Task developed by Dylan Sherman, University of Sydney, 2018

STATE DA VINCI DECATHLON 2018

CELEBRATING THE ACADEMIC GIFTS OF STUDENTS IN YEARS 9,10 & 11

SCIENCE

TEAM NUMBER ______________

1	2	3	4	Total	Rank
/11	/36	/5	/28	/80	

QUESTION 1 – A SUCCESSFUL FAILURE (11 MARKS)

Science experiments rarely go to plan. Often, they will produce unexpected results and lead to unique observations. Below are a series of experiments that haven't gone to plan. There may be more than once thing wrong with the experiment design! Your task is to firstly hypothesise and explain why these experiments did not work as planned. You are to then suggest a change you could make to the experiment so that the correct result might be achieved. When responding, consider including terms such as independent, dependent and control variables along with reliability, accuracy and validity.

Experiment 1: Joe wanted to test whether the colour of water affected how hot the water was when exposed to the sun. Each day he put out a bucket of water with different food dye and left it in the sun for 4 hours on his back veranda. He measured the temperature before and after the time, along with every hour during the four hours. (5 marks)

Experiment 2: Angela wanted to see whether a speaker who was yelling louder made people quieter in the audience. She asked a person to whisper, speak and then yell at a group of 20 students in a class. The speaker would say anything that came to mind for a while. Angela then wrote down an estimate of the volume either as quiet, normal or loud for the audience. (6 marks)

QUESTION 2: MIRAGING DISASTER (36 MARKS)

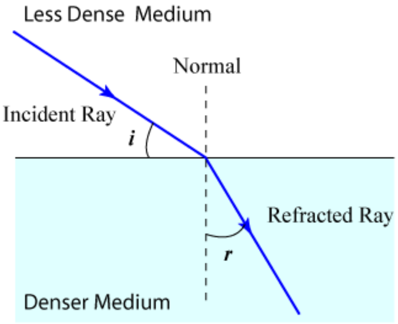
Mirages are often considered a sight of beauty, derived for the Latin *mirari* meaning to look at, to wonder at. They produce unexpected optical illusions due to the way the air bends light.

1. Light rays can be considered as a stream of particles called **photons** travelling at a constant speed from their source (the sun). When light hits a material, some light may reflect while other light will travel **through** the material. Material that is less dense has fewer atoms in the same amount of space as a denser material. Using these observations **explain** why light travels more slowly in denser materials. (2 marks)

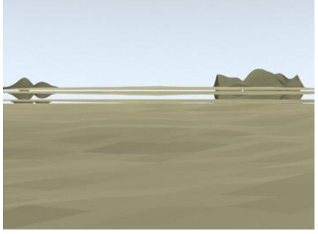
2. By thinking of the density of the objects below, order the objects in terms of the speed light travels through them, from slowest to fastest (1 mark):

