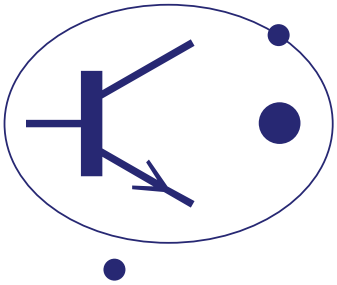
BRITISH PHYSICS OLYMPIAD



British Physics Olympiad 2011

Paper 1

September /October 2010

Answer all questions

Allow 1 hour Total 50 marks

$g = 9.8\ \text{ms}^{-2}$ or N kg^{-1}

$c = 3.0 \times 10^{8}\ \text{ms}^{-1}$

$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

Question 1

A network of resistors, each of resistance *R*, is shown in **Figure 1** below.

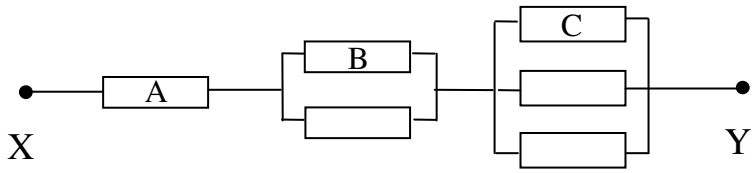


Figure 1.

(a) The overall resistance, measured between X and Y, is 33 kΩ.
What is the value of *R*?

[4]

(b) The power developed in resistor A, due to the current flowing from X to Y, is 1.8 mW.
Calculate the power developed in the resistor

(i) B

(ii) C

[4]

(8 marks)

Question 2

When a beam of protons from a particle accelerator hits a target, particles are produced which have a very short lifetime. For a particle to be formed, one side of the particle must "be in touch with" the far side of the particle, so that a signal from one side of the particle must reach the other side before the particle decays.

The diameter of the particle can be taken as the range of the Strong Nuclear Force which is about 1×10^{-15} m. If the signal propagates at the speed of light, what would be the shortest lifetime of such a particle?

(4 marks)

Question 3

(a) A broom used to sweep up dust is pushed steadily across the floor of a room, as shown in **Figure 2** below. Sketch a free body diagram for the head of the broom, showing the push, the weight of the broom head, the reaction of the floor and the frictional force due to the floor.

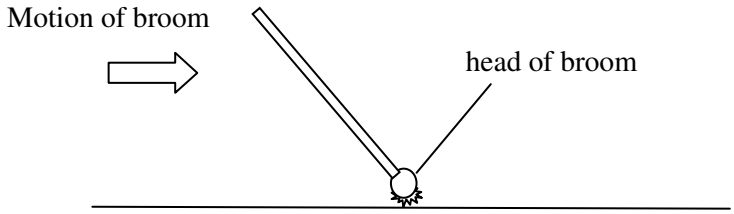


Figure 2. *Motion of broom to the right.*

[4]

(b) In **Figure 3** below, a ladder is shown leaning against a wall. The ladder remains in place because there is both friction of the ladder on the wall and friction of the ladder on the floor. Draw a free body diagram for the ladder showing all of the forces acting upon it.

[2]

(c) If the wall was made frictionless, the ladder would still remain upright. Draw a free body diagram for the ladder in this situation.

[1]

(d) If the floor was made frictionless, whilst the wall is rough and produces friction, decide and explain whether the ladder would fall or remain upright. Use a free body diagram for the ladder to help explain your answer.

[4]

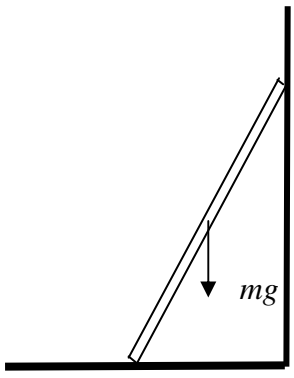


Figure 3. *Ladder leaning against a wall.*

(11 marks)

Question 4

A typical value for the atmospheric pressure on Earth is 101 kPa. The surface area of the Earth A, is related to its mean radius R by the expression $A = 4\pi R^2$, where R has the value 6400 km.

(a) How is the weight of the atmosphere related to the pressure of the atmosphere acting on the Earth's surface?

[1]

Calculate:

(b) The weight of the atmosphere.

[2]

(c) The mass of the atmosphere, assuming that g does not vary with height between the bottom and the top of the atmosphere.

[2]

(d) The number of molecules in the atmosphere, assuming that the mass of a mole of air is 30 g.

[2]

(e) The height of the atmosphere if the density $\rho = 1.2$ kg m^{-3}.

[4]

(f) The height of the atmosphere calculated in (iii) is less than the height at which aircraft often fly. Explain why our calculation gives a low result for the height.

[2]

(g) The height of the atmosphere is typically given as 200 km. Does this mean that our calculation of the mass is completely wrong (by a significant factor)?

[1]

(14 marks)

Question 5

Johannes Kepler used Tycho Brahe's detailed observations on planetary motion, made without the use of telescopes, to determine the elliptical orbits of the planets. He also ascertained that the square of the period of orbit T is proportional to the cube of R (Kepler's Third Law). The radial distance R for a planet is the simple arithmetic average of the closest distance of approach to the Sun, R_{min} and the furthest distance from the Sun, R_{max}.

(a) Sketch a diagram of a planetary orbit, marking on it R_{min} and R_{max}.

[1]

(b) From the statement above, write down two equations, the first one relating T and R with a constant of proportionality k, and a second equation relating R, R_{min} and R_{max}.

[2]

(c) The average distance of the Earth from the Sun is defined as 1 Astronomical Unit (1 AU). Determine the value of k for part (a), including units.
(The period T can be measured in years).

[1]

(d) Halley's Comet also orbits the Sun and so the value of k is the same as in (b). Its period of orbit is 75.3 years. Determine the value of R for its orbit about the Sun.

[1]

(e) The closest distance of approach to the Sun for the comet is 0.585 AU, when it is visible to the naked eye. Calculate the furthest distance of the comet from the Sun.

[1]

(f) The comet's speed is 70.6 km s^{-1} at closest approach to the Sun. Is the speed greater or smaller than this at the comet's furthest distance from the Sun? Give a reason for your answer.

[3]

(g) As a man-made satellite orbits the Earth, there is always a point on the Earth directly below it. This point follows the path of a satellite's orbit and is plotted on a map of the Earth, as shown below in **Figure 4**. Describe or sketch the satellite's orbit i.e. how it is oriented about the Earth, and its shape.

[3]

(h) This orbit is known as a Molnya orbit and is used for some spy satellites. Apart from the obvious feature that it covers Russia and the USA, what is its advantage?

[1]

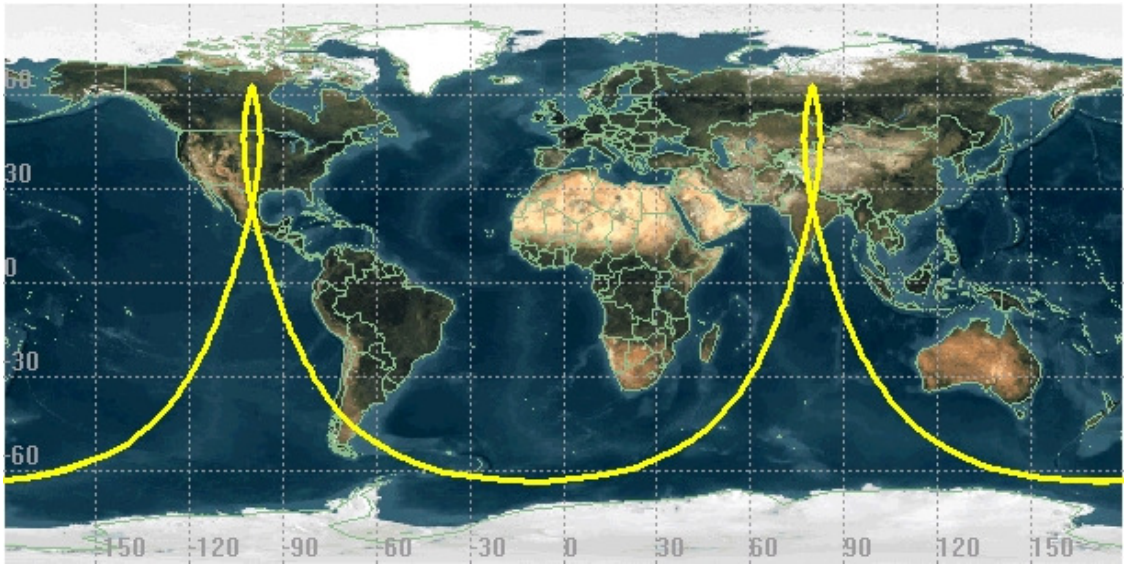


Figure 4. *Path of a satellite in a Molnya orbit around the Earth.*

(13 marks)

[End of Questions]