Eton College King's Scholarship Examination 2021

SCIENCE 1 (Theory)

(60 minutes)

Candidate Number: _____

Remember to write your candidate number on every sheet in the space provided.

*You should attempt **ALL** the questions. Write your answers in the spaces provided.*

The maximum mark for each question or part of a question is shown in square brackets.

Calculators are allowed. In questions involving calculations, all your working must be shown.

Total Marks Available: 70

For examiners' use only.

1	2	3	4	5	TOTAL [70]

Do not turn over until told to do so.

1. Below is a photograph of a tiger shark. Tiger sharks are large predators, capable of growing to a length of 5m.

(a) Tiger sharks are varied hunters. Their diet consists of fish, crustaceans, sea birds, sea snakes, seals and turtles. To which kingdom do all the tiger shark's prey belong?

_____**[1]**

(b) If you were a scientist, how could you quickly tell whether tiger sharks were carnivorous predators?

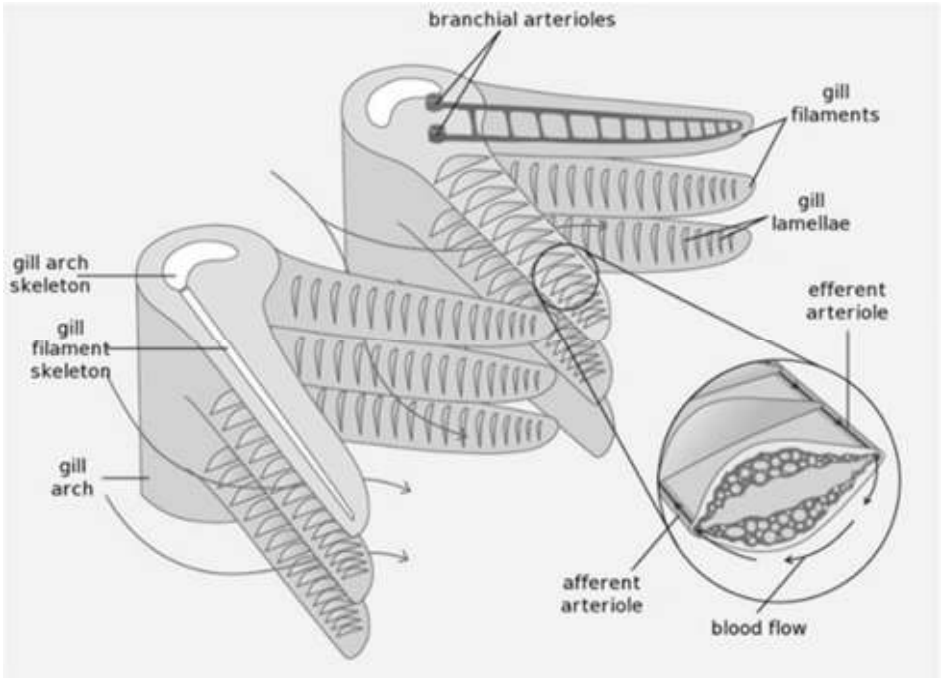
_____**[1]**

(c) Tiger sharks have similar colouration to most other species of sharks. They have darker backs and lighter underbellies. Explain why this is an advantage.

_____

_____**[2]**

One of the species that the tiger shark preys upon is the bottlenose dolphin. These animals belong to different phyla: tiger sharks are fish; bottlenose dolphins are mammals. The diagram below shows the structure of fish gills.



(d) Name two adaptations shared by the structure of fish gills and mammal lungs. Explain how each adaptation assists in absorbing oxygen.

