$\phi + \frac{1}{2}mv^2 = hf$

$hf =$

$\frac{1}{2}mv^2 = \frac{q q_2}{4\pi\epsilon_0 r}$

PART B

The questions in this part relate to Unit 13.

Q5 [*Photoelectric effect*] When monochromatic light of wavelength 400 nm falls on a piece of metallic foil, it is observed that photoelectrons are emitted with kinetic energies ranging from 0 to 3×10^{-19} J. Estimate the threshold frequency for the emission of photoelectrons from this metal. Choose from the key the *one* response that is closest to the correct answer, and pencil across *one* cell in row 5.

$W = hf = \frac{hc}{\lambda}$

KEY for Q5

A 3×10^{15} Hz

B 2×10^{14} Hz

C 7×10^{15} Hz

D 4×10^{15} Hz

E 7×10^{14} Hz

F 3×10^{14} Hz

G This question cannot be answered because the work function of the metal is not specified.

3E-19 = 6.6E-34×3E8/4E-7

Q6 [*Early atomic models*] Which *two* of the following statements concerning the Thomson and Rutherford models of the atom are correct? Pencil across *two* cells in row 6.

$\phi = hf - \frac{1}{2}mv^2$

KEY for Q6

A The uniform sphere of positive charge in Thomson's model of the atom has a diameter of about 10^{-15} m.

B The Rutherford model of an atom cannot explain why the typical radius of an atom is about 10^{-10} m.

C The Thomson model predicts that an electron in an atom has one of a number of discrete energies.

D In the Thomson model, the positive and negative charges associated with an atom are uniformly spread through the sphere with a radius equal to that of the atom.

E The Rutherford atom successfully accounts for the stability of electron orbits.

F When an α-particle is fired head-on towards a stationary nucleus in the Rutherford model, the distance of closest approach r_{cl} of the α-particle is inversely proportional to the square of the magnitude of its momentum (i.e. $r_{cl} \propto p^{-2}$).

G According to ideas based on Thomson's model of the atom, it is absolutely impossible for any high energy α-particle incident perpendicularly on a gold foil 10^{-5} m thick to be scattered through more than 90°.

Q7 [*Bohr model*] An electron in a Bohr hydrogen atom undergoes a transition from the $n = 5$ to $n = 4$ orbit. Choose from A–D in the key the response closest to the ratio r_5/r_4 of the radii of the initial and final orbits, and from E–H the response closest to the energy of the photon emitted. Pencil across *two* cells in row 7.

KEY for Q7

13.6/

A 0.64

B 0.8

C 1.25

D 1.56

E 0.68 eV

F 0.31 eV

G 0.35 eV

H 0.67 eV

$\frac{mv^2}{r} = \frac{e^2}{4\pi\epsilon_0 r^2}$

$r = \frac{e^2}{4\pi\epsilon_0 mv^2}$

Q8 [*X-ray emission*] The X-ray spectrum of the fictional material, nullium, is capable of exhibiting up to 8 characteristic lines at wavelengths ~~0.015~~ nm, 0.030 nm, 0.040 nm, 0.043 nm, 0.051 nm, 0.060 nm, 0.065 nm and 0.070 nm. Choose from the key the number of lines that would be present in the X-ray spectrum emitted by a nullium target in an X-ray tube with an accelerating voltage of 30 kV. Pencil across *one* cell in row 8.

KEY for Q8

$E = hf = \frac{hc}{\lambda} = 1.33E-1$

A 0

B 1

C 2

D 3

E 4

F 5

G 6

H 7

E = 4.8E-15

E = 30E3×1.6E-19

$hf = \frac{hc}{\lambda} = 4.8E-15$

$\lambda = \frac{hc}{4.8E-15}$

$\frac{1}{2}mv^2 = \frac{Q_1 Q_2}{4\pi\epsilon_0 r}$

$\lambda_1 - \lambda_0 = h/mc(1-\cos\theta)$

$r = q_1 q_2 / 2\pi\epsilon_0 mv^2$

PART C

The questions in this part relate to Unit 14.

Q9 [*Compton effect*] In a Compton effect experiment, an X-ray photon from electromagnetic radiation of wavelength 3.5×10^{-3} nm collides with a stationary free electron and as a result is scattered by an angle of 45° relative to its initial direction. What is the wavelength of the scattered X-ray? Choose the *one* response from the key that is closest to the correct answer, and pencil across *one* cell in row 9.

KEY for Q9

A 0.0011 nm

B 0.011 nm

C 0.0028 nm

D 0.028 nm

E 0.0042 nm

F 0.042 nm

G 0.0059 nm

H 0.059 nm

$E = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

Q10 [*de Broglie waves*] The statements in the key are related to the de Broglie relation and to the wave-like behaviour of particles. Select the two *correct* statements from the key, and pencil across *two* cells in row 10.

KEY for Q10

A The relation $\lambda = h/p$ applies to photons and X-rays, but not to particles having rest mass, such as protons.

B The magnitude of the momentum of a grain of sand, of mass 1.00×10^{-6} kg, blown in the wind at 20 m s^{-1} is approximately 10^{17} times larger than the momentum of a photon with associated wavelength 3.32×10^{-12} m.

$\lambda = \frac{h}{p}$

$p = \frac{h}{\lambda}$

C The amplitude of the de Broglie wave for an electron in a given region is directly proportional to the probability of detecting the electron in that region.

D If the kinetic energy of an electron is halved, its de Broglie wavelength is doubled.

E In a two-slit electron diffraction experiment quantum mechanics enables us to predict the probability of detecting the electron in a given region of the screen.

F In a two-slit electron diffraction experiment, if one slit is blocked, the electron intensity is reduced by a factor of two at all regions of the screen.

G If electrons are fired at a double slit, it is impossible to determine which slit each electron passes through.