   Air, diamond, sapphire, water

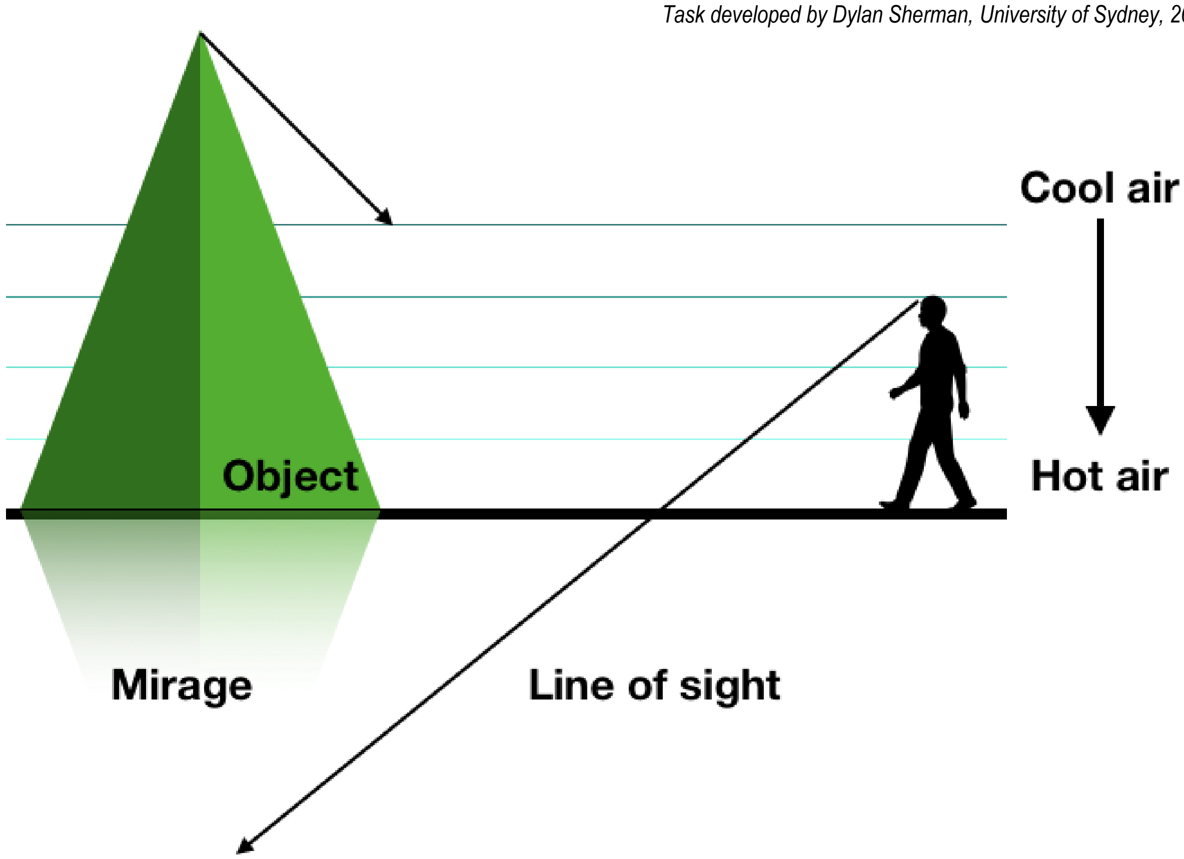
3. When light is slowed more by a material it will 'bend' more, becoming closer to a 'normal' line (see the sketch below). **Sketch** what would happen to a light ray as it passes from a more dense to less dense material. (2 marks)



4. An **inferior mirage** produces an image located under the real object further away, often observed as a rippling pond. The mirage makes the larger object in the distance look much closer. You may have seen these phenomena popularised in desert scenes from classic adventure movies.



The mirages only occur when the surface is a material that retains a large quantity of heat, meaning that while hot air usually rises (leaving the cool air near the surface) the inverse occurs (hot air on the ground and cooler air above that moving in a gradient). From your understanding of refraction in this question, and the inverse air temperature above a hot asphalt road, sketch on the image below the pathway a light ray (started for you) that will travel from the real object to the viewer's eyes (2 marks)



5. Now sketch on the same image a light ray from the real object if the air was all the same temperature (1 mark)

6. Using the last two questions explain how an inferior mirage forms. (2 marks)

7. A further element of magic to a mirage is a shimmering effect that creates ripples through the virtual image. This rippling effect is also seen as hot gases are blown out of a jet or the exhaust of a car. Hypothesise how convection currents (the flow of air between hot and cold layers to move hot air higher than cold air) may cause this to occur. (3 marks)

