Welcome to the 2023 National Scientific Thinking Challenge.

Read every question carefully and work steadily. We deliberately create questions that are not connected to the courses you study at school so make sure you read the information we give you at the start of each question.

There are 34 questions for you to try. Do not press "submit" until you have tried them all!

Question 1

On a bicycle, the pedal for your left foot screws on in the opposite direction to the pedal for your right foot. (Not a lot of people know this fascinating fact!)

What is the most likely reason for this?

To stop the left-hand pedal from unscrewing itself and falling off as you ride the bicycle.

To stop you fitting the pedals backwards.

To make it harder for people to repair their own bicycles which could lead to more accidents.

To stop other parts of the bicycle becoming unscrewed as you tighten up the left pedal.

Question 2

Engineers can join pieces of metal together by welding them. An arc welder creates a powerful electrical discharge between a pointed metal tip and the metal pieces being welded. During this process, metal will melt, very intense ultra-violet and visible light is emitted, and small pieces of molten metal could fly into the air.

Here are 4 possible rules for welding safely:

A: Wear a face shield with dark tinted glass

B: Wear a long sleeved, fire-resistant welding jacket to prevent your skin suffering the equivalent of sun burn

C: Wear thick, strong gloves that go a long way up your arms to protect from burns

D: Do not let a dog come near to you when you are welding, or the dog could suffer permanent eyesight damage.

Which are likely to be correct?

All of them

A and C only

D only

A, B and C only.

Question 3

If you open a freezer to get some ice cubes, close the door and then try to open the door again straightaway, it can be harder to open the door the second time. What is the best explanation for this?

When the door was opened, warm air entered the freezer. Once shut inside the freezer, this warm air contracted. The air pressure inside the freezer then became lower that the air pressure outside the freezer. The higher air pressure outside the freezer was pushing against the freezer door.

Magnets on the door stick to the steel case of the freezer so it does not open accidentally causing the things inside the freezer to thaw.

As it was so cold, the rubber door seal became wet with condensation when the door was opened. When the door was closed, the condensation froze solid, sticking the door to the frame of the freezer.

The rubber seal running around the inside of the freezer door was compressed, this created a suction affect, sticking the door closed.

Question 4

If you open a bottle of fizzy drink when it is warm, the drink often sprays everywhere. If you open a cold bottle of fizzy drink, it generally does not spray out. Why?

Gases do not dissolve so well in cold liquids, so the cold drink contains less gas to be released.

Gases dissolve better in cold liquids than warm liquids. When you open a cold bottle of fizzy drink, more of the gas remains dissolved in the cold drink so there is less pressure inside the bottle to force the liquid out.

Bubbles form when you shake the bottle. The bottle had been in the fridge and had not been moving for a long time.

In a cold liquid, the bubbles can't move as quickly and so they can create less force when the bottle is opened.

Question 5

When a dishwasher tells you it has finished a cycle of washing up, china, glass and metal things are dry but plastic things (like a lunchbox) are still wet. Why?

Water sticks to plastic things very well because of surface tension effects.

The plastic is easily scratched, and those scratches hold water onto plastic surfaces.

Everything gets hot inside the dishwasher, but the metal, china and glass objects hold onto that heat for longer than the plastic things. This causes water on their surfaces to evaporate whilst water on the plastic does not.

The detergent used in the machine helps water to stick onto the plastic things so it cannot evaporate so easily. Therefore, the plastic things are still wet at the end of the washing cycle.

Question 6

A survey was done to find out which type of biscuit was the most popular. Which method was likely to get the best, most useful and reliable results?

"During a tea break, I asked a group of my friends. Although there were only about 6 of us, we all have friends and families so the answers sort of included those people as well. The answer seemed to be Bourbons."

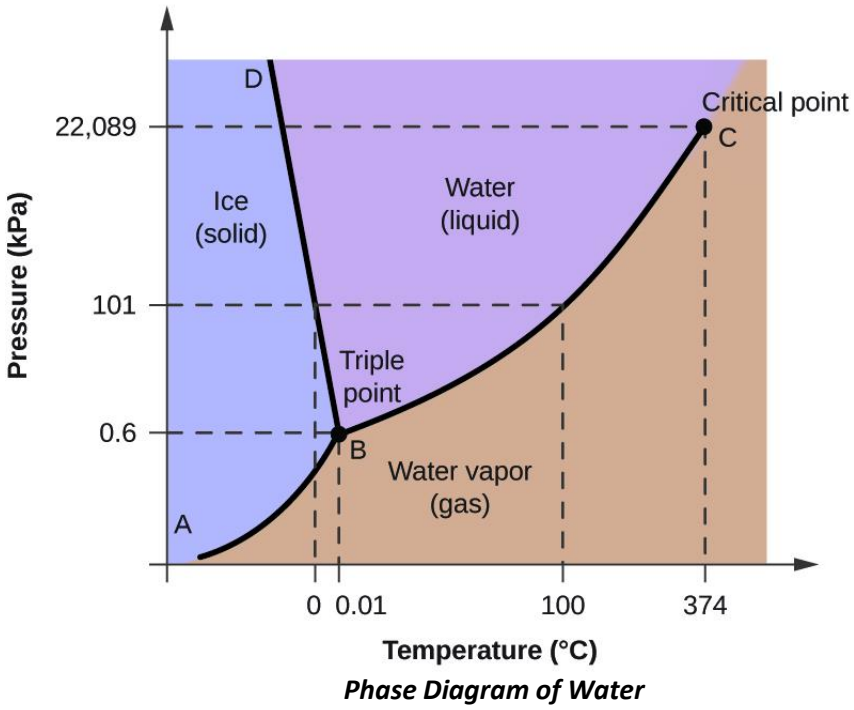
"A supermarket helped me. As they left the shop, people could put a token in one of 5 boxes corresponding to five very popular types of biscuit. The box with the most tokens in at the end of the day corresponded to chocolate digestives."

