The University Of Sheffield.

DEPARTMENT OF PHYSICS AND ASTRONOMY

Data provided*:*
Linear:linear graph paper.
A formula sheet and table of physical constants is attached to this paper.

Spring Semester 2010-2011

PHYSICS **3 HOURS**

Answer questions ONE, FOUR and SEVEN plus ONE other from each section, 6 in all.

Answers to different sections must be written in ***separate books,*** *the books tied together and handed in as one.*

All questions are marked out of twenty. The breakdown on the right-hand side of the paper is meant as a guide to the marks that can be obtained from each part.

SECTION A

1. COMPULSORY

(a) A oil-drop, mass 3.8×10^{-13} kg, is held stationary between two parallel plates 20 mm apart with a potential difference of 800 V between them. Calculate the magnitude of the charge on the drop. [2]

(b) Calculate the speed of a proton if its de Broglie wavelength is 2.0×10^{-11} m. [2]

(c) A hydrogen atom has energy levels (in J) given by

$$E_n = -\frac{2.18 \times 10^{-18}}{n^2} \qquad \text{where } n \text{ is an integer, } n \geq 1.$$

For an electronic transition from the $n = 3$ state to the ground state, calculate

(i) the energy change of the electron, [2]

(ii) the wavelength of the photon emitted. [2]

(d) (i) Sketch an intensity / wavelength graph illustrating a typical spectrum for X-rays emitted by a tube with a tungsten target (numerical values are NOT required). [2]

(ii) State how the spectrum would change if a higher value of tube potential difference were used. [2]

(e) State the nucleon composition of an alpha particle. [2]

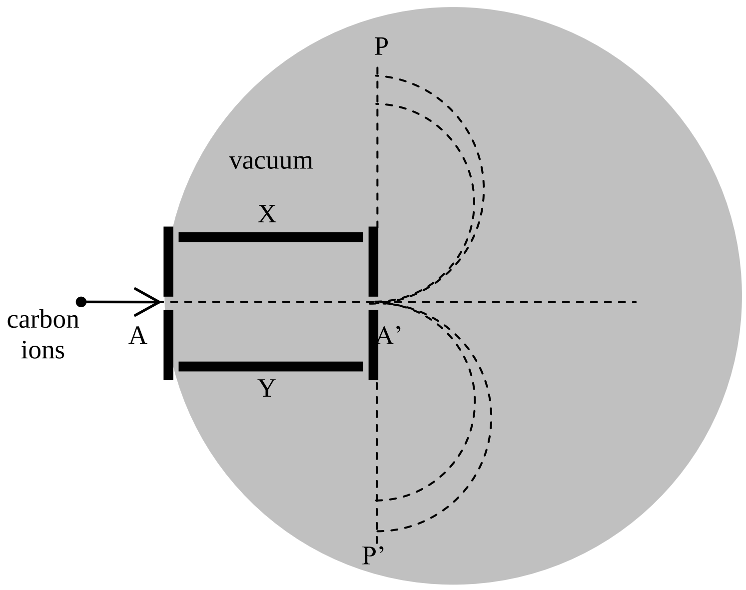
(f) (i) Explain what is meant by *nuclear fusion*. [2]

(ii) In terms of the forces between nuclei, explain why the fusion of two nuclei can only occur at high energies. [2]

(iii) In terms of nuclear masses, explain why energy is released in a fusion reaction. [2]

2.

(a) In the mass spectrometer illustrated, a uniform electric field is produced in a vacuum by applying a potential difference (V) between the horizontal, parallel plates X and Y. A uniform magnetic field (B = 120 mT) is applied to the shaded area perpendicular to and INTO the paper.



A beam of singly ionised carbon ions enters the apparatus at A, in the direction shown.