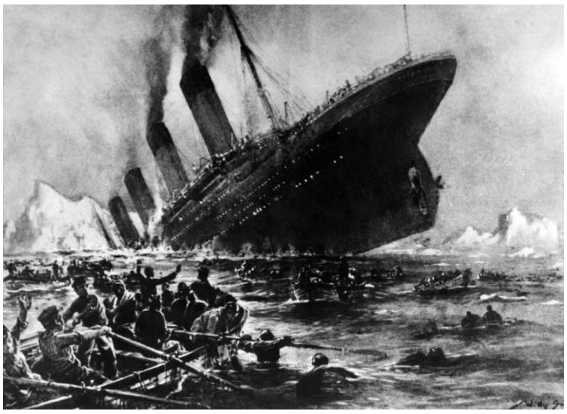
8. A less commonly observed type of mirage are **superior mirages**. These occur in the opposite conditions of **inferior mirages** – ice sheet ridden cold regions. Here the temperature gradient is reversed – cold air permeates from the ice to form a film of cold air, above which gradually sits warmer air. Often the mirage is unclear and quite hazy, making it difficult to see anything in the direction of the mirage. By first sketching an image similar to that in question 4, **predict** where the mirage will be located, explain how this occurs using the principles of refraction and sketch the position of the viewer's line of sight (4 marks).

9. Why don't these mirages appear to ripple like inferior mirages? (2 marks)

10. A final geographical element to consider is the curvature of the earth's surface. If the earth was flat, lights rays that bend downwards would not travel very far. Explain why the curvature of the earth may allow superior mirages to be seen much further away and predict whether the viewer will therefore perceive the real object to be closer or further away than it actually is (3 marks)

11. The horizon is normally the limit of view for a viewer on a ship in the ocean. Ancient Nordic texts, however, record ships and coastal cities flying on or above an **observed** horizon (which appears higher than the actual horizon). Why? (2 marks)

Some time ago, you may have read the title to this question and pondered how disaster might be relevant. Well, in 1912 during the early morning hours of 15 April, the RMS Titanic collided with an iceberg, tragically sinking into the cold waters below. A historian, Tim Maltin, recently professed a theory that claimed the errors that led to the sinking of the titanic are in fact all able to rationalised by considering the science of mirages and light refraction (https://timmaltin.com/2016/04/10/the-hidden-cause-of-the-titanic-disaster/).



The Titanic was travelling through an area normally occupied by water from Gulf Stream. The day of the maiden Titanic voyage, however, saw a field of icebergs "20 or 30 miles along with icebergs on every point of the compass" according to the Titanic's Quartermaster Hitchens. These icebergs were flowing in meltwater from the Labrador Current, creating freezing water and air up to at least the height of the tallest iceberg (10s of metres tall).

The sharpness of the boundary between the warm waters of the Gulf Stream and the freezing waters of the Labrador Current, and its proximity to Titanic's wreck site, was recorded after the disaster by the SS Minia, who whilst drifting and collecting bodies near Titanic's wreck site noted in her log: *"Northern edge of Gulf Stream well defined. Water changed from 36 to 56 [degrees Fahrenheit] in half mile".*

The cold icebergs and icy meltwater in the Labrador Current had chilled the formerly warm air, which had previously been heated to approximately 10 degrees Celsius by the warm waters of the Gulf Stream; so the air column at Titanic's crash site was freezing from sea level, up to a height of about 60 meters – almost the height of the tallest icebergs, and then about 10 degrees Celsius above that height.

12. Using the environmental conditions and data above, along with the theory you have learnt during this question, scientifically rationalise the following observations recorded in historic texts from the night of the titanic sinking (12 marks):

(a) Titanic First Class passenger Philipp Edmund Mock from Lifeboat Number 11 recalled:

"We were probably a mile away when the Titanic's lights went out. I last saw the ship with her stern high in the air going down. After the noise I saw a huge column of black smoke slightly lighter than the sky rising high into the sky and then flattening out at the top like a mushroom."

(b) **Reginald Lee, Titanic Lookout, testimony:**

2401. What sort of a night was it?
– A clear, starry night overhead, but at the time of the accident there was a haze right ahead.

2402. At the time of the accident a haze right ahead?
– A haze right ahead – in fact it was extending more or less round the horizon. There was no moon.