"A supermarket helped me. They used sales records from their Worcester store over a whole year and we worked out which type of biscuit they had sold most of."

"A supermarket helped me. They used their sales records from 40 stores from all over the UK during a 6-month period and worked out which type of biscuit they had sold most of."

Questions 7 – 11 relate to some of the scientific properties of water.

Additional Information: Water can exist as a solid, liquid or gas depending upon its temperature and pressure (force per unit area). This diagram shows the "Phase Diagram" for water which shows which state of matter water will be at different combinations of pressure and temperature. On the vertical axis, the unit for pressure is given as kPa, short for kiloPascals. 101 kPa represents normal atmospheric pressure at around sea level on Earth.



Phase Diagram of Water

Question 7

On the graph, what can you notice, mathematically, about the scales on the horizontal and vertical axes <u>which might affect the shape of the lines</u>?

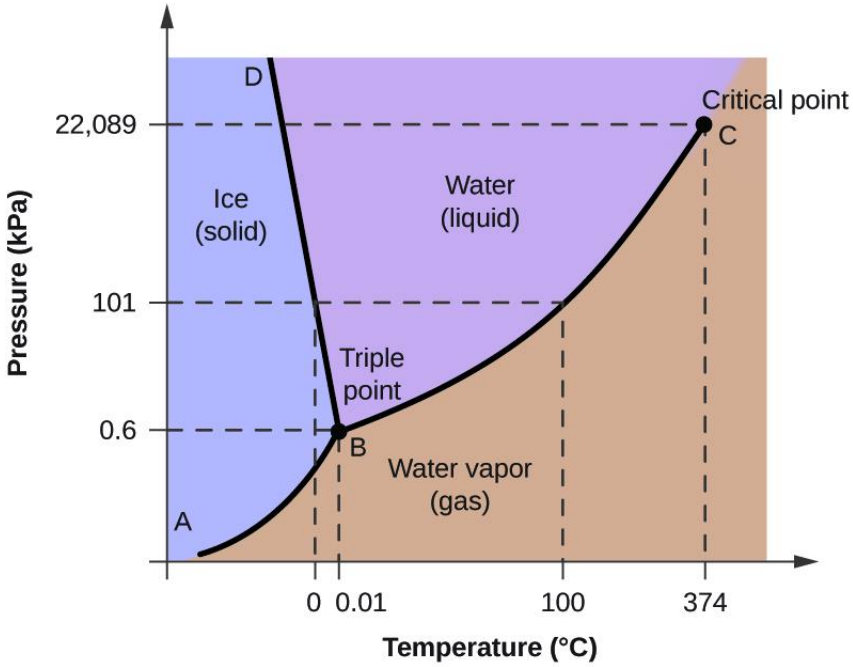
The numbers are not spaced out evenly in size order (the scales are non-linear).

The negative numbers are not shown clearly.

Not all of the numbers are shown.

There are no squares shown, like on graph paper, which means it is easier to make mistakes when reading information from the graph.

Question 8 – use the diagram showing the phase diagram of water and the additional information given just before Question 7 to answer this



At the "Triple Point", water can exist as a mixture of solid ice, liquid water and water vapour at the same time! Look at the "Triple Point" on the graph. Which of these statements about the Triple Point of Water is correct?

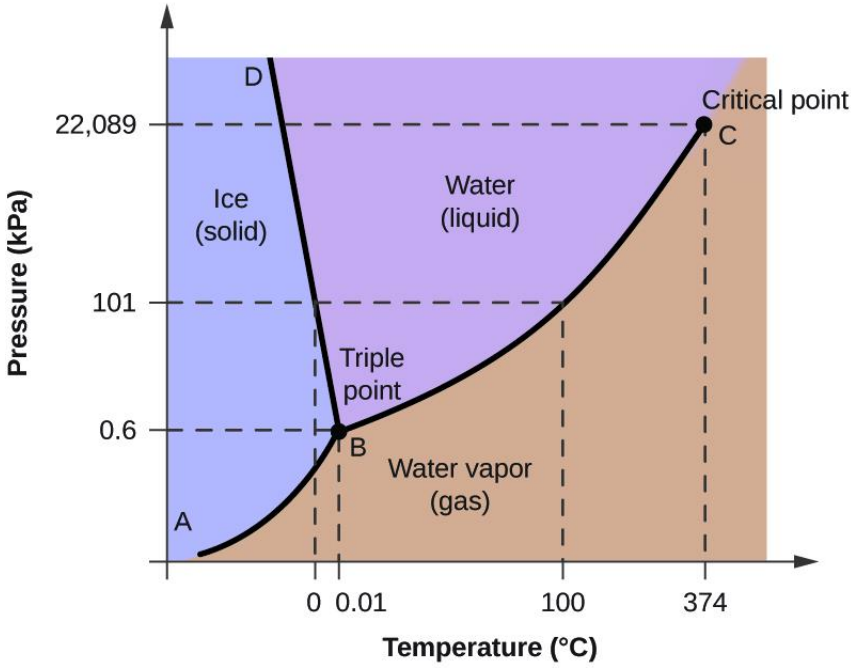
The temperature of the Triple Point is ever so slightly greater than zero centigrade and the pressure is very low compared to normal laboratory conditions.