Adaptation:_____

Explanation:_____

_____

_____

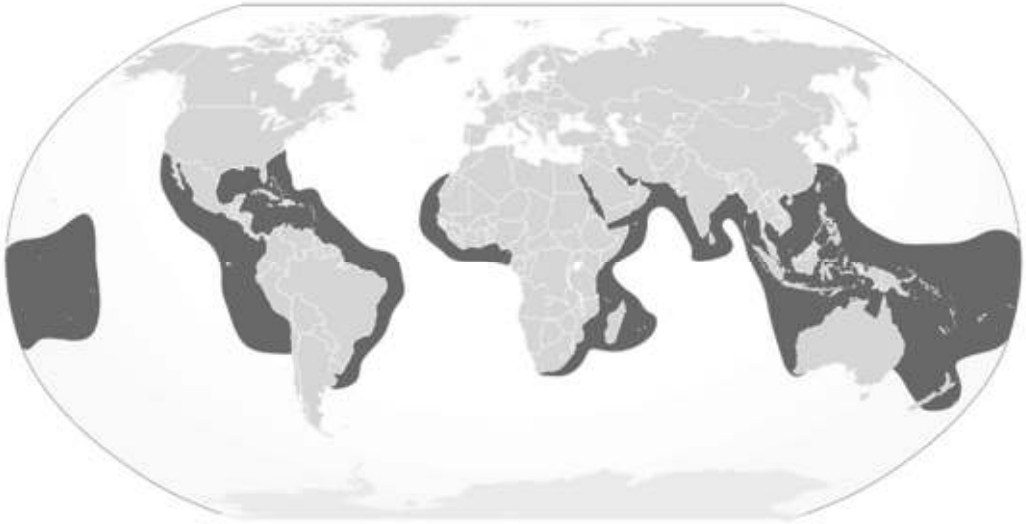
Adaptation:_____

Explanation:_____

_____

_____**[4]**

The map below details the range of the tiger shark on Earth.



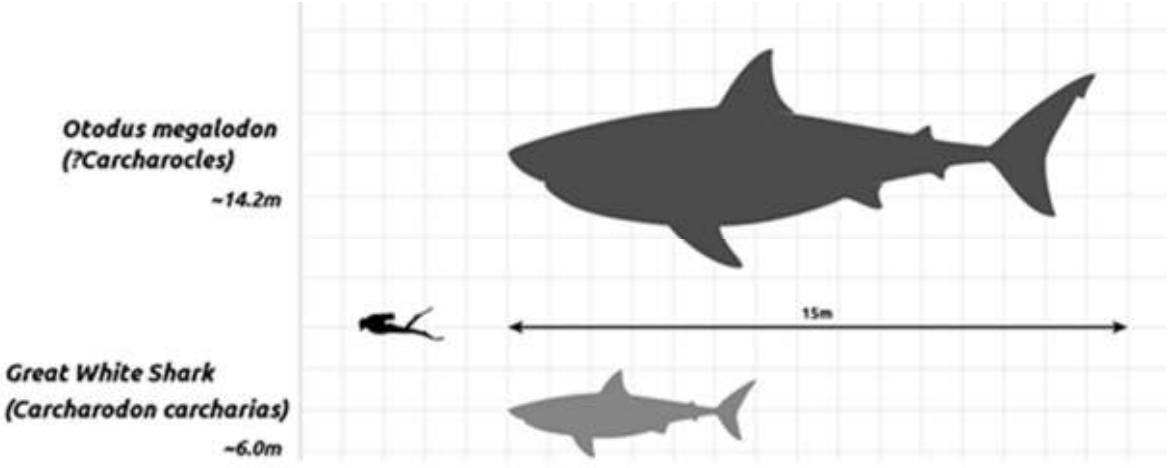
(e) Suggest what may happen to the tiger shark's range if the climate continues to warm.

_____

_____

_____**[3]**

Sharks have existed for millions of years. Though numerous changes have occurred through evolution, many characteristics have remained similar for millennia. One extinct species of shark is megalodon, which lived approximately 23 to 3.6 million years ago. Below is a diagram comparing the size of megalodon to modern day sharks and humans.



Megalodon is thought to have hunted baleen whales to survive. Unlike most fish, it is suspected megalodon was mesothermic: while not truly warm blooded, it could maintain a body temperature greater than the surrounding water temperature. This is a characteristic shared by many modern sharks today.

Despite ice ages around the time of extinction, scientists now believe megalodon went extinct owing to changes in its feeding habits.

(f) With reference to its prey, suggest three changes that may have occurred to cause megalodon to become extinct.

One:_____

_____

Two:_____

_____

Three:_____

_____ **[3]**

2. This question is about seawater.

(a) Seawater covers over 70% of the earth's surface. It is a solution. What do you understand by the word *solution*?

You might like to use some of the following words in your definition: solid, liquid, gas, element, compound, mixture, soluble, insoluble, solvent, solute.

_____

_____

_____ **[2]**

(b) The following table shows the percent by mass of the six most abundant elements, but there are two gaps. Fill in the missing, non-metal, elements.

Element	Percent by mass
Oxygen	85.84
	10.82
	1.94
Sodium	1.08
Magnesium	0.1292
Sulfur	0.091

[2]

(c) Draw a particle diagram of seawater in the box below. It should show clearly that it is a liquid and a mixture. You should take gravity into account in your diagram. You should use a minimum of 20 particles but may wish to use more.

[3]

(d) Seawater is slightly alkaline. Suggest a pH value that seawater might have.