2403. And no wind?
– And no wind whatever, barring what the ship made herself.

2404. Quite a calm sea?
– Quite a calm sea.

2405. Was it cold?
– Very, freezing.

2408. Did you notice this haze which you said extended on the horizon when you first came on the look-out, or did it come later?
– It was not so distinct then – not to be noticed. You did not really notice it then – not on going on watch, but we had all our work cut out to pierce through it just after we started. My mate happened to pass the remark to me. He said, "Well; if we can see through that we will be lucky." That was when we began to notice there was a haze on the water. There was nothing in sight.

2441. Can you give us any idea of the breadth [of the iceberg]? What did it look like? It was something which was above the forecastle?
– It was a dark mass that came through that haze and there was no white appearing until it was just close alongside the ship, and that was just a fringe at the top.

Answer:

(c) Stars can never be seen setting on the horizon, as they disappear as they approach the real horizon, due to the depth of air one has to seem them through at a low altitude. However, Second Class passenger Lawrence Beasley noticed the following:

"we could see the stars setting down to the horizon. [*It was] a phenomenon I had never seen before: Where the sky met the sea the line was as clear and definite as the edge of a knife, so that the water and the air never merged gradually into each other and blended to a softened rounded horizon, but each element was so exclusively separate that where a star came low down in the sky near the clear-cut edge of the water-line, it still lost none if its brilliance. As the earth revolved and the water edge came up and covered partially the star, as it were, it simply cut the star in two, the upper half continuing to sparkle as long as it was not entirely hidden, and throwing a long beam of light along the sea to us.*

Answer:

(d) Murdoch and Lightoller, watchers on the high up Titanic bridge, saw no iceberg until the last moment when the iceberg was almost directly in front of the ship. Note: your answer should refer to horizon positions along with mirages.

Answer:

(e) Captain Lord on the nearby ship Californian concluded the Titanic was a 400ft ship 5 miles away, not an 8—ship about 10 miles away.

Answer:

(f) Titanic's distress rockets, which exploded at a height of about 600 feet above the Titanic, appear to Californian's Second Officer Herbert Stone to be much lower than they really were:

7921. …these rockets did not appear to go very high and were hazy; they were very low lying; they were only about half the height of the steamer's masthead light and I thought rockets would go higher than that.

Answer:

QUESTION 3 – A STRANGE PLACE (5 MARKS)

Thought experiments sometimes allow scientists to move beyond the constraints of reality to question the theory that governs and operates our natural world. By imagining changes, we can begin to predict the unpredictable.

Imagine that the earth, over the next 1000 years, will increase its gravity 1.5 times the current strength. Suggest **5** scientific consequences of this occurring, ensuring to include one consequence in each of these categories: humans, flora, architecture, terrain/geography, transport.

1.

2.

3.

4.

5.

QUESTION 4 – SURPRISING SYNCHRONISITY (28 MARKS)

Read the article below and answer the following questions after the article:

Syncing our brain activity may help us interact with each other

By **Helen Thomson**

It's said that imitation is the sincerest form of flattery. Monkeys synchronise their brain activity during social interactions, possibly helping them to learn from each other. Understanding how this might work in humans could help groups of people work together more efficiently.

To study brain activity in social situations, Miguel Nicolelis at Duke University Medical Centre, in Durham, North Carolina and his colleagues developed a wireless system that can record the neuronal activity from two monkey brains simultaneously.

During the experiment, one monkey was propelled in an electric wheelchair towards a fruity treat, while a second monkey sat across the room and watched. This monkey was incentivised to pay attention – the more closely he observed the moving monkey, the more treats he was given. When the passenger monkey reached the fruit dispenser, the observer received a large juice reward.

The team recorded brain activity from the motor cortex – the region responsible for movement – in both monkeys. They repeated the experiment with various pair combinations of three monkeys.

Monkey see, monkey sync

They found that, as the first monkey travelled across the room under the gaze of the second monkey, specific groups of neurons in the motor cortex showed the same pattern of activity at the same time in both monkey's brains.