Water is 0.6 times less dense than normal at the Triple Point.

Water can be 0.01 time hotter than normal at the Triple Point.

The temperature is 101 centigrade and the pressure is 0.01 of what it would be in a normal room.

Question 9 - use the diagram above, showing the phase diagram of water to answer this



On the graph, what does the line between the points labelled as B and C tell us about some of the properties of water?

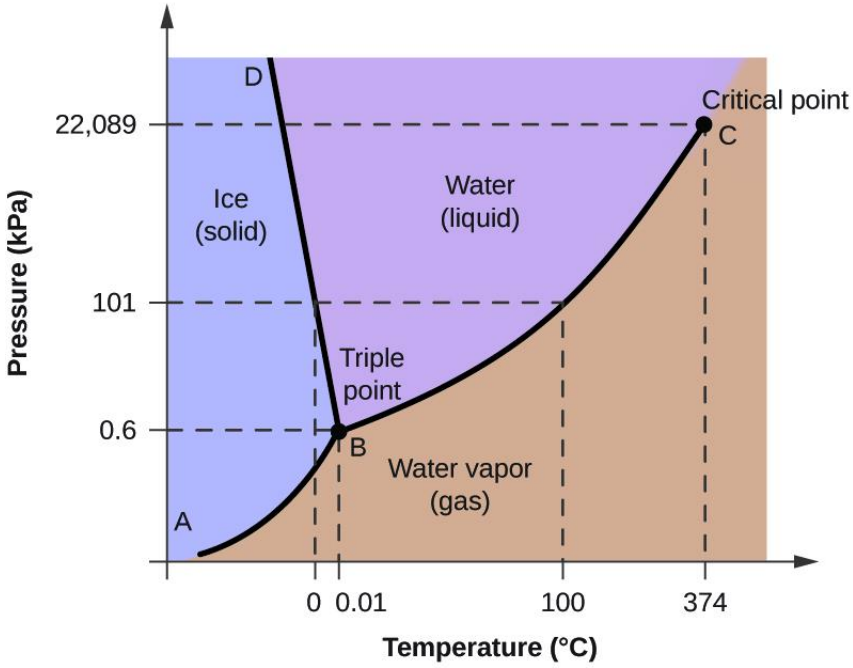
At higher pressures, water boils at a higher temperature than at lower pressures.

Water at a low temperature must be at low pressure.

Water can flow easily when it is a liquid because it has a low viscosity.

Water is a colourless liquid at 25 centigrade and normal atmospheric pressure.

Question 10 - use the diagram, showing the phase diagram of water to answer this question



The Critical Point of water refers to the conditions of pressure and temperature at which water has the same density (mass per unit volume) as both a liquid and a gas and so those two phases are indistinguishable. What is the temperature and the pressure which corresponds to the Critical Point of water?

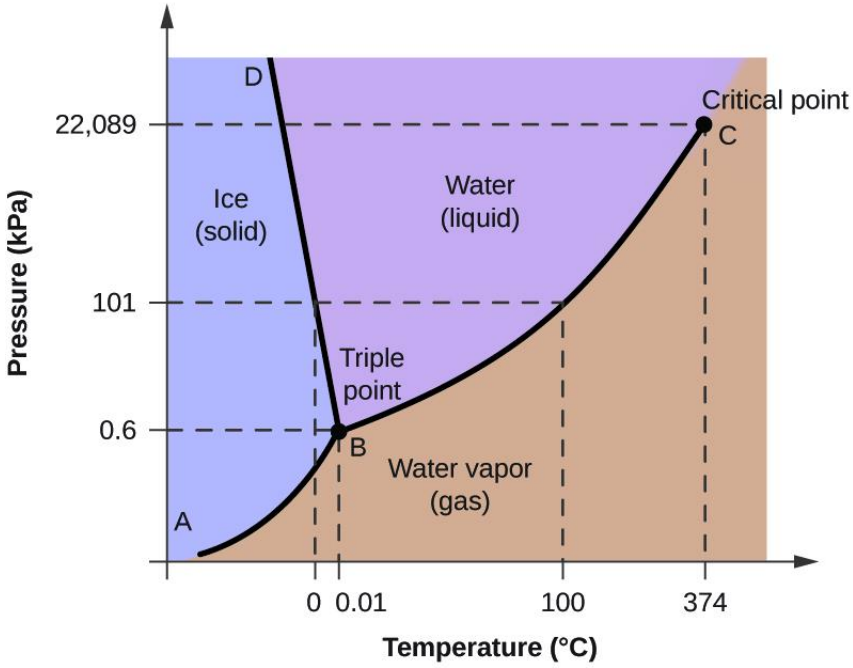
22,089 kPa and 374 ^{o}C

22,089 degrees Fahrenheit and 374 Newtons

The graph cannot tell us this information

0.6kPa and 0.1 degrees centigrade.