_____ **[1]**

(e) An estimated 30-40% of the carbon dioxide that humans release into the air dissolves into the oceans. What effect will that have on the acidity of the oceans?

_____

_____ **[1]**

(f) The four most abundant metals in seawater are sodium, magnesium, potassium and calcium. They do not exist as their atoms but as their ions (charged particles), as part of a compound which dissolves in the water. To discover whether these elements could be extracted from their compounds using carbon an investigation was designed where carbon was mixed with a solution of each element and observations made. It was known that iron is extracted from iron oxide using carbon as a reducing agent in blast furnaces. For all the experiments the same result was observed because all the metals are more reactive than carbon. What was this result?

_____

_____ **[1]**

(g) Describe an experiment you might conduct to put these four metals in a reactivity series. You should include:

- any chemicals used;
- the observations you make to show a reaction has occurred;
- the conclusions you could come to;
- at least **one** word equation.

_____

_____

_____

_____

_____

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_____

_____

_____

_____

_____ **[4]**

3. This question is about the difference between chemical and physical changes.

(a) Explain what the difference is between a chemical and a physical change. You should use specific examples in your explanation.

[2]

(b) To test whether a gas is carbon dioxide, it is bubbled through limewater which will turn cloudy in the presence of carbon dioxide. Limewater is a solution of calcium hydroxide (chemical formula $Ca(OH)_2$) which reacts with the carbon dioxide. How is the observation that the limewater turns cloudy linked to the solubility of the product of this reaction?

[1]

(c) The substance produced in the reaction in (b) has the same chemical composition as limestone. State the chemical name of this substance.

[1]

(d) If you continue bubbling carbon dioxide through limewater, the cloudiness disappears. The chemical that is produced is calcium hydrogencarbonate [chemical formula $Ca(HCO_3)_2$]. Explain this observation.

[2]

(e) Write a word chemical equation for the reaction between limestone and hydrochloric acid.

[2]

(f) Give a use of carbon dioxide and explain a chemical or physical property that is the reason for this usage.

[2]

(g) Mass is conserved both in physical changes and in chemical changes. However, when a sample of copper powder, a sample of copper oxide powder and a sample of copper carbonate powder were heated separately in a test tube using a Bunsen burner, the mass of only one of the samples stayed the same. Describe and explain any observations and this result.

In your answer you should include:

- which sample stays the same and why;
- what happens to the other samples in terms of their masses and why;
- any observations you might make;
- any chemical equation you think is relevant;
- any comments on chemical or physical changes.

[4]

4. In his 1687 work *Philosophiae Naturalis Principia Mathematica,* Newton proposed that the *acceleration* of an object depends on the resultant force acting on it divided by its mass, according to the equation:

$$\text{acceleration} = \frac{\text{resultant force}}{\text{mass}}$$

(a) Define the term acceleration.

_____

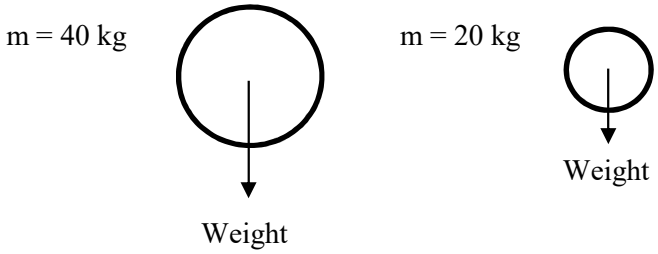
_____**[1]**

(b) According to Newton's Law, what is the physical difference between an object with a large mass and one with a smaller mass?

_____

_____**[1]**

(c) Roughly 100 years earlier, Galileo Galilei supposedly dropped two cannonballs from the Leaning Tower of Pisa to show that their time of descent was independent of their mass.



i. By using Newton's Law to calculate their acceleration, show that the cannonballs both hit the ground at the same time [Take g = 10 N/kg and ignore air resistance].

_____

_____

_____**[2]**

ii. Justify why air resistance can be ignored in this example.