This synchronisation could be used to predict what was going on in the room. For instance, certain groups of neurons in the observer's brain only matched those in the moving monkey when they got within touching distance. Other groups of neurons might become synchronised only when the moving monkey was travelling at a certain speed, or when they were nearing the treat dispenser.

Intriguingly, the monkeys' social status affected how well a pair's brains synchronised. When a less dominant monkey was observing a more dominant monkey, synchronisation was higher than when a more dominant monkey was doing the observing.

It suggests that brain activity is heavily influenced by social relationships among these animals, says Nicolelis.

Learning from others

The team hypothesise that less dominant animals may mimic the brain activity of more dominant animals more to better understand their actions. The mirroring of their brain activity might help the monkey put themselves in the other's shoes, and help them to learn skills merely from observing.

The researchers say that certain groups of neurons active in the moving monkey were associated with the reward hormone dopamine, so it may be that any mimicry of brain activity in the observer's brain leads them to experience a reward too. This may explain how monkeys and people learn by watching others: we get a little taste of reward simply by watching someone else succeed at something, which incentivises us to try it ourselves.

The team thinks similar synchronisation might take place during human interactions, too. Analysing this synchronisation using non-invasive brain recordings might allow us to quantify how well people are working together in a group. Neurofeedback – in which people view their brain activity in real time and learn to modulate it – might help them improve those interactions.

"The finding that one of the variables that affects synchronisation was the monkey's social rank is amazing," says Ron Frostig, a professor of neurobiology and behaviour at University of California, Irvine. He says that more research is needed to understand how different aspects of the room, the monkeys' movements and the social cues might influence brain synchronisation, but that once this is accomplished, but the work has exciting potential applications – perhaps for understanding social interactions in conditions like autism, for example.

You have been asked to produce a **critique** of this research in the news section of Science. Your article is to be titled **Monkey Business** and should include the following:

Element	Criteria	Mark
Paragraph 1/2		
Introduction (1 mark)	evident or not	
Short summary of the experiment's aim (1 mark)	evident or not	
The hypothesis (1 mark)	evident or not	
Method used (in brief) (2 marks)	2 marks for summary with **objective details**, 1 mark for superficial description [note does not need to be quantitative]	
The results (1 marks)	evident or not	
The conclusions drawn from the results (2 marks)	2 marks – specific conclusion that were drawn from the data only; 1 mark – general conclusions that make assumptions/aren't directly related to data.	
Paragraphs 3+		
Limitations of the experiment (3 marks)	3 limitations must be present.	
Factors that may have made the results less **valid** (3 marks)	3 variables not controlled.	
Factors that may have affected the **accuracy** of the results (3 marks)	Inherent qualities of experiment that will make results WRONG. 3 ideas required for 3 marks.	
The **impact** this research may have on being able to understand, alter and control human behaviour (use specific examples!) (3 marks)	3 marks for 3 links to human behaviour and how it may help us later.	
Final paragraph		
Future directions of research and a possible experiment that could be undertaken (don't provide a complete method, only an overview) (3 marks)	3 marks – a useful experiment to try applicability to humans with detailed objective approach that is realistic and scientific (one variable to be measured) 2 marks – a good scientific experiment but lacks specificity of variables or objectivity 1 mark – a general experiment idea	

A final **evaluation** of whether the research was successful and whether it has made a significant contribution to science (and if so what that contribution is) (2 marks)	1 mark for conclusion as to success with a reason (both required) 1 mark for contribution conclusion with explanation of what it is OR why not (both required)	
Scientific writing	3 marks – concise, objective and well organised (e.g. inclusion of diagrams) 2 marks – lacks one of these elements 1 mark – lacks 2 of these elements 0 marks – does not consider writing scientifically	

Be sure to use sub headings to make it easy to distinguish between these sections. Marks will be awarded for overall organisation, cohesiveness, and scientific writing! A key part of scientific writing is being **concise and objective**.

END OF PAPER