Question 11: use this graph to answer the question



Estimating from the graph, at a pressure of 1000 kPa what would the physical state of water be at 50°C?

A liquid

A solid

A mixture of ice and water

A gas

Questions 12 – relate to the science of Marine Biology and Conservation.

OSPAR is a multi-governmental organisation which monitors the health of the North-East Atlantic.

They recently published a survey of Bottlenose Dolphins to be found in the blue areas on this map.

Bottlenose Dolphins

This important message is taken from the OSPAR report:

"Coastal bottlenose dolphin populations declined through the 19th and 20th century and have remained low, but stable, in the 21st century. However, the population in the Sado Estuary (Portugal) has declined since monitoring began (1980s). Abundance and distribution of bottlenose dolphins (as top predators) is indicative of environmental health."

Question 12:

The last sentence from that OSPAR report, ("*Abundance and distribution of bottlenose dolphins (as top predators) is indicative of environmental health*.") is very important. Below are four attempts at re-writing that sentence.

Which attempt best explains <u>why</u> the "abundance and distribution of bottlenose dolphins (as top predators) is indicative of environmental health?

A bottlenose dolphin is a predator. If it is healthy then the environment in which it lives must be healthy too.

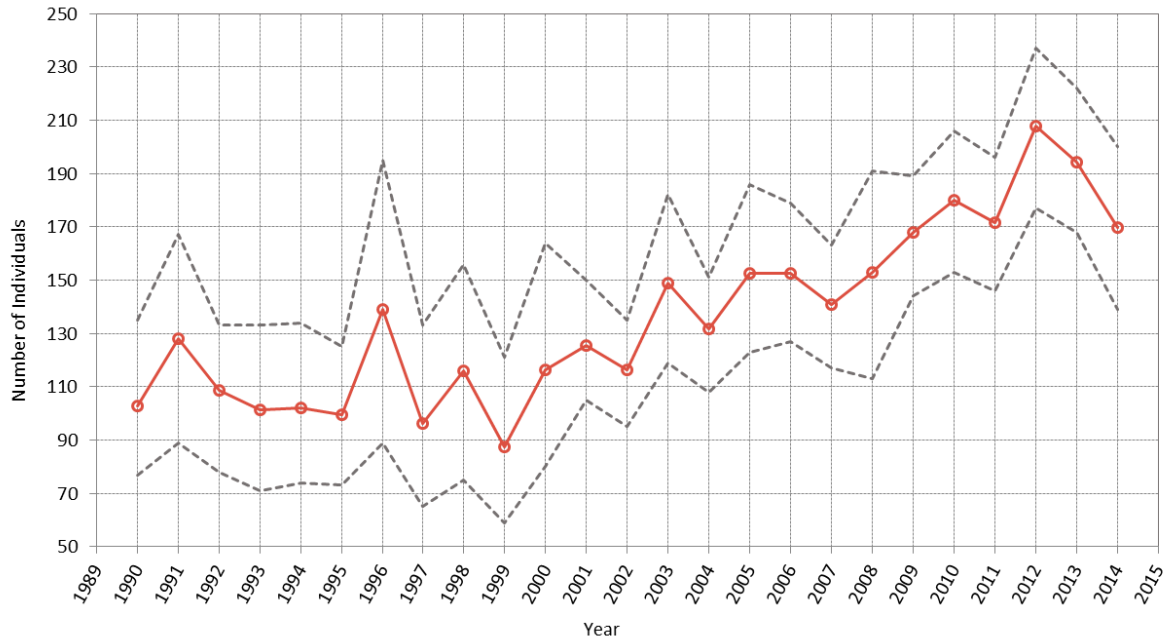
Bottlenose dolphins are part of a complex eco-system in the oceans. They feed on fish and those fish feed on other things, including plants. If dolphins can be found in good numbers, then all the other parts of the entire global eco-system need to be healthy too.

Bottlenose dolphins are part of complex eco-systems to be found in the oceans. They feed on fish and those fish feed on other things, including plants. In a region where the dolphins can be found in good numbers, we can conclude that the other parts of that regional eco-system must be healthy too.

The geographical distribution of bottlenose dolphins in the oceans tells us a lot about health of ocean ecosystems. This is because they are very successful predators and, therefore, they will not be found in places where there is a poor availability of food.

Questions 13 and 14 relate to this graph of bottlenose dolphin population changes:

Look at this graph from the OSPAR report:



Yearly abundance estimates for the population of bottlenose dolphins along the east coast of Scotland

Dashed lines show the 95% upper and lower confidence interval.

Question 13

From the graph, how many bottlenose dolphins could we say, with 95% confidence, were to be found living along the east coast of Scotland in 1996?

Somewhere between 90 and 195 but probably about 140.

Exactly 138

Anywhere between 78 – 134

195

Question 14

(The word "interannual" means "from one year to the next".)

Which one of these statements, referring to this graph of bottlenose dolphin population changes, is most likely to been taken from the OSPAR report? (In other words, which statement most accurately reflects what the graph shows?)

Despite interannual variability, the population of bottlenose dolphins is considered to be stable and may be showing signs of increase.

