Sixth Form STEM Scholarship Examination
November 2022
90 Minutes

Instructions to Candidates

- **Students should choose THREE sections from the following to complete.**
  - **Biology** page 1
  - **Chemistry** page 2-3
  - **Computing** page 4
  - **Design Engineering** page 5
  - **Mathematics** page 6-7
  - **Physics** page 8-9

- **All answers to be written on separate paper, which must be clearly labelled.**
- **You may use a Calculator if required**
- **Graph paper will be supplied on request**

Biology

Write an essay discussing **one** of the following statements

[23 marks]

Statement 1

The importance of responses to changes in the internal and external environment of an organism.

Statement 2

How bacteria can affect the lives of humans and other organisms

Statement 3

Carbon dioxide in organisms and ecosystems.

Chemistry

Q1. This question is about hydrocarbons.

The carbon atom in organic compounds is classified as primary, secondary, tertiary or quaternary, depending on how many neighbouring carbon atoms it is associated with (one, two, three or four). The table provides information on the structure of some hydrocarbons that do not contain multiple bonds.

Draw the displayed formulae for the following compounds A–H. Do not forget about the valency of carbon and hydrogen atoms.

Hydrocarbon	Number of primary atoms	Number of secondary atoms	Number of tertiary atoms	Number of quaternary atoms
A	4	1	0	1
B	2	5	0	0
C	4	1	2	0
D	1	2	1	0
E	3	0	3	0
F	8	0	4	1
G	2	0	0	0
H	0	0	0	0

[8 marks]

Q2. This question is about air.

Hundreds of years ago, scientists believed that air was a pure substance which, along with earth, wind and fire, made up all matter on Earth. Now we know that air is a mixture of gases. 1 mole of air contains:

0.78 moles of nitrogen
0.21 moles of oxygen
0.01 moles of argon

a) Calculate the relative molecular mass of N_2, O_2 and state the relative atomic mass of Ar. (Relative atomic masses: N = 14.01, O = 16.00, Ar = 39.95)

[3 marks]

b) Using your answer to a), calculate the mass of 1 mole of air. Give your answer to 3 significant figures.

[4 marks]

The first layer of the Earth's atmosphere is called the troposphere. It ends approximately 10 km above the ground. At standard room temperature and pressure, 1 mole of gas occupies a volume of 24 dm^3

c) Assuming that the earth is a perfect sphere with a radius of 6371 km, estimate the volume of gas in the troposphere. Give your answer in dm^3.

[5 marks]

d) Using your answer to c), estimate the mass of the air in the troposphere. Assume that the gas in the troposphere is at standard room temperature and pressure.

[3 marks]

Computing

1. In recent years, there has been a large growth in the use of cloud storage.

   Discuss the advantages and disadvantages of using cloud storage.

   In your answer you should include an explanation of the reasons for the large growth in recent years and consider any legal, ethical and environmental issues related to the use of cloud storage.

   [9 marks]

2. Many people use smartphones. Smartphones often include a range of sensors and have the ability to run software known as apps. Smartphones are an example of a mobile technology.

   Discuss some of the ethical, legal and environmental issues that surround the use of smartphones and apps on them.

   [9 marks]

3. Explain two reasons why software companies usually do not make their source code publicly available. Source code is the code they wrote to create the software.

   [4 marks]

Design Engineering

For a variety of reasons, many people have the use of only one arm. Produce one solution for **each** of the following three tasks:

(i) Chopping vegetables

(ii) Putting on a pair of socks

(iii) Unscrewing a jar

Quality of your THREE solutions - how well you solve the problem along with the flair and imagination of your ideas.

[15 marks]

Technical knowledge & reasoning of solutions - how well they may work, with operating principals explained and justified; how much technical / engineering knowledge you demonstrate in your ideas and annotations.

[8 marks]

1.

(a)

A linear sequence has first term $7 + 12\sqrt{5}$

The term-to-term rule is

add $9 - 2\sqrt{5}$

One term of the sequence is an integer.

