**UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS**

General Certificate of Education Advanced Level

**PHYSICS**

Paper 4

**9702/04**

October/November 2005

**Answers**

1. The Earth may be considered to be a sphere of radius 6.4 × 106 m with its mass of

6.0 × 1024 kg concentrated at its centre.

A satellite of mass 650 kg is to be launched from the Equator and put into geostationary orbit

1. Show that the radius of the geostationary orbit is 4.2 × 107m.

**Solution**

$\frac{GM}{r^{2}} $= r$ω$2

$ω$ = $\frac{2π}{24 x 3600}$ = $\frac{2π}{86400}$ = 7.27 x 10-5 rad s-1

Gm = r3 $ω$2

6.67 x 10-11 x 6.0 x 1024 = r3 (7.27 x 10-5)2

R = $\sqrt[3]{\frac{6.67 x 10^{-11} x 6.0 x 10^{24}}{(7.27 x 10^{-5})^{2}}}$

 = 4.23 x 107 m

 **QED**

b. Determine the increase in gravitational potential energy of the satellite during its launch from the Earth’s surface to the geostationary orbit.

**Solution**

 $∆∅$ = $\frac{GM}{R\_{e}}$ - $\frac{GM}{R\_{o}}$

 = $\frac{6.67 x 10^{-11} x 6.0 x 10^{24}}{(6.4 x 10^{6})}$ - $\frac{6.67 x 10^{-11} x 6.0 x 10^{24}}{(4.2 x 10^{7})}$

= 5.3 x 107 J kg-1

ΔEp = 5.3 x 107 x Ms

 = 5.3 x 107 x 650

 = 3.445 x 1010 J

c. Suggest one advantage of launching satellites from the Equator in the direction of rotation of the Earth.

**Solution**

The satellites can accelerate easier due to geostationary gravity force.

1. The air in a car tyre has a constant volume of 3.1 × 10–2m3. The pressure of this air is 2.9 × 105Pa at a temperature of 17 °C. The air may be considered to be an ideal gas.

a. State what is meant by an *ideal* gas.

**Solution**

pV = k x T always valid at all values of P, V, and T

b. Calculate the amount of air, in mol, in the tyre.

**Solution**

 pV = k x T

 3.1 x 10-2 x p = 8.31 x 290 x k

 K = $\frac{3.1 x 10^{-2} x 2.9 x 10^{5}}{8.31 x 290}$ = $\frac{3100}{831}$ = 3.73 mol

1. The pressure in the tyre is to be increased using a pump. On each stroke of the pump, 0.012 mol of air is forced into the tyre.

Calculate the number of strokes of the pump required to increase the pressure to 3.4 × 105Pa at a temperature of 27 °C.

**Solution**

n2 = 3.73 x $\frac{3.4}{2.9}$ x $\frac{290}{300}$ = 4.23 mol

 Δn = 4.23 – 3.73 = 0.5 mol

 Strokes = $\frac{0.5}{0.012}$ = 41. 66 = 42 strokes

1. a. State the first law of thermodynamics in terms of the increase in internal energy

Δ*U*, the heating *q* of the system and the work *w* done on the system.

**Solution**

The change in the internal energy (ΔU) of a closed thermodynamic system is equal

to the sum of the amount of heat (q) energy supplied to the system and the work (w) done to the system.

ΔU = q - w

b. The volume occupied by 1.00 mol of liquid water at 100 °C is 1.87 × 10–5m3. When the water is vaporised at an atmospheric pressure of 1.03 × 105 Pa, the water vapour has a volume of 2.96 × 10–2m3.The latent heat required to vaporise 1.00 mol of water at 100 °C and 1.03 × 105 Pa is 4.05 × 104 J.

Determine, for this change of state,

(i) the work *w* done on the system,

**Solution**

w = p.ΔU

= 1.03 x 105 (2.96 x 10-2 – 1.87 x 10-5)

= 3046.87 J

= 3047 J

(ii) the heating *q* of the system,

**Solution**

q = latent heat = 4.05 x 104 J

(iii) the increase in internal energy Δ*U* of the system.

**Solution**

ΔU = 4.05 x 104 – 3047

 = 37,453 J

1. Using your answer to (b)(iii), estimate the binding energy per molecule in liquid water.

**Solution**

Number of molecules = 6.02 x 1023 (Avogadro’s number)

 E = $\frac{37,453}{6.02 x 10^{23}}$ = 6.2 x 10-20 J

1. The centre of the cone of a loudspeaker is oscillating with simple harmonic motion of

frequency 1400 Hz and amplitude 0.080 mm.

a. Calculate, to two significant figures,

(i) The angular frequency $ω$ of the oscillations,

**Solution**

 $ω$ = 2$π$f

= 2$π$ x 1400

= 8796.45 = 8800 rad s-1

(ii) the maximum acceleration, in m s–2, of the centre of the cone.