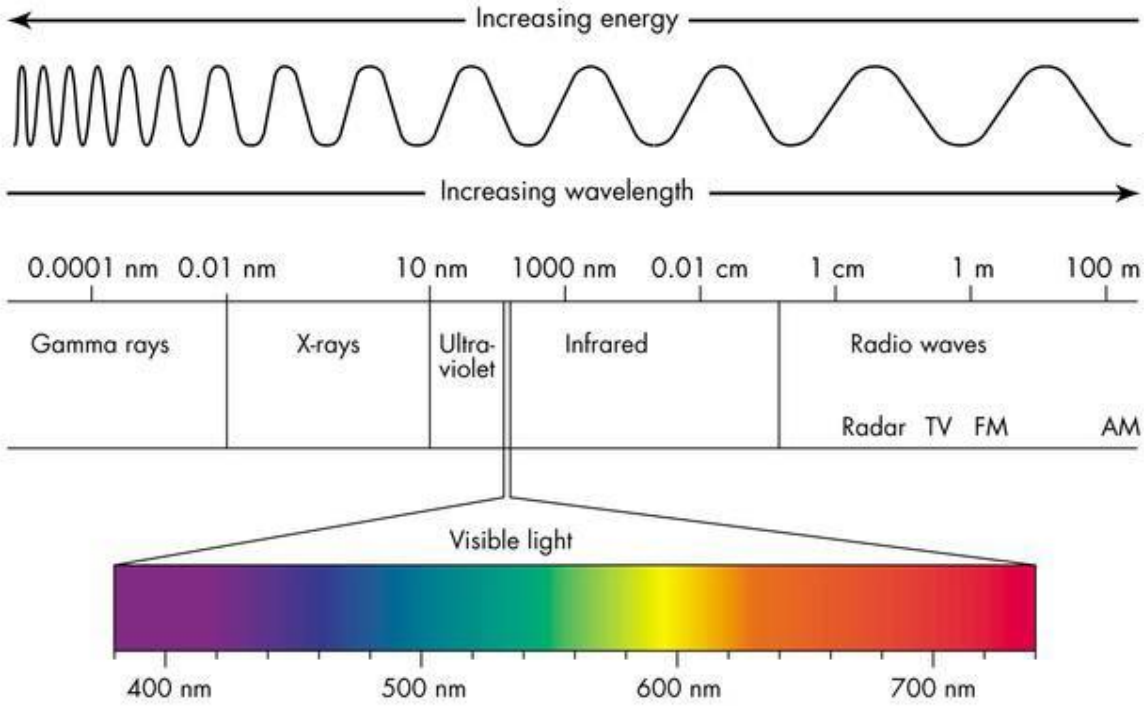
Despite recent conservation efforts, our interannual analysis shows that the population of bottlenose dolphins along the east coast of Scotland is in steep decline (falling quickly).

The drop in numbers seen in 1999 is extremely worrying and might indicate a possible total loss of all bottlenose dolphins along the east coast of Scotland.

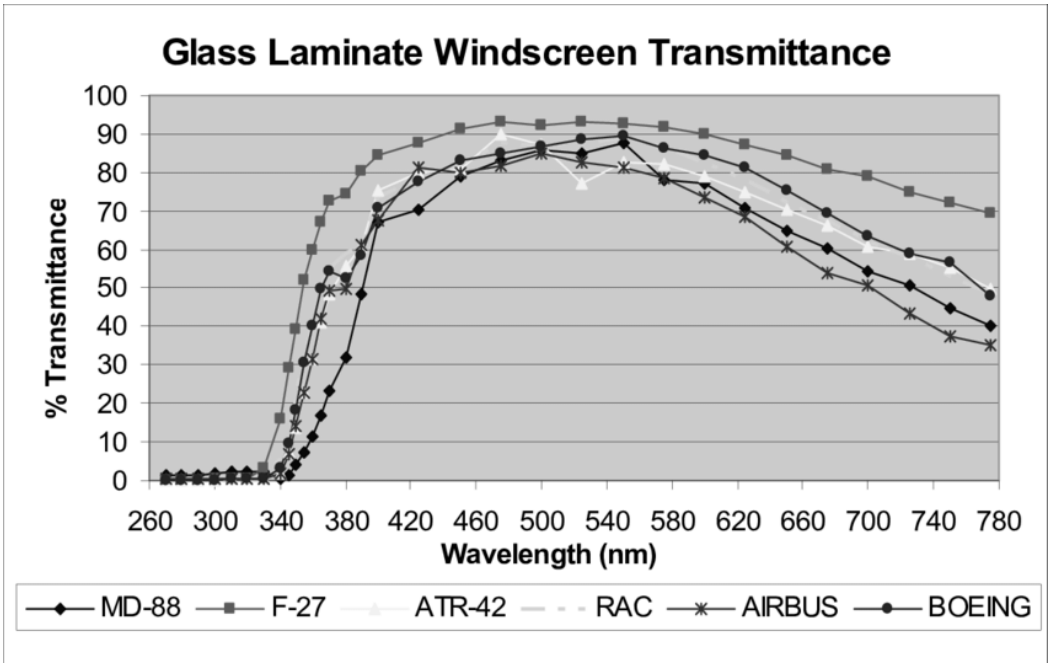
The population of bottlenose dolphins is showing very rapid growth and this may have serious consequences for regional ecosytems caused by over-predation.