Work out the value of this integer.

[2 marks]

(b) (i)

The nth term of a different sequence is $\frac{3n^2 - 1}{n^2 + 1}$

Work out the sum of the first three terms.

[2 marks]

(b) (ii)

What is the limit of the sequence. Show how you decide.

[2 marks]

(c) (i)

The first four terms of a quadratic sequence are

$-3 \qquad 3 \qquad 13 \qquad 27$

Work out an expression for the nth term.

[3 marks]

(c) (ii)

Determine whether the number **195** is part of this sequence.

[2 marks]

(c) (iii)

Find the 200^{th} term.

[2 marks]

2.

(a)

$$f(x) = \frac{x-3}{2x}$$

Solve $f(x+1) - f(2x) = 0.5$

You **must** show your working.

[6 marks]

(b)

A function is given by

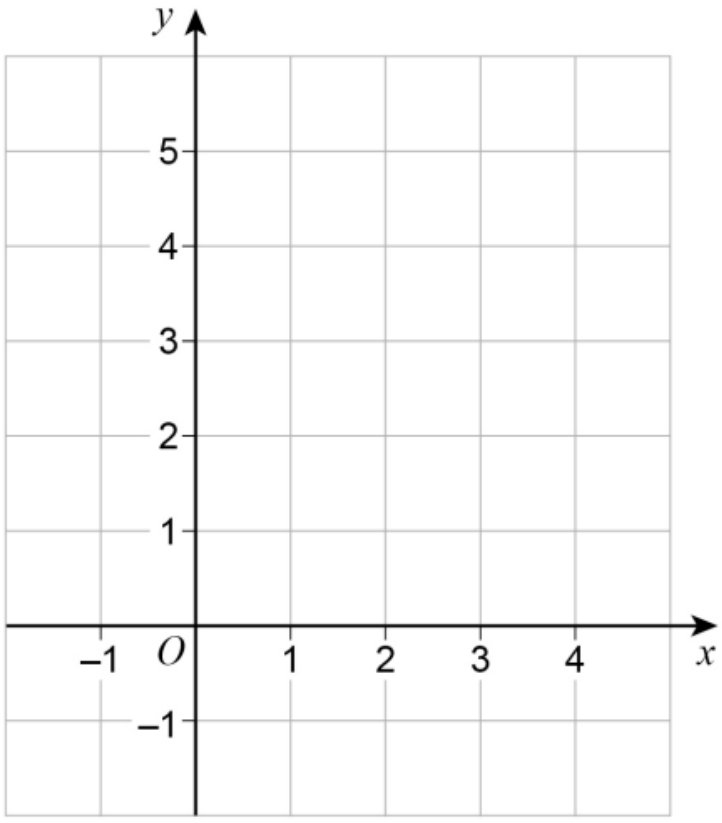
$$f(x) = -2x \qquad -1 \leqslant x < 0$$

$$= x(4-x) \qquad 0 \leqslant x < 3$$

$$= 2x - 3 \qquad 3 \leqslant x \leqslant 4$$

Draw the graph of $y = f(x)$ on the grid.

