BRITISH PHYSICS OLYMPIAD

British Physics Olympiad 2010

Paper 2

13^{th} November 2009

Section 1

Important Constants

Speed of light	c	3.00×10^{8}	ms^{-1}
Planck constant	h	6.63×10^{-34}	Js
Electronic charge	e	1.60×10^{-19}	C
Mass of electron	m_e	9.11×10^{-31}	kg
Permittivity of a vacuum	ε_0	8.85×10^{-12}	Fm^{-1}
Gravitational constant	G	6.67×10^{-11}	Nm^2kg^{-2}
Acceleration due to free fall	g	9.81	ms^{-2}
Mass of Earth	M_E	5.9700×10^{24}	kg
Mass of Moon	M_M	7.35×10^{22}	kg
Radius of Earth	R_E	6.38×10^{3}	km
Radius of the Moon	R_M	1.74×10^{3}	km
Earth – Moon distance	R_{EM}	3.84×10^{5}	km

Q1

(a) Molten lead, mass 3.0 kg and melting point 600 K, is allowed to cool down until it has solidified. It is found that the temperature of the lead falls from 605 K to 600 K in 10 s, remains constant at 600 K for 300 s, and then falls to 595 K in a further 8.4 s.
Assuming that the rate of loss of energy remains constant, and the specific heat of solid lead is 140 $Jkg^{-1}K^{-1}$, calculate:

- (i) the rate of loss of energy from the lead
- (ii) the specific latent heat of fusion
- (iii) the specific heat capacity of liquid lead [4]

(b) One end of a rope is fixed to a vertical wall, making an angle of 30^0 with the wall, and the other end is pulled by a horizontal force of 20N.. What is the mass of the rope?

[3]

(c) A compact disc, CD, contains 650 MB (megabyte) of information. Estimate the area of one bit on the CD (8 bits =1 byte).The inner diameter of a CD is 4.4 cm and the outer diameter is 11.0 cm.

[3]

(d) A camera, which has a lens of diameter of 2.0 cm, takes a photograph of a 100 W filament lamp from 100 m away. If 1.0 % of the energy is emitted as light and the exposure lasts 0.015 s, estimate the number of photons that strike the film, assuming all have a wavelength of 600 nm.

[5]

(e) A tungsten filament rated at 250 W, 230 V, has a resistance of 20 Ω at 273 K. Its mean temperature coefficient of resistance is 5.0×10^{-3} K^{-1}.
What is its working temperature?

[4]

(f) A monochromatic light wave of amplitude *a* is incident normally on a Polaroid sheet at an angle θ to the plane of polarization. What is the amplitude of the transmitted wave? The intensity of an unpolarized light beam incident normally on the Polaroid sheet is *I*.
What is the intensity of the transmitted light?

[3]

(g) Determine an expression for the escape velocity of a body of mass *m* from a planet of mass *M* and radius *R*. Why do some planets possess an atmosphere and others do not?

[4]

(h) A plane mirror rotates about a vertical axis in its plane at 35 revs s^{-1} and reflects a narrow beam of light to a stationary mirror 200 m away. This mirror reflects the light normally so that it is again reflected from the rotating mirror. The light now makes an angle of 2.0 minutes with the path it would travel if both mirrors were stationary. Calculate the velocity of light.

[3]

(i) A battery, internal resistance r and emf E, drives a current of 3.0 A round a circuit consisting of two 2.0 Ω resistors connected in parallel. When these resistors are connected in series the current is 1.2 A. Calculate:

(i) the emf of the battery E
(ii) the internal resistance of the battery r
(iii) the power dissipated in a resistor in each case, P_p and P_s respectively [4]

(j) A rocket stands vertically on its launch pad. Prior to ignition the mass of the rocket and its fuel is 4.1×10^3 kg. On ignition gas is ejected from the rocket at a speed of 2.5×10^3 ms^{-1} relative to the rocket and the fuel is consumed at a constant rate of 16 kgs^{-1}.

(i) Show that the rocket does not leave the pad immediately.
(ii) Calculate the time interval between ignition and lift off. [4]

(k) What properties do molecules of an ideal gas possess? How do they differ from those of a real gas? What macroscopic properties distinguish an ideal gas from a real gas?
[3]

(l) A boat can travel at a speed of 3.0 ms^{-1} on a pond. A boatman wants to cross a river by the shortest path. In what direction should he row, with respect to the bank, if the speed of the water is 2.0 ms^{-1}.
Explain, using a diagram, which path he should take if the water speed is 4.0 ms^{-1}. [7]

(m) A small positively charged ball B, mass m, is suspended by an insulating thread of negligible mass. Another identical ball, with the same charge, is moved slowly, from a great distance, to the original position of B. B rises by a distance h.

(i) What is the final tension in the thread?
(ii) Obtain an expression for the work done, W, and show that it is independent of the charges. (Hint: identify similar triangles) [8]

(n) Two identical parallel insulating plates, each of area A and having a charge $+Q$, are separated by a distance x. Sketch the field lines between the plates:

(i) for the system

(ii) for a capacitor with identical dimensions having charges Q and $-Q$

(iii) Deduce, giving an appropriate explanation, the ratio of the forces between the plates in (i) and (ii).

(iv) Obtain an expression for the energy, E, of the capacitor using an appropriate expression for its capacitance as a function of x.

(v) Determine the force between the plates of the capacitor either directly or by comparison with the energy of a physical system with the same dependence on the parameter 'x'.

[7]

(o) A student rotates a whistle, of frequency 256 Hz, at the end of a 1.2 m length of string, at 3.0 revs. per sec. Derive the extreme values of the frequency experienced by an observer at some distance from the student. The velocity of sound is 340 ms^{-1}.

[7]

(p) Electrons with speed v, much less than c, are injected into a uniform magnetic field of flux density B at an angle θ to the field.

(i) Show the motion is periodic.

(ii) Determine the time for one period, T.

(iii) Determine the distance travelled, L, along the direction of the field in time T.

Hint: Consider the motion along and perpendicular too the field.

[8]

End of Section 1