Questions 15 – 18 relate to the information shown below about the electromagnetic spectrum and the graph showing how well light passes through different types of aircraft windshields (the glass the pilot looks through at the front of the plane.)

This chart gives us information about something called the Electromagnetic Spectrum. This is a family of types of energy, carried by waves at the speed of light. Visible light is one member of the spectrum, you can see the other types of light and rays listed below. (Gamma Rays, X-Rays, Ultra-violet, Visible light, Infrared and Radio waves.)



This chart shows the transmittance of light through glass windscreens (for aircraft). Transmittance means how much of the light shone onto the glass can pass through it. (A laminate windscreen is made of two layers of glass and a thin plastic mid-layer. It is strong and resistant to shattering.)



Source: ResearchGate

NOTE: on the graph, it is hard to see data for the windscreen RAC, this windscreen is not the correct answer for any of the questions which follow!

Question 15

Using the graph "Glass Laminate Windscreen Transmittance" which aircraft windscreen has the lowest transmittance of light of wavelength of 780nm?

Airbus

Boeing

MD-88

F-27

Question 16

Using the graph "Glass Laminate Windscreen Transmittance" and the additional information given above it about the electromagnetic spectrum, which glass is best at transmitting visible light?

F-27

Boeing

Airbus

ATR-42

Question 17

Using the information provided about the Electromagnetic Spectrum, can you tell **from the graph**, "Glass Laminate Windscreen Transmittance", which part of the electromagnetic spectrum cannot pass through the windscreens?

Ultra-Violet

Visible

Radio Waves

Infra-Red

Question 18

Using the graph "Glass Laminate Windscreen Transmittance" and the additional information given above it about the electromagnetic spectrum, which windscreen would you predict is most likely to be best at screening (blocking out) radio waves?

Airbus

Boeing

ATR - 42

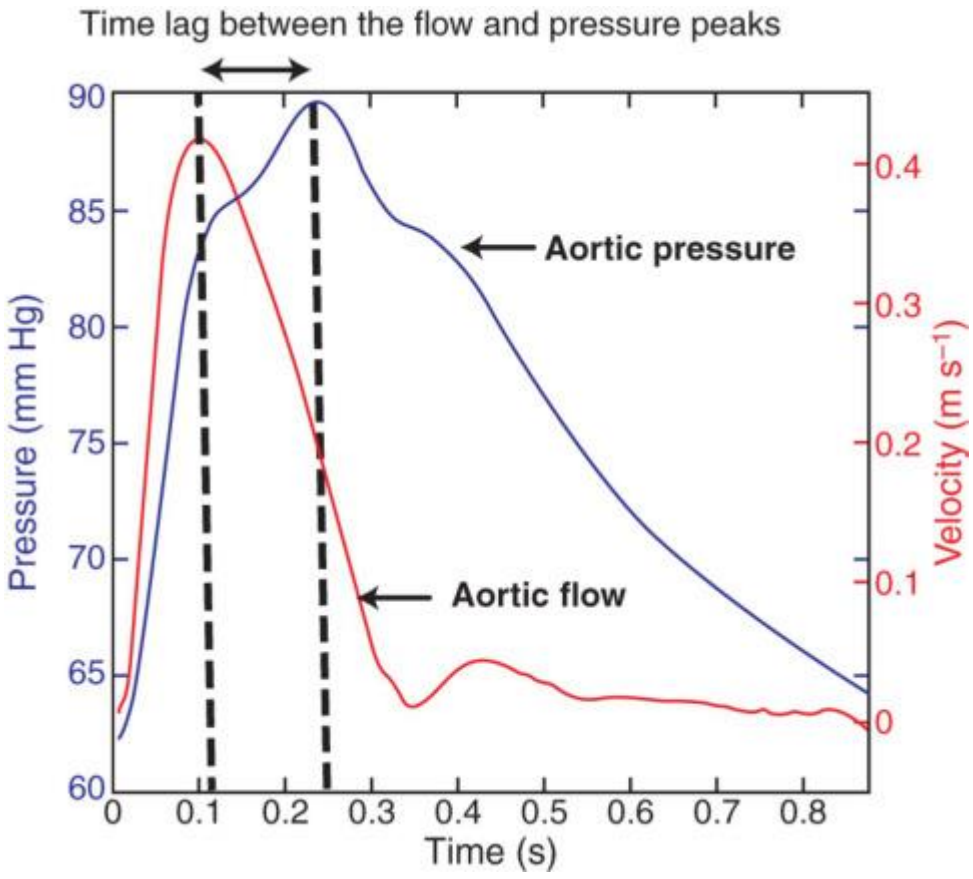
F-27

Questions 19 – 21 relate to the heart and blood flow

Additional information: The muscle tissue in the heart contracts as blood is pumped. As the part of the heart called the left ventricle contracts (or squeezes) it pumps blood through the aorta, a large blood vessel, sending oxygenated blood on its way round the body.

This graph shows how blood pressure and blood velocity (speed) varies with time as the left ventricle beats to push blood out of the heart and through the aorta. The graph calls these things "aortic pressure" and "aortic flow"

Blood pressure is being measured in units of millimetres of mercury (mmHg) and blood flow velocity is being measured in metres per second (ms^{-1}).



