Senior Phase Natural Science Olympiad 2023

Energy & Change

1. **ANSWER: A**

A. Is losing potential energy and gaining kinetic energy. This is conservation of mechanical energy.

2. **ANSWER: C**

Electromagnetic forces. The three other distractors are all contact forces.

3. **ANSWER: D**

Johannesburg. A, B, and C are all coastal cities situated at sea-level. Johannesburg, on the Highveld at an altitude of 1750m, is the obvious exception (this alone should tip learners off). The boiling point of any liquid depends on the air pressure. At nearly 2000m above sea-level, the air pressure in Johannesburg will be **lower** than at sea-level, so water will boil at less than 100^{o}C.

4. **ANSWER: D**

Sunlight is polychromatic. It is our perception of sunlight that is trichromatic and this is due to the three types of cone cells in our eyes which are sensitive to short (blue), medium (green), and long (red) wavelengths of light.

Since both RED and BLUE are being absorbed, the shirt must appear to be green.

Question 5 and 6 are related to the diagram of the National Grid

5. **ANSWER: A**

Less electric energy is lost as heat.

B is wrong because we do not use DC on the grid.
C is a distractor
D is wrong because smoke doesn't come out of the cooling towers – it is steam and water vapour.

6. **ANSWER: D**

All three of these are actually advantages saving materials and costs. Since the current is smaller the high-voltage cables can be thinner so they weigh less and need less support. In addition, Eskom uses aluminium for the cables which is lighter than copper and also cheaper than copper – so it is less likely to attract cable thieves.

7. ANSWER: B

All the plug sockets are connected in parallel.

Household wiring is always connected in parallel. This has the following advantages:

- ALL the connected components have the same voltage i.e. 230 volts.
- Different parts of the circuit can be controlled individually e.g. kettle and TV and lights.
- If one component fails it does not affect the other components.

7. **ANSWER: D**

It is safe to sit in a car because the metal frame will conduct the lightning around the outside of the car to the ground (N.B. It has nothing to do with the tires).

The fact that a metal box (like a car or an aeroplane) is safe is because the metal forms a “Faraday Cage” preventing charge from entering the box. This has been misinterpreted and people jump to the wrong conclusion that the rubber tyres can somehow prevent a multimillion volt charge – which has travelled several thousand metres from the cloud to the car – from leaping the last 10 cm from the car body to the ground. The truth is that the charge travels around the OUTSIDE of the metal frame – so people inside are safe as long as they don’t lean against the door. Note: Sitting under a tree is dangerous, and so is standing on a hilltop – it is safer to crouch down in the rain with your shoes ON. If you lie on the ground even inside a hut during a thunderstorm, you may be injured or even killed if lightning strikes the top of the nearby koppie. The charge can run along the wet ground outside and can kill or hurt people inside – lying down is dangerous because that increases the amount of contact and allows more charge to enter your body (that is why some people die while others survive).

8. ANSWER: D

Gamma Rays**:** From the diagram, gamma rays are the most energetic and, therefore, the most dangerous – they can penetrate **inside your bones.** X-Rays can penetrate your flesh but not your bones. Ultra violet rays cause damage to skin (sun burn). Infrared is heat, and can be dangerous is very intense or very long exposure.

9. ANSWER: C

Ultraviolet rays. In the upper atmosphere there is a thin layer of ozone. When a UV-ray strikes an O_3 molecule the energy is absorbed because it converts the O_3 to a normal O_2. The ozone needs to be replenished to retain its protective function. Look up the “Chapman Cycle” on the Internet.

11. **ANSWER: A:** “Soft” iron core, about 5 metres of insulated wire, a 6 volt battery and a switch.

B A steel bolt, about 5 metres of insulated wire, a 6 volt battery and a switch.

A steel bolt is far too hard, It won’t magnetise well AND it will keep the small amount of magnetism you have given it – so it won’t switch fully ON & OFF like a proper electromagnet.

C & D A wooden dowel or a Plastic Ruler are non-magnetic materials and will do nothing to enhance the magnet.

“SOFT” iron sounds like a contradiction, but pieces of iron are <u>not all</u> <u>equally</u> hard.

A good guide is “if-it-has-a-screw-thread-for-a-nut” then it is too hard for an electromagnet.

Items like spanners, chisels, drill bits and bolts are made of “steel” and are unsuitable to be used as the core of an electromagnet because they are too hard.

