earth's surface. The mass of the Earth is 5.972 x 10^{24} kg, the radius of the Earth is 6370 km and the gravitational constant is 6.67 x 10^{-11} $m^3kg^{-1}s^{-2}$. [5]

4 Give the fundamental SI units for each term in the equation below that connects energy (E), potential (V), momentum (p) and mass (m). [5]

$$E = Vm + \frac{p^2}{2m}$$

5 A solenoid consists of 100 turns of conducting wire around a cylindrical core of length 2 cm and cross-sectional area 10 mm^2. Draw a diagram of the magnetic field and calculate the magnetic flux density at the centre of the solenoid when there is a direct current of 10 A in the wire. The permeability of the core is 1.26 x 10^{-7} Hm^{-1}. and the flux density at the centre of the solenoid, in the usual notation, $B = \frac{\mu n I}{l}$. [5]

6 The star Sirius A has a mass of 2.06 $M_\odot$ and a radius of 1.71 $R_\odot$ ($M_\odot$ is the mass of the Sun (1.988 x 10^{30} kg) and $R_\odot$ is the radius of the Sun (6.96 x 10^5 km)). Sketch the gravitational potential around Sirius A, which a hydrogen particle would experience at distances where r is greater than the radius of Sirius A. Calculate the gravitational potential energy of the particle-star system when the hydrogen particle has reached a distance of 10 $R_\odot$. The mass of a hydrogen atom is 1.674 x 10^{-27} kg, the gravitational constant is 6.67 x 10^{-11} $m^3kg^{-1}s^{-2}$ and the gravitational potential due to a spherical mass, in the usual notation, $V = \frac{GM}{r}$. [5]

7 Considering the conservation laws, state why the following reactions are forbidden. [5]

i. $\nu_\mu + p \rightarrow \mu^- + n$

ii. $\Lambda \rightarrow \pi^+ + e^- + \overline{\nu_e}$

iii. $K^+ \rightarrow \pi^0 + \mu^- + \nu_\mu$

iv. $e^- + p \rightarrow p + e^+$

v. $K^- \rightarrow \pi^- + \pi^+$

8 Considering the constituent quarks and conservation laws, determine the missing particle in the interaction: $K^- + ? \rightarrow \Lambda_S^0 + \pi^-$ [5]

Section B

Answer TWO questions

9 A parallel plate capacitor is made from two metal plates of area 0.1 m^2, separated by an insulator of relative permittivity, 1.5 and thickness, 2 mm.

a) Sketch the electrostatic field between the plates when the capacitor is connected to a d.c. voltage source of 12 V.

[5]

b) Using Gauss' law, show that the electrostatic field at the centre of the plate is given, in the usual notation, by, $E = \frac{\sigma}{\varepsilon_r \varepsilon_0}$.

[5]

c) Derive an equation for the capacitance of the capacitor and calculate its value. Take the permittivity of free space to be 8.85 x 10^{-12} Fm^{-1}.

[5]

d) Calculate the charge and energy stored and suggest methods for increasing this.

[5]

10 A rectangular coil of area 0.1 m^2 and 100 turns is rotated with a frequency, f = 50 Hz in a uniform magnetic field of flux density, B = 0.1 T. The axis of rotation is perpendicular to the magnetic field.

a) Using Faraday's law, describe how this coil can be used as an alternating voltage source.

[5]

b) Derive an equation for the variation of voltage with time and calculate the root mean square voltage.

[5]

c) If this voltage source is connected to a circuit containing two components in series, Z_1 = 20 + j150 Ω and Z_2 = 30 – j100 Ω, calculate the equivalent impedance.

[5]

d) Calculate the root mean square current and the average power in this circuit.

[5]

11 There are three stable natural isotopes of magnesium: ^{24}Mg, ^{25}Mg, and ^{26}Mg, with relative abundances on Earth of 79%, 10%, and 11% respectively. The atomic number of magnesium is 12.

a) Describe what is meant by an *isotope* with reference to atomic and mass numbers. Determine the number of protons and neutrons for each of the three stable isotopes of magnesium.

[5]

b) A magnesium–24 nucleus can be considered as nucleons uniformly distributed in a spherical volume. Calculate the energy required to construct a uniformly charged sphere, using the equation, $\mathrm{U} = \frac{3\mathrm{Q}^2}{20\pi\varepsilon_0\mathrm{R}}$. (Q is the total charge and R is the radius, in the usual notation, $\mathrm{R} = \alpha\mathrm{A}^{1/3} = 1.2 \times 10^{-15} \times \mathrm{A}^{1/3}\ fm$.)

[5]

c) Calculate the binding energy (in eV) of magnesium-24, which has an atomic mass of 23.9850 amu. The mass of a neutron is 1.0087 amu and the mass of a proton is 1.0073 amu. (1 amu = 931.494 MeV.)

[5]

d) The radioisotope of magnesium with the longest half-life is magnesium–28, with a half-life of 20.9 hrs. Magnesium–28 decays, through β^- decay, into aluminium–28. With reference to fundamental particles, describe the process of beta-minus decay. Hence determine the equation for the decay of magnesium-28 into aluminium-28.

[5]

END OF PAPER