Question 19

What does this graph show us about the relationship between Pressure (mmHg) and Velocity (ms^{-1})?

They are proportional; a higher blood velocity corresponds to a higher blood pressure and vice versa.

They are inversely proportional; a low blood velocity corresponds to a high blood pressure and vice versa.

The pressure is proportional to the square of the velocity, eg: as the velocity doubles, the pressure becomes four times greater.

There is no connection between blood velocity and blood pressure.

Question 20

From the graph, how long is the contraction (or beat) of the heart (which is causing the blood to flow) likely to last?

Slightly more than 0.1 second

Slightly more 1 second

The graph does not tell us

It carries on for the lifetime of the person

Question 21

What does the graph show about the peak (maximum) blood flow speed compared to the peak (maximum) blood pressure?

The peak blood pressure occurs a short time after the peak blood velocity.

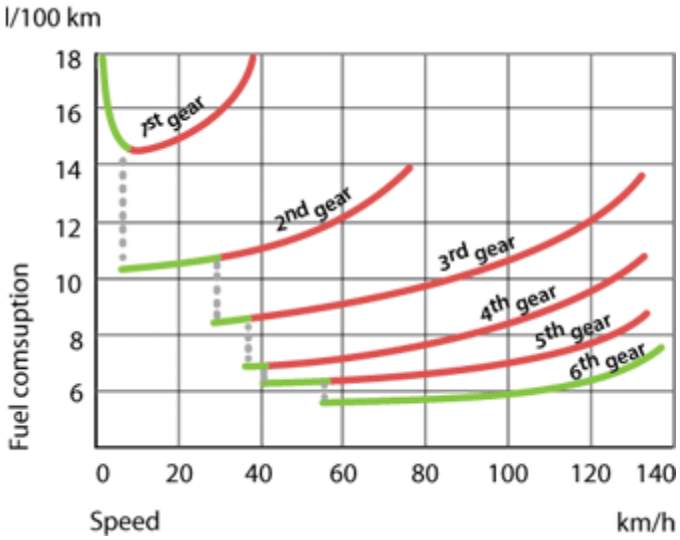
The peak blood pressure occurs a short time before the peak blood velocity.

The peak blood pressure occurs at the same time as the peak blood velocity.

The graph does not give us this information.

Questions 22 – 26 are to do with how much fuel a car uses in different gears and at different speeds

A certain car has 6 forward gears. Here is a graph showing how fuel consumption varies with speed for that car when being driven in each of the different gears.



Additional Information: This graph uses units commonly used in most European countries. The speed is shown in kilometres per hour (km/h) and the fuel consumption is shown as the number of litres of fuel used to cover a distance of 100 km (l/km).

In the UK, speed of road vehicles is shown in miles per hour (mph) and fuel consumption is shown with units of miles covered per gallon of fuel. (mpg)

There are 4.55 litres in a (UK) gallon and 1.61 km in 1 mile.

Question 22

From the graph, which gear will provide the best fuel consumption at a speed equivalent to 30 **mph**? (THINK! You have to convert miles per hour to kilometres per hour before reading off the graph. See above for useful information.)

5^{th} gear

4^{th} gear

3^{rd} gear

2^{nd} gear

Question 23

Which of these values represents the best (ie: most efficient) fuel consumption? (Think carefully about what the units are telling you.)

8 litres/100km

10 litres/100km

12 litres/100km

18 litres/100km

Question 24

Which calculation correctly converts a fuel consumption of 5 litres per 100 km (5 l/km) into the equivalent miles per gallon (mpg) figure? (See above in the additional information for the conversion values you will need for this question)

(100 ÷ 1.62) ÷ (5 ÷ 4.55) = 56.17

(100 ÷ 5) x (4.55 ÷ 1.61) = 7.08

((100 ÷ 4.55) x 5) – 4.55 = 105.34

(100 ÷ (5 ÷1.61)) + 4.55 = 36.75

Question 25

From the information shown of the graph, which gear gives the worst (least efficient) fuel consumption?

1st

2nd

3rd

4th

Question 26

And finally for this set of questions, use the graph to estimate the most likely top speed for this vehicle in kilometres per hour km/h.

137

88

243

Questions 27 – 32 are about three different small aircraft, the questions let you show us how well you can read information from tables of data.

Cessna 172s

Cirrus SR22

KAI KC-100

Here is a data sheet about three different small aircraft. It uses non-metric units.

The word "Variant" is being used to mean the type of aircraft.

"Fuselage" is the main body of an aircraft.

"MTOW" stands for Maximum Take-Off Weight

(nm: nautical miles)

Variant	Cessna 172s	Cirrus SR22	KAI KC-100
Passengers	3	3	3
Flight crew	1	1	1
Length	27ft 2in	26 ft	28ft 2in
Wingspan	36ft 1in	38ft 4in	37ft 4in
Tail height	8ft 11in	8ft 11in	9ft 4in
Fuselage max diameter	48 in	50 in	55.9
Max takeoff weight (lbs)	2,450	3,400	3,00
Max range (nm)	696	1,170	1,321
Max cruise speed (knots)	122	185	240
Typical cruise speed (knots)	105	170	220
Take off run at MTOW (ft)	1,685	1,594	1,600
Landing field length (ft)	1,295	1,141	1,200
Altitude ceiling (ft)	14,000	17,500	18,000
Engine power (hp)	180	310	315

Question 27:

Using the table of data above, which value is most likely to have been recorded incorrectly in the table?