Steel reinforcing bars used in concrete are also too hard, but round-bar or square-bar as used in making burglar guards are actually soft enough (Burglars cut through them quite easily).

12. **ANSWER: C**

The angle of refraction is between the light ray and the “normal” as it goes into the water.

13. **ANSWER: A** Since the water is above its normal boiling point it will “flash” instantly into steam and blast the hot food all over the kitchen severely burning the chef and his assistants.

Note: This is “Science-in-the-Home” and knowing this can save you from serious burns and also eye damage.
ONE litre of boiling water will “flash over” forming nearly 2000 litres of super-heated steam. The entire kitchen will be engulfed in scalding hot steam AND because of the “Latent Heat of Phase Change” it will burn you 8-times more badly than boiling water.

The three distractors B, C, and D are actually dangerous pieces of ignorance.

B. Nothing will happen because the water will instantly drop to its normal boiling temperature.
C. The water will instantly turn into steam but the food will remain in the pot.
D. The water will instantly turn into steam but this will lower the temperature to normal.

14. **ANSWER: C**

Many people, including some science teachers, think that GOLD is the best conductor. However, although it is a "Noble Metal" and does not rust AND is the most ductile and malleable metal, it is NOT the best conductor – it ranks only 3rd.
The conductance of the four best conductors are as follows:

Silver	63	Ms/m @ 20^{o}C
Copper	58	Ms/m @ 20^{o}C
Gold	41	Ms/m @ 20^{o}C
Aluminium	35	Ms/m @ 20^{o}C
Iron	1	Ms/m @ 20^{o}C

Don't worry about the Units. Just note that Silver is slightly better than copper, and 63x better than Iron.

Gold is 3rd best and Aluminium is 4th.

So why do we use copper?? It is nearly as good as silver and it corrodes less, and of course it is cheaper. Aluminium is 4th best, cheaper than copper and weighs less. We use Aluminium in High Voltage Powerlines of the National Grid.

So Where and Why do we ever use GOLD?
Because gold does not rust AND because gold can be drawn (pulled) into extremely thin wires it is used (sparingly) in computer chips making it possible to miniaturise the chips (which makes them faster).

15. **ANSWER: C:** Both A & B are correct.

LIFE and LIVING

16. **ANSWER: B** Sends electrical impulses to control the heart beats.

17. **ANSWER:** C Isolate him and arrange for his mother or father to fetch him as soon as possible. After our experience with the Covid Pandemic this should not need explanation.

18. **ANSWER: D** Oxygenated blood can be carried from your lungs to your muscles so that they can do work.

19. **ANSWER: C** They have an exoskeleton

20. **ANSWER: A** Ultraviolet radiation in sunlight
Some learners will be aware of the SPF (i.e. Sun Protection Factor) used in marketing sun screen. Even those who do not use such products can still answer this question using the Information given in Questions 8 and 9.

21. **ANSWER: A** They can gather as much sunlight as possible for photosynthesis.

22. **ANSWER: A** RED & BLUE but not GREEN

Photosynthesis is a complex series of reactions which can be divided into the Light Reactions and the Dark Reactions. During the Light Reactions, RED and BLUE energies are used in certain stages. The energy of GREEN LIGHT **is not used** and is radiated outwards. **That is why plants appear GREEN – it is this colour (energy) that IS NOT USED.**

23: **ANSWER: B** Phytoplankton. Phytoplankton are responsible for producing **more oxygen** via photosynthesis than all the green plants on Earth (that includes all the rainforests).

24. **ANSWER: C** Animals like cats and dogs have rods, but no cone-shaped photoreceptors in their eyes. We know about the roles of rods and cones from studies of humans. We apply that knowledge to interpret how other animals can see.

25. **ANSWER: B** A worker communicating information on a food source. By marking specific bees (using a dot of paint) who were feeding on a saucer of honey and then videoing their behaviour when they returned to the hive, scientists were able to interpret and decode the actions of the "waggle dance." By placing saucers in various locations in different directions and at various distances, the scientists were able to collect a range of data and applied that to distance, direction, and even food-type of the targets. After a lot of careful observation the scientists were able to decode and understand the different messages.

26. **ANSWER: D** Mating with the queen.