(i) State the direction of the magnetic force on the ions as they enter the shaded region. [1]

(ii) State which of the two plates, X or Y, must be at the higher electrical potential if carbon ions are to experience an electrical force in the opposite direction to the magnetic force. [1]

(iii) The p.d. between plates X and Y is 2000 V, and the distance between X and Y is 40 mm. Show that the speed of the carbon ions that pass through A and travel along the straight line to exit at A' is approximately 4×10^{5} m s^{-1}. [2]

(iv) Beyond A' the ions are in the magnetic field only, and follow one of the semicircular paths as shown in the diagram. Calculate the radius of the circular path, given that their mass is 1.99×10^{-26} kg. [4]

(v) The beam contains a second carbon isotope, mass 2.16×10^{-26} kg. Ions of both isotopes strike the line PP'. Calculate the separation of the points of contact on PP' of the two isotopes. [2]

(b) Photoelectrons are emitted by a metal surface when it is illuminated with monochromatic light from a lamp. Describe and explain the changes (if any) in the emission of photoelectrons when the frequency of the light is increased without changing the intensity of the source. [4]

(c) A potassium surface is illuminated by monochromatic light of wavelength 480 nm. The work function energy of potassium is 2.9×10^{-19} J. Calculate

(i) the frequency of the light, [1]

(ii) the maximum kinetic energy of the photoelectrons, [3]

(iii) the maximum speed of the photoelectrons. [2]

3.

(a) The equation

$$ {}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{55}^{138}Cs + {}_{Z}^{95}Rb + X({}_{0}^{1}n), $$

where Z and X are integers, represents the neutron induced fission of uranium-235.

(i) Determine the values of Z and X. [2]

(ii) Calculate the energy released per fission, given the following atomic masses. [4]

Atomic masses	^{235}U	235.044 u
	^{138}Cs	137.911 u
	^{95}Rb	94.929 u
Mass of neutron	${}_{0}^{1}n$	1.009 u

(b) The isotope ${}_{10}^{19}Ne$ is radioactive, decaying to an isotope of fluorine.

(i) Write a full equation for the decay process clearly identifying the particles involved. The proton number of fluorine is 9. [4]

(ii) The isotopes ${}_{10}^{20}Ne$, ${}_{10}^{21}Ne$ and ${}_{10}^{22}Ne$ are all stable. ${}_{10}^{23}Ne$ is radioactive. State, giving a reason, what type of radiation you might expect it to emit. [2]

(c) A radioactive source of ^{60}Co has an initial activity of 1.6 MBq and a half-life of 5.3 years. Calculate

(i) the decay constant of ^{60}Co, stating its units clearly, [2]

(ii) the time taken for the activity of the source to decrease to 0.4 MBq, [3]

(iii) the activity of the source 8 years after its production. [3]

SECTION B

4. COMPULSORY

(a) (i) Define simple harmonic motion (SHM). [2]

(ii) Sketch a graph showing the variation of acceleration with displacement for simple harmonic motion. [2]

(b) Explain what is meant by *resonance*, and give an example where its effects are undesirable. [3]

(c) An elastic cord, 2.0 m long with a mass of 35 g, is stretched between fixed points under a tension of 8.0 N. Calculate

(i) the speed of transverse vibrations along the cord, [2]

(ii) the frequency of the fundamental mode of vibration of the cord. [2]

(d) Explain, with the aid of a simple sketch, the difference between *transverse* and *longitudinal* waves. Give an example of each type of wave. [4]

(e) A diffraction grating has 6.0×10^5 lines per metre. Calculate the wavelength of the light that has a first-order diffraction image at 22°. [2]

(f) A diverging lens, focal length 10 cm, has an object placed 8 cm from its pole. Sketch a ray diagram showing the formation of the image and state the image characteristics. [3]

5.

(a) A mass of 0.40 kg is in equilibrium when hanging from a spring with an extension of 34.0 cm. The mass is displaced 2.0 cm below its equilibrium position and released.

(i) Calculate the elastic constant of the spring. [2]

(ii) Show that the period of oscillation of the mass/spring system is approximately 1.2 s. [2]

(iii) Giving approximate scales on the axes, sketch graphs of
1. displacement against time, and
2. velocity against time

for the first 2 seconds after the mass is released. [6]

(iv) Sketch a graph of kinetic energy against time, showing how the kinetic energy of the mass varies over one complete oscillation. [4]

(b) A glass block has refractive index 1.51.