**Solution**

a = $ω$2 x am

= (8800)2 x 0.080 x 10-3

= 6200 m s-2

b. On the axes of Fig. 4.1, sketch a graph to show the variation with displacement *x* of the acceleration *a* of the centre of the cone.



**Solution**

c. (i) State the value of the displacement *x* at which the speed of the centre of the cone is a maximum.

**Solution**

v = max

 Displacement = 0 (zero)

(ii) Calculate, in m s–1, this maximum speed.

**Solution**

v = $ω$ x Amplitude

= 8800 x 0.080 x 10-3

= 0.7 m s-2

1. a. An electron is accelerated from rest in a vacuum through a potential difference of

1.2 × 104 V. Show that the final speed of the electron is 6.5 × 107ms–1.

**Solution**

 mv2 = 2qV

9.11 x 10-31 x v2 = 1.6 x 10-19 x 1.2 x 104 x 2

 V = $\sqrt{\frac{1.6 x 10^{-19} x 1.2 x 10^{4} x 2}{9.11 x 10^{-31}}}$

= 6.49 x 107 = 6.5 x 107 ms-1

b. (i) The accelerated electron now enters a region of uniform magnetic field acting into the plane of the paper, as illustrated in Fig. 5.1.

Describe the path of the electron as it passes through, and beyond, the region of the magnetic field. You may draw on Fig. 5.1 if you wish.

**Solution**

Within Field =

 Beyond Field =

(ii) State and explain the effect on the magnitude of the deflection of the electron in the magnetic field if, separately,

1. the potential difference accelerating the electron is reduced,

**Solution**

v is reduced

 Deflection increases

2. the magnetic field strength is increased.

**Solution**

Magnetic force increases

Deflection increases

1. a. Define *magnetic flux density*.

**Solution**

Magnetic flux density (B) = the amount of magnetic flux through a unit area taken

perpendicular to the direction of the magnetic flux.

b. A flat coil consists of *N* turns of wire and has area *A*. The coil is placed so that its plane is at an angle Ѳ to a uniform magnetic field of flux density *B*, as shown in Fig. 6.1.



Using the symbols *A*, *B*, *N* and Ѳ and making reference to the magnetic flux in the coil, derive an expression for the magnetic flux linkage through the coil.

**Solution**

Flux through coil = BA sin Ѳ

 Flux linkage = BAN sin Ѳ

c.(i) State Faraday’s law of electromagnetic induction.

**Solution**

Faraday’s Law of electromagnetic induction =

(1) An e.m.f. is induced in a conductor when the magnetic field surrounding it changes.

 (2) The magnitude of the e.m.f. is proportional to the rate of change of the field.

 (3) The sense of the induced e.m.f. depends on the direction of the rate of change

of the field.

(ii) The magnetic flux density *B* in the coil is now made to vary with time *t* as shown in Fig. 6.2.



On Fig. 6.3, sketch the variation with time *t* of the e.m.f. *E* induced in the coil.

1. a. Fig. 7.1 illustrates the variation with nucleon number *A* of the binding energy per

nucleon *E* of nuclei.

1. Explain what is meant by the *binding energy* of a nucleus.

**Solution**

Binding energy of a nucleus = the energy required to completely separate the

nucleons in a nucleus

(ii) On Fig. 7.1, mark with the letter S the region of the graph representing nuclei having the greatest stability.

 

S

b. Uranium-235 may undergo fission when bombarded by a neutron to produce Xenon-142 and Strontium-90 as shown below.



1. Determine the number of neutrons produced in this fission reaction.

**Solution**

Left hand side

Number of neutrons present in Uranium-235 = 235 – 92 = 143 neutrons

 Total number of neutrons in left side = 143 + 1 = 144 neutrons

 Right hand side

Number of neutrons present in Xenon-142 = 142 – 54 = 88 neutrons

 Number of neutrons present in Srontium-90 = 90 - 38 = 52 neutrons

Total number of neutrons in right side = 88 + 52 = 140 neutrons

**Number of neutrons produced = 144 - 140 = 4 neutrons**

1. Data for binding energies per nucleon are given in Fig. 7.2.



Calculate

1. the energy, in MeV, released in this fission reaction,

**Solution**

Energy released = EXe + ESr – EU

= (8.37 x 142 + 8.72 x 90) – (235 x 7.59)

= 1188.54 + 784.8 – 1783.65

= 189.69 MeV = 190 MeV

2. the mass equivalent of this energy

**Solution**

Energy = mc2

1 MeV = 1.6 x 10-13 J

Mass = $\frac{E}{c^{2}}$

= $\frac{190x 1.6 x 10^{-13}}{(3.0 x 10^{8})^{2}}$

= 3.3778 x 10-28 kg

= 3.4 x 10-28 kg