27. **ANSWER: C** nerves and hormones

28. **ANSWER: A** This will provide the wasp larva with a source of fresh food when it hatches. Parasitic behaviour like this is fairly common in the insect world. Although the spider is paralysed, we have no way of knowing whether the victim feels any pain as it is eaten alive. It lives long enough to ensure that the meat stays fresh. This may or may not be painful – we just don't know. Our human empathy (kindness) makes us hope that the spider feels no pain, but nature can be cruel.

29. **ANSWER: B** Eyes that are forward facing giving binocular vision. Forward-facing eyes giving binocular vision (like we have) allows the predator to judge distance to the target very accurately – this is a key requirement for successful hunting.

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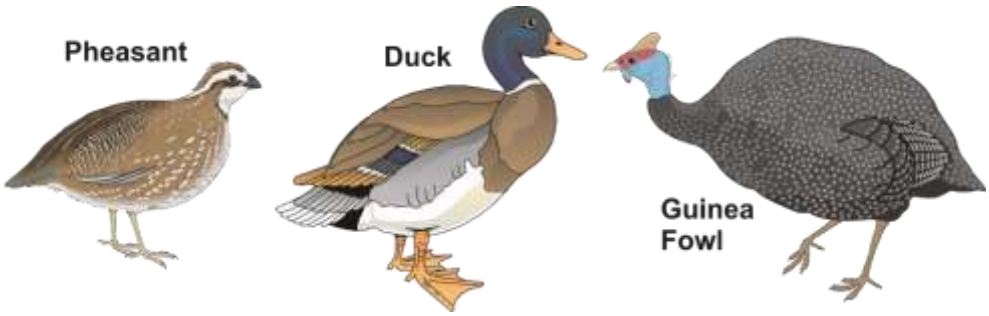
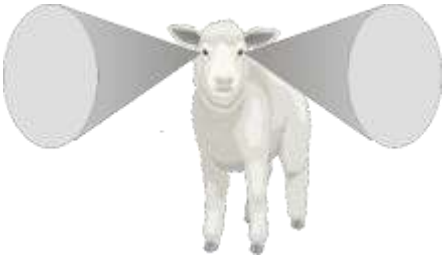
PREDATORY BIRDS: Note forward-facing eyes focussed on target



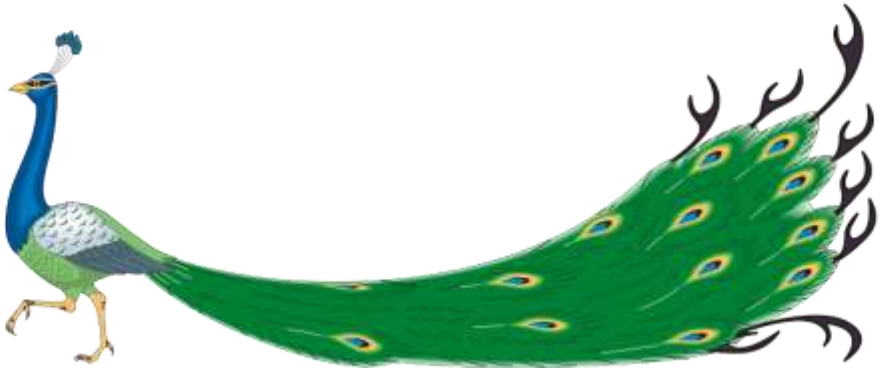
PREDATORY MAMMALS: Note forward-facing eyes focussed on target

PREY MAMMALS: Note eyes facing sideways – they just need to notice movement



30. **ANSWER: B** Show off and impress females for mating.

In most bird species it is the males that have to put on a show to attract females



MATTER and MATERIALS

31. **ANSWER: B**

Volume = length x width x height

The volume of the cube is **2cm x 2cm x 2cm = 8cm^3.**

$$Density = \frac{Mass}{Volume}$$

$$Density = \frac{40g}{8cm^3} = 5.0\ \frac{g}{cm^3}$$

Therefore, **the cube is NOT gold**, but pyrite.

The value of pyrite is R 5.50 per gram.

The value of the cube is therefore **40 x R 5.50 = R 220.00**

32. **ANSWER: D**

The independent variable is the variable that you manipulate or change during the investigation. This change will influence the value of the dependent variable which is measured during the investigation.
A scientific investigation is only a fair test if one independent variable is changed at a time. All other variables, known as the control variables, must be kept constant during the investigation.
In this investigation, the length of the Mg ribbon (independent) is changed and its effect on the amount of hydrogen gas (dependent) is measured. Control variables in this investigation is the concentration of the acid (and temperature).