(i) Light, in air, is incident on the glass with an angle of incidence of 40°. Calculate the angle of refraction. [2]

(ii) Calculate the critical angle for this glass block. [2]

(iii) Calculate the speed of light in the glass. [2]

6.

(a) Light of wavelength 590 nm is incident on a pair of parallel slits whose centres are 0.85 mm apart. Interference fringes are produced on a screen 1.2 m away from the slits. Calculate

(i) the spacing of the bright interference fringes on the screen. [4]

(ii) the number of bright fringes that will be visible in the central part of the interference pattern, given that each slit is 0.060 mm wide. [2]

(b) A converging lens, focal length 20 cm, produces an upright, magnified image with a transverse (linear) magnification of 3.0.

(i) Sketch a simple ray diagram showing how this image is formed. [2]

(ii) Calculate the distance between the object and pole of the lens. [2]

(c) The following pairs of values of object distance (u) and image distance (v) are obtained in an investigation to determine the focal length of a converging lens.

u / cm	20.0	24.0	28.0	32.0	36.0
v / cm	59.6	40.3	32.3	28.0	25.1

Using a graphical method, calculate the focal length of the lens. [10]

SECTION C

7. COMPULSORY

(a) The molar mass of the iron isotope ^{56}Fe is 55.935 g mol^{-1}. Calculate

(i) the mass of one atom of ^{56}Fe. [2]

(ii) the number of atoms of ^{56}Fe per cm^3, given the density of iron is 8.9 g cm^{-3}. [2]

(b) A spherical droplet of oil is 0.2 mm in diameter. When placed on a water surface it spreads out into a circular oil patch 25 cm in diameter. Calculate the thickness of the oil patch, assuming it has uniform thickness. [4]

(c) Draw the unit cell for the face-centred cubic (fcc) crystal structure. [2]

(d) A rubber cord has a rectangular cross-section 5.0 mm x 2.0 mm. Calculate the tensile stress when the tension in the band is 5.0 N. [3]

(e) Distinguish between *plastic* and *elastic* deformation of a solid. [3]

(f) The resistivity of copper is $1.68 \times 10^{-8}\ \Omega$ m. Calculate the conductivity of copper. [2]

(g) State the majority carriers in a p-type semiconductor. [2]

8.

(a) A platinum rod has a length of 1.20 m at 0°C. Its length increases by 1.1 mm when it is heated to a uniform temperature of 100°C. Calculate the coefficient of linear expansivity of platinum. [4]

(b) Define the Young modulus of a solid. [2]

(c) A steel wire has a circular cross-section of 0.37 mm diameter and a length of 2.3 m. The wire is fixed vertically and has an extension of 2.4 mm when the wire supports a load of 2.5 kg. Calculate

(i) the tension in the wire, [2]

(ii) the cross-sectional area of the wire, [2]

(iii) the stress in the wire, [2]

(iv) the strain in the wire, [2]

(v) the Young modulus of steel, [3]

(vi) the energy stored in the stretched wire. [3]

9.

(a) (i) Sketch a labelled graph showing the variation of interatomic potential energy E_p as a function of atomic separation (r). Label the point on the r-axis corresponding to the equilibrium separation (r_0) of the atoms. [5]

(ii) Use the graph to explain, in terms of atomic behaviour, the expansion of solids with increased temperature. [3]

(b) (i) Calculate the drift speed of electrons in a copper wire of diameter 2.5 mm^2 when carrying a current of 3.0 A. The number density of conduction electrons in copper is 1.0×10^{29} m^{-3}. [4]

(ii) Explain, in terms of atomic behaviour, why the resistivity of copper increases with increased temperature. [2]

(c) Explain, using a labelled energy band diagram, what is meant by an *intrinsic semiconductor*. [6]

END OF QUESTION PAPER