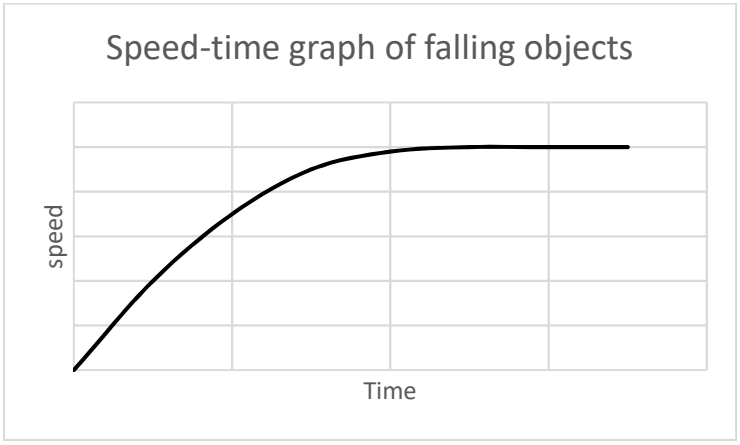
_____

_____**[1]**

(d) For an object falling downwards, the force of air resistance acts in the opposite direction to weight, meaning:

$$\text{resultant force} = \text{weight} - \text{air resistance}$$

The graph shows a speed-time graph for a falling hammer.



i. A feather is also dropped. Sketch a line describing the falling feather on the same set of axes. **[2]**

ii. The hammer has a mass of 0.5 kg. What is the maximum air resistance force the hammer experiences during its fall? [Take g = 10 N/kg]

_____

_____

_____**[2]**

iii. Explain the microscopic origin of air resistance.

_____

_____**[2]**

iv. The force (in newtons) of air resistance for the hammer is modelled by the equation.

$$\text{air resistance} = 0.002 \times v^2$$

Where 0.002 is a co-efficient that accounts for the shape of the object and the medium through which it moving and v is the speed (in ms^{-1}) of the object experiencing the air resistance.

What is the maximum speed reached by the hammer?

_____

_____

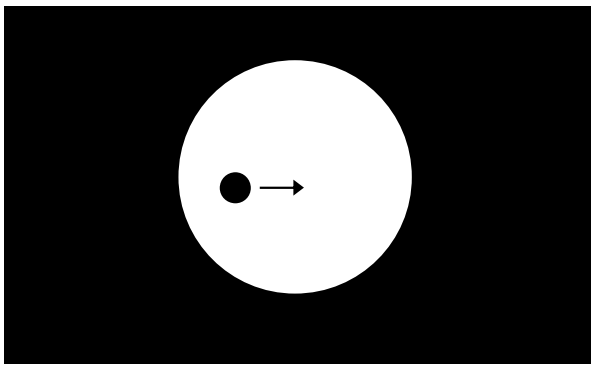
_____

_____**[3]**

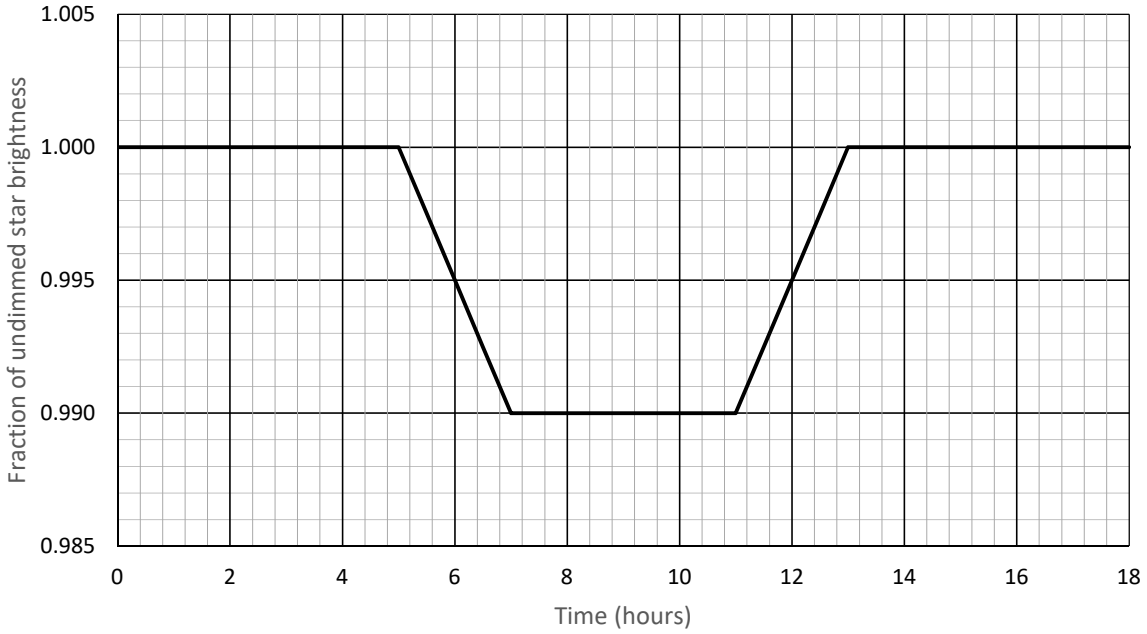
5. This question is about exoplanets.