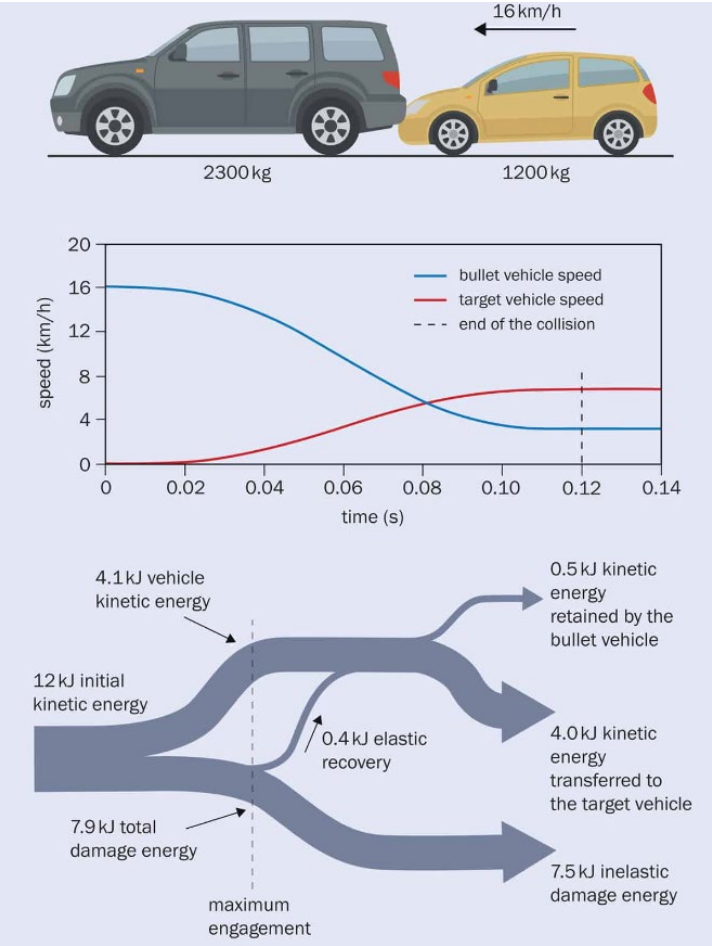
[4 marks]



Physics

Please read the following article.

Energy pathways in a collision



Newtonian physics can tell us a lot about what should happen in collisions, such as a small car with a mass of 1200 kg crashing at a speed of 16 km/h into the back of a stationary 2.3 tonne SUV. Assuming neither vehicle is braking, data from previous test crashes indicate that the collision is likely to last 0.12 s, with the coefficient of restitution, e, being 0.22. (middle) From this information, we can plot how the small car slows down and the SUV accelerates. At the "point of maximum engagement" (at around 0.08 s) the two vehicles momentarily have the same speed. Immediately after the collision, the SUV is moving at 6.8 km/h – meaning that any correctly seated occupants are unlikely to suffer soft injuries. The small car, however, will have a speed change of –12.9 km/h, which is high enough to lead to injury. (bottom) This flow chart shows what happens to the initial 12 kJ kinetic energy of the small car. At the point of maximum engagement, it has dropped to 4.1 kJ, with the rest (7.9 kJ) causing damage to both vehicles. The bulk of this energy (7.5 kJ) causes "inelastic damage": broken components, bent or deformed panels, scuffs, scratches and so on. But a small amount of the damage energy (0.4 kJ) will be "elastic" because some parts of the car will deform back to their original shape, effectively springing the vehicle apart. After the collision, the striking vehicle has lost all but 0.5 kJ of its original kinetic energy while the SUV has gained 4 kJ of kinetic energy.

From https://physicsworld.com/a/using-newtons-laws-to-weed-out-bogus-car-crash-claims/ August 2022

1. Give an example of a typical 2.3 tonne SUV

[1 mark]

2. Convert 16km/h into metres per second.

[2 marks]

3. Explain how a collision can lead to injury (line 9). Use data/estimation to support your answer. State clearly any assumptions you make.

[4 marks]

4. Suggest what a '*correctly seated occupant*' (line 8) might be. Explain why it might make a difference to whether one is injured in a collision or not.

[3marks]

5. Calculate the kinetic energy of the bullet vehicle in the article before the imagined collision

[2 marks]

6. Calculate or otherwise deduce the total kinetic energy of both vehicles after the imagined collision.

[3 marks]

7. Calculate the ratio total kinetic energy before the collision: total energy after the collision

[1 mark]

8. Suggest how *'e', the coefficient of restitution* might be defined (line 4). Explain your answer.

[2 marks]

9. It is suggested that all cars should be fitted with spring loaded bumpers. Discuss the advantages and disadvantages of such a proposal in the light of the information in the article and diagram. Illustrate your argument(s) with calculated examples.

[5 marks]