Max take-off weight of the KAI KC-100

Typical Cruise Speed of the Cessna 172s

Landing field length of the Sirrus SR22

Engine power of the Cessna 172s

Question 28

Using the table of data above, which aircraft is likely to have the most space inside for passengers and their luggage?

KAI KC-100

Cessna 172s

Sirrus SR22

The table does not tell us this information.

Question 29

Using the table of data above, which aircraft has the lowest altitude ceiling (can climb to the lowest maximum height)?

Cessna 172s

KAI KC-100

Sirrus SR22

The table does not tell us this information.

Question 30

Using the table of data above, which aircraft is most likely to be the cheapest to buy and operate?

Cessna 172s

KAI KC-100

Sirrus SR22

There is simply no way to guess this from the information provided in the table.

Question 31

Using the table of data above, how many seats are these aircraft likely to have inside them?

4

1

3

The table does provide any relevant information.

Question 32

Using the table of data above, which aircraft could be adapted to land on water?

The table does not tell us any information we can use to work this out.

Cessna 172s

Sirrus SR22

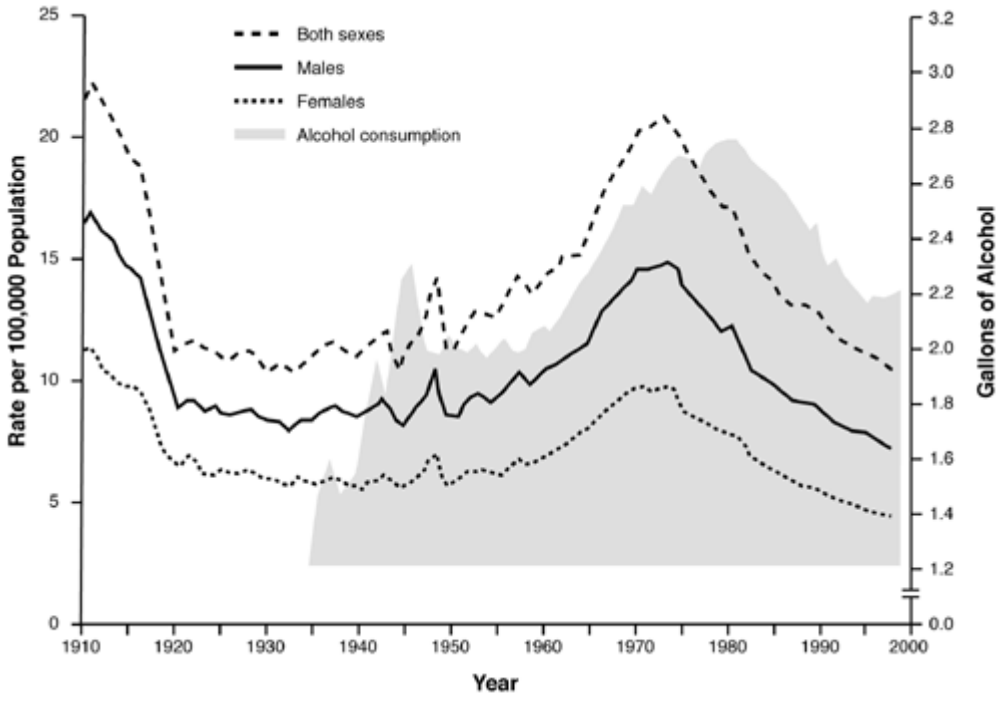
KAI KC100

Questions 33 – 36 relate to the graph showing alcohol consumption and rates of liver disease in the United States during the 20th Century. This is the final set of questions.

This graph shows how the number of deaths from a liver disease called cirrhosis varied during the 20th Century in the United States of America.

"Rate per 100,000 Population" means the number of deaths from cirrhosis per 100,000 people.

"Gallons of alcohol" refers to the mean (average) quantity of alcohol consumed per person per year.



Reference: The Epidemiology of Alcoholic Liver Disease, R. E. Mann, R.G.Smart, R. Govoni, Alcohol Research & Health. 2003;27(3): 209-219,

Question 33

Which of these observations can be made by studying the graph shown above?

A: Fewer women die from cirrhosis than men.

B: Death rates from cirrhosis approximately follow (or track) the alcohol consumption data from 1935.

C: Female deaths from cirrhosis were at their lowest levels at the end of the 20th century.

A, B and C

Just A and B

C only

A only

The Prohibition, effectively banning alcohol consumption from 1920 – 1933, explains why there was a drop in cirrhosis deaths during those years. Also, perhaps, you can see a spike upwards in alcohol consumption in 1945, after World War 2.

Question 34: The graph shows that deaths from cirrhosis had fallen to Prohibition levels by the year 2000. Which of these suggestions is the most plausible explanation for that?

Health Education. A growing awareness in the population that drinking heavily is not good for you.

The population of the United States had fallen.

Alcoholic drinks were made to higher safety standards by the end of the 20th Century

Drinking and driving was made illegal.

There are no more questions for you to attempt. You can go back and check your answers. Press the "submit" button when you are ready to send your answers to be marked.