**Option B — Quantum Physics and Nuclear Physics**

**B1.** This question is about photoelectric emission.

A piece of metal is placed in an evacuated container. Light of wavelength 444 nm is incident on the surface of the metal. The surface has a work function of 4.60 eV.

(a) (i) Calculate the energy, in joule, of a photon of light of wavelength 444 nm. *[1]*

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(ii) Deduce whether photoelectric emission of electrons will occur. *[3]*

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(b) The wavelength of the light incident on the surface is now reduced to 222 nm. State and explain why electrons having a range of kinetic energy from zero to approximately 1.0 eV will be emitted. *[4]*

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**B2.** This question is about radioactive decay.

A cobalt-60 nucleus decays with the emission of a $\beta^-$ -particle to form a nucleus of nickel-60. The nickel nucleus then decays with the emission of two $\gamma$-ray photons of energies 1.17 MeV and 1.33 MeV.

(a) Explain why the decay of nickel-60 leads to the conclusion that atomic nuclei have discrete energy levels. *[2]*

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(b) A fresh sample of cobalt-60 contains $N_0$ cobalt nuclei. Initially, there are no nickel-60 nuclei in the sample. After 3.0 years, the ratio

$$\frac{\text{number of nickel-60 nuclei}}{\text{number of cobalt-60 nuclei}}$$

is $\frac{1}{2}$.

(i) Deduce that the number of cobalt-60 nuclei remaining after 3.0 years is $\frac{2}{3}N_0$ *[2]*

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(ii) Calculate the half-life of cobalt-60. *[3]*

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**B3.** This question is about fundamental particles.

Particle production and annihilation are subject to conservation laws. Two of these laws are conservation of mass-energy and conservation of momentum.

(a) State the names of **three** other conservation laws. *[3]*

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2. . . . . .

3. . . . . .

(b) Free neutrons are unstable. A neutron may decay to become a proton with the emission of an electron. A student represents the decay by the following equation.

$$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$$

(i) State, by reference to conservation laws, why the student's equation is not correct. *[1]*

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(ii) Write down the correct decay equation. *[1]*

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