33. ANSWER: B

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

In this equation, we have 2 sodium, 4 hydrogen and 2 oxygen particles as reactants (left of the arrow) and the same amount of each as products (right of the arrow). In any reaction mass is conserved. None of the other options have balanced equations.

34. **ANSWER: C**

Elements cannot be chemically broken down into simpler substances and consist of single atoms or diatomic molecules (2 of the same atoms bonded together). These elements are arranged on Mendelev's Periodic Table. Blocks 2 represent 2 different diatomic molecules, block 3 represent atoms of the same element and block 4 represent a single diatomic element.
Block 1 represent a pure compound made up of two different elements. Elements and compounds are pure substances. Block 2 consist of 2 different diatomic elements. It is not a pure substance, but a mixture of substances.

35. **ANSWER: D**

The Law of Conservation of Matter states that matter cannot be created or destroyed, only changed. In a chemical reaction matter is conserved and the number of each type of atom that react must balance with the number of those atoms that are formed as products. The balanced equation is:

$$\mathbf{4Fe + 3O_2 \rightarrow 2Fe_2O_3}$$

4 **Fe** atoms react with 3 $\mathbf{O_2}$ molecules to form 2 $\mathbf{Fe_2O_3}$**.**

36. **ANSWER: C**

Statement I is incorrect. The same mass of oxygen gas will contain the same number of particles.
Statement II is correct. Adding more gas to balloon 1 increases the pressure and the balloon expands (volume increase) under the higher pressure
Statement III is correct. A characteristic of gasses is that they expand (move further apart) to fill the volume of a container.

37. ANSWER: B

Water is unique because its solid state (ice) is less dense than its liquid phase. Ice has a density of 0.917 g/cm³ at 0 °C, whereas water has a density of 0.9998 g/cm³ at the same temperature. Water molecules begin to form a lattice structure in which they are farther apart from each other as the temperature drops to 0 °C.

38. **ANSWER: B**

Statement I is correct. As seen in the diagram, a power source (battery) is needed to provide the electrical energy for the chemical reaction to occur. The electric energy is converted to chemical energy, stored in the bonds of the products formed during the reaction.
Statement II is incorrect. The positive Cu^{2+}-ions will be attracted to the negative electrode and will be reduced to copper. Reduction (gain of electrons) happens at the cathode. Oxidation happens at the anode.

Statement III is correct. The negative Cl^--ion will be oxidized to Cl_2 gas at the positive electrode. The gas will escape as bubbles.

39. **ANSWER: C**

If the downward gravitational force is less than the upward buoyancy force then the object floats, otherwise it sinks. That is, if an object weighs less than the amount of water it displaces then it floats otherwise it sinks. A boat floats because it displaces water that weighs more than its own weight.

40. **ANSWER: B**

When an acid reacts with a metal, hydrogen gas (H_2) is released. To test for hydrogen gas, a glowing splint brought near the gas will produce a popping sound. The glowing splint provides the spark for hydrogen gas to react with oxygen in the air.
A glowing splint that re-lights is the test for oxygen gas. Oxygen is needed for combustion.
Clear lime water turns murky when in contact with carbon dioxide.
Litmus paper will turn white when in contact with chlorine gas (Cl_2) due to the bleaching effect of chlorine gas.

41. **ANSWER: B**

When the metal is covered with the acid, adding more acid will not have any influence on the speed of the reaction.
To speed up the reaction, more effective collisions must occur between the reacting particles per unit time.
Replacing the acid with a more concentrated acid, increasing the temperature or using zinc powder will cause more effective collisions per unit time and therefore increase the rate of the reaction.

42. **ANSWER: B**

Mercury is the only metal that is in liquid form at room temperature. It is used inside thermometers because of its ability to shrink at lower temperature and expand at higher temperatures.
Chlorine gas (Cl_2) is used to purify water our drinking water. Chlorine is a reliable disinfectant against a wide spectrum of pathogenic (that cause sickness) organisms.
Sodium chloride is the chemical name for table salt (NaCl).
Argon gas is an inert gas used in electric bulbs to prevent corrosion of its tungsten filament. Since it doesn't react with tungsten, it stops the filament from burning away in the presence of oxygen. Hence, increases the bulb's life.
In a nuclear reactor the uranium fuel is assembled in such a way that a controlled fission chain reaction can be achieved. The heat created by splitting the U-235 atoms is then used to make steam which spins a turbine to drive a generator, producing electricity. Koeberg nuclear power station in Cape Town is currently the only one on the entire African continent.