In 2019 Michel Mayor and Didier Queloz were awarded part of the Nobel Prize in Physics for their 1995 discovery of the first planet around a star other than the Sun. Since then, over 4000 other 'exoplanets' have been discovered.

Many of the discoveries have been made using the so-called 'transit method', in which the passage of the exoplanet between us and the star causes a measurable dip in the brightness of the star's light. The figure below shows the dark disk of the planet moving across the bright disk of the star:



The graph below is a simplified example of the 'light curve' of a star. The dip in the star's brightness, expressed as a fraction of the undimmed brightness, is due to a planet's transit.



(a) From the graph, determine the time of transit from the moment the planet's disk is fully in front of the disk of the star until the moment it begins to leave the disk of the star.

_____

_____ **[1]**

(b) Explain briefly why the light curve decreases gradually from 1.000 to 0.990, rather than dropping abruptly.

_____

_____**[1]**

(c) Using data from the graph, calculate the radius of the planet as a fraction of the radius of the star.

_____

_____

_____**[2]**

(d) The star is like our Sun, and has a radius of 1 solar radius (700 000 km). Calculate the radius of the planet (in metres).

_____

_____

_____**[2]**

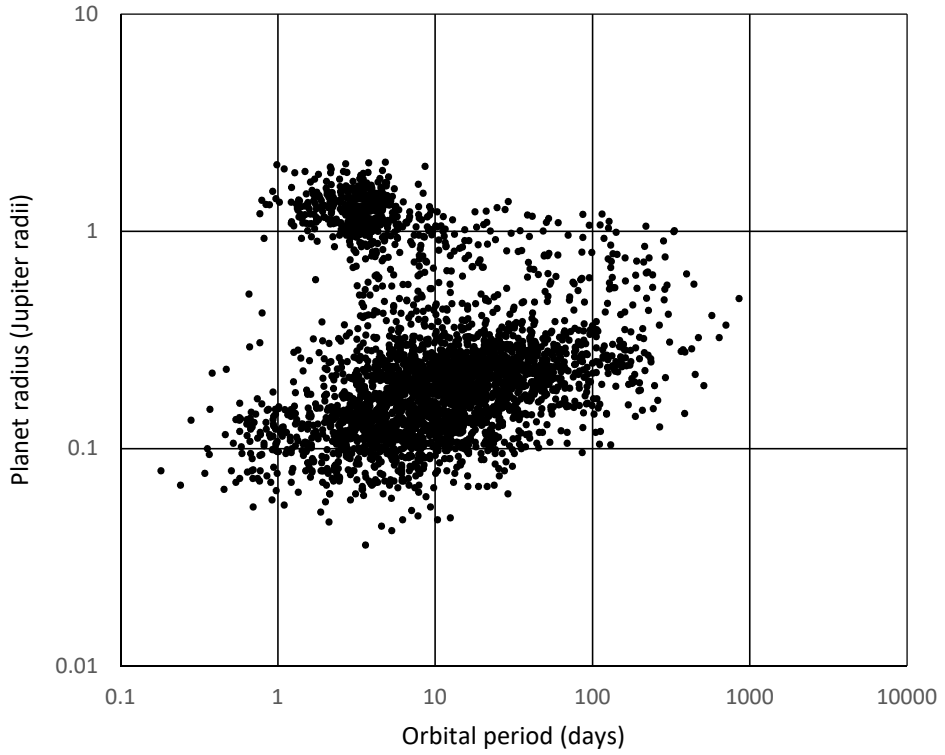
(e) Calculate the speed of the planet in metres per second.

_____

_____

_____**[2]**

Different discovery methods are more or less sensitive to different types of planets. The graph below shows the distribution of over 3200 exoplanets as a function of their orbital period (measured in Earth days) and their radius (measured in Jupiter radii). It is obvious that there are two main groups of planets; these two groupings are a result of using two different discovery methods.



(f) By circling one of the groups, identify which group was discovered via the transit method. **[1]**

(g) Justify your choice.

_____

_____

_____ **[2]**

(h) Indicate where you think Jupiter would lie on this graph by adding a point on the graph and labelling it 'J'. **[1]**

(i) Explain whether or not you think Jupiter would be an obvious candidate for detection by the transit method by an alien observer looking at our Solar System.

_____

_____

_____**[2]**

[End of paper]