RADLEY COLLEGE
Entrance Scholarships

SCIENCE AND TECHNOLOGY

March 2007

Time allowed: 2 hours

*Answer **all** questions.*

Write the answers to each section on a separate sheet of paper.

Biology **[25 marks]**

Hyaenas, having spent the day **skulking** aimlessly in the thickets or strolling in a leisurely way across open ground, now become transformed into determined hunters. As they set off across their territory in the darkness to look for prey, they leave pungent signposts. Not only do they defecate **communally** in special **latrine** areas, but they "paste". Special **glands** beneath the tail produce a powerfully smelling white substance. When they reach the borders of their territory, they take a few steps with lowered hindquarters so that long grass passing between their back legs rubs against this gland and acquires a smell that even a human nose can easily detect.

A hyaena's nose, however, is vastly more sensitive than ours. We have **olfactory** membranes in our noses that are about the size of a postage stamp. A hyaena's nasal **membranes** have a surface area fifty times bigger and the richness of the information they can gather is so great and varied that it is difficult for us to appreciate it. With a sniff a hyaena can perceive not only the here and now but, simultaneously, a whole series of events stretching back into the past. It can identify the brief passage of an animal that might have run across the ground in front of it several hours previously. It can recognise the particular smell signature of each member of its group. The pasted patches of grass must shine in the distance like lighthouses and the pack's trails, perfumed by their paws, must stretch ahead like lines of reflector studs down the middle of a motorway. For mammals with such receptive and informative noses as hyaena, bush babies and mice, darkness is little **impediment** in finding their way around.

(Adapted from: *The Trials of Life,* David Attenborough)

Using information in the passage and your own knowledge, answer the following questions.

1. What is meant in the passage by the words indicated in bold as follows:

   (i) **skulking**
   (ii) **communally**
   (iii) **latrine**
   (iv) **glands**
   (v) **olfactory**
   (vi) **membranes**
   (vii) **impediment** [7]

2. Give an example from the passage of each of the following

   (i) a producer
   (ii) a primary consumer [2]

3. To which Phylum and Class do hyaenas belong? [2]

4. To which Kingdom do grasses belong? [1]

5. How might being warm-blooded be a disadvantage to a bush-baby or a mouse? [2]

6. Give two other distinguishing physical features of mammals. [1]

7. Suggest why it is useful for hyaenas to have a more sensitive sense of smell than humans and how we got it? [5]

8. Discuss whether humans have lost or just did not develop such a sensitive sense of smell. [5]

Chemistry **[25 marks]**

Consider the table below that shows the calorific (heat) energy content of various fuels measured in MJ per kg of the fuel. Assume that the heat content is also a measure of the amount of heat generated when 1 kg of the fuels are combusted.

Note that 1 MJ is the same as 1 000 000 J.

Heat (calorific) values of solid, liquid and gaseous fuels

Type of Fuel	Gross calorific value/ MJ per kg
Alcohols	
Ethanol	**30**
Methanol	**23**
Petroleum and petroleum products	
Diesel fuel	**46**
Gas oil	**46**
Heavy fuel oil	**43**
Kerosine	**47**
Petrol	**45**
'Natural' products	
Wood (including 15% water)	**16**

1. Which type of fuel (alcohols, petroleum products or 'natural' products) contains the highest amount of energy? [1]

2. How much heat energy is produced when 50 kg of wood is burnt? Give your answer in MJ. [2]

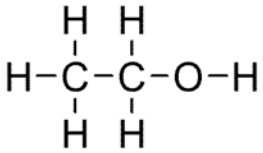
3. What mass, in kg, of petrol is needed that would produce the same quantity of heat as the wood in part b? [2]

4. Give the names of THREE pollutants formed when a fuel like diesel burns in air. [3]

5. Describe an experiment that would show the presence of the TWO of the pollutants that you indicate in part d of this question. You MUST draw a diagram to help you with your answer(s). [5]

Alcohols, like ethanol, can be made by fermenting sugars in the presence of yeast. The ethanol formed may be separated from the solution formed, and then used as a fuel.

Ethanol has the following molecular structure:



Ethanol burns in air according to the following balanced chemical equation:

$$C_2H_5OH + \mathbf{3}O_2 \rightarrow \mathbf{2}CO_2 + \mathbf{3}H_2O + \text{heat}$$

6. Indicate how ethanol may be removed from the mixture after fermentation has taken place. [2]

7. Suggest where the heat comes from when a fuel, like ethanol is burnt. [2]

8. Given the molecular structure above for ethanol, suggest why ethanol tends to produce less pollution than a fuel like petrol, when it is burnt. [2]

9. Explain why numbers like '3' have to be written in front of the O_2 in the balanced chemical equation shown above. [2]

10. Copy and balance the following equation that shows another alcohol called methanol burning in air: [2]

$$\ldots\ldots CH_3OH + \ldots\ldots O_2 \rightarrow \ldots\ldots CO_2 + \ldots\ldots H_2O$$

11. A challenging question:

Balance the chemical equation shown below:

$$KMnO_4 + HCl \rightarrow MnCl_2 + KCl + H_2O + Cl_2$$ [2]

Physics **[25 marks]**

This question is about a special kind of star that has some amazing properties. Read the short passages below and then answer the questions. Excerpts from the passage are included next to the questions to help you.

YOU MUST SHOW ALL YOUR WORKING

Neutron Stars

Neutron stars are about 10,000m (1 x 10^4m) in radius and have the mass of about 1.4 times that of our Sun. This means that a neutron star is so dense that on Earth, one teaspoonful would weigh a billion tons!

1 ton = 1000kg

1 billion tons = 1 x 10^{12} kg

$$Density = \frac{mass}{volume}$$

Neutron stars are about 10,000m (1 x 10^4m) in radius

1. Roughly what would be the volume of a neutron star in m^3 if it were spherical? [3]

Volume of a sphere = $\frac{4}{3}\pi r^3$

Assume that $\pi = 3$ to make the calculation easier.

2. Estimate the volume of liquid in a teaspoon in cm^3. [1]

3. a) Draw a cube. Mark the length of the sides as 1m long. [1]

   b) What is the volume of the cube in m^3? [1]

   c) What is the length of each side in cm? [1]

   d) Therefore calculate the volume of the cube in cm^3 [1]

4. Now calculate the volume of water on your teaspoon in m^3. [3]

This means that a neutron star is so dense that on Earth, one teaspoonful would weigh a billion tons.

1 ton = 1000kg

1 billion tons = 1×10^{12} kg

$$Density = \frac{mass}{volume}$$

5. Using the mass of a teaspoon of a neutron star given in the passage and the data above, calculate a rough value for the density of a neutron star in kg/m^3. [3]

A recent newspaper article about astronomy said that a spoonful of a neutron star would weigh more than all the people on earth. The population of the earth is about 6 billion people (6×10^9).

6. Estimate (with an explanation) the average mass of a person in kg. [2]

7. Use your answer from part 6 to calculate the total mass of people on earth in kg. Was the newspaper article correct? [3]

When stars run out of fuel they collapse under the force of gravity. What happens then depends upon the mass of the star. Neutron stars are formed when massive stars which have mass greater than 4 to 8 times that of our sun run out of fuel. After these stars have finished burning their nuclear fuel, they undergo a supernova explosion. This explosion blows off the outer layers of a star into a beautiful supernova remnant. The central region of the star collapses under gravity. It collapses so much that protons and electrons combine to form neutrons. Hence the name "neutron star".

8. If a supernova explosion happened in the Milky Way, would we ever hear it on earth? Explain your answer. [2]

9. Heat energy can be transferred by 3 mechanisms. Conduction is one. Name the other two. [2]

10. If heat from the Supernova were to reach earth, by what mechanism would it be transferred? Explain your answer. [2]

Design and Technology **[25 Marks]**

Designing a product to make going down a hill fun!

A company wants to develop a system to get down from a hill-top using very little energy. It is intended to be used by walkers who want to introduce a thrill to their journey or by children who will use it as an alternative activity to sledging when there is no snow.

Using notes and diagrams, you are asked to help them develop the product.

1 What kind of materials would you choose for the system considering the environment it is to be used? [2]

2 What would be your 'top 8' most important design features when designing a product like this? [4]

3 Sketch **AND** label three **DIFFERENT** diagrams, showing three **DIFFERENT** solutions to this problem (but **NOT** your favourite idea - you have been asked to sketch this in the next question). [9]

4 Sketch **AND** label your final chosen idea, provide as much detail as possible. [6]

5 How would you minimise the impact on the body? Sketch **AND** label a diagram, giving the reasons why you have designed the system in this way. [2]

6 What would control the movement of your system **and** why? Sketch **AND** label a diagram, giving the reasons why you have designed the system in this way. [2]