43. **ANSWER: D**

Water cools down the fire and is suitable for paper, wood & textiles.

Foam cools and smothers, while dry powder and CO_2 only smothers the fire.
They are all suitable for use on flammable liquids such as petrol.
Wet chemicals cool and smothers the fire and is suitable for oils and fat.
Dry powder and CO_2 are suitable for electrical fires.

44. **ANSWER: B**

Room temperature is at 25 °C.
All the compounds have a melting point (changing from solid to liquid phase) below 25 °C.
Methane and butane, however, have a boiling point (changing from liquid to gas phase) below 25 °C. Therefore, only ethanol, acetone and benzene will be a liquid at room temperature.

45. **ANSWER: B**

I Magnetism – iron is magnetic and copper not.
II Evaporation – water will evaporate (change into gas phase) when boiled, leaving the salt behind.
III Distillation - Compounds in the mixture have different boiling points. Since ethanol boils at a lower temperature (78.5 °C) than water, the alcohol vaporizes while most of the water remains a liquid.
IV Chromatography – When black ink moves through filter paper, different colours will move at different speeds through the filter paper and separate.

EARTH AND BEYOND

46. **ANSWER: C**

Newton’s theory of gravity helped us understand many things about the universe. It explains why the planets continue orbiting around the sun, the tides of the sea and so much more about our world.

47. ANSWER: B

Stars are born in vast clouds of gas and dust. Stars spend most of their lives on the main sequence fusing hydrogen gas to helium gas. Stars eventually swell up to form a red giant star. Stars like the Sun end their lives as planetary nebulae and white dwarfs.

48. ANSWER: A

High and low tides are caused by the moon. The moon's gravitational pull generates something called the tidal force. The tidal force causes Earth—and its water—to bulge out on the side closest to the moon and the side farthest from the moon. These bulges of water are high tides. A Full Moon is when the Sun

and the Moon are aligned on opposite sides of Earth. Full Moon is the most striking moon phase when the entire face of the Moon is lit up.

49. **ANSWER: D**

GPS satellites can transmit geolocation and time information to GPS receivers anywhere on or near Earth if there is an unobstructed line of sight to the satellites, meaning that the GPS signals can pass through glass and plastic, but not buildings.

50. **ANSWER: B**

The overall chemical reaction in a hydrogen fuel electrochemical cell involves the oxidation of hydrogen by oxygen to produce only water.

51. **ANSWER: C**

Hydrogen gas will react with oxygen gas to create an explosion when ignited by a spark. This led to the Hindenburg disaster in 1937 when the airship burst into flames and completely burned in 37 seconds. 13 Passengers and 22 crew lost their lives in the disaster. Helium is an inert gas, meaning it is unreactive and will not react with any substance.

52. **ANSWER: C**

The value of the mass number of hydrogen is 1, while the mass number of helium is 4. Considering the mass number, the helium is four times heavier than that of the hydrogen element. Helium consist of single atoms while hydrogen exist as a diatomic element in the form of hydrogen gas (H_2). Therefore, Helium gas is twice as heavy as hydrogen gas.

53. **ANSWER: A**

Earthquakes are caused by tremors due to the shaking of ground. These tremors are caused by disturbances caused in the tectonic plates. These plates are deep down inside the uppermost layer of the earth called the crust, which ranges from the earth's surface to about 800 kilometers deep.

54. **ANSWER: C**

The Southern Cross – also known as Crux – is an iconic constellation for people south of the equator. It’s visible every clear night, and its stars shine brightly enough to be picked out easily, even from urban locations and could be used to determine which direction is South.

55. **ANSWER: A**

The Square Kilometre Array (SKA) is an intergovernmental international radio telescope project being built in Australia (low-frequency) and South Africa (mid-frequency). The South African MeerKAT radio telescope is situated 90 km outside the small Northern Cape town of Carnarvon in the Karoo.

56. **ANSWER: B**

ZACube-1 orbited the earth about 15 times a day (every 96 minutes)

57. **ANSWER: D**

Mass is a fundamental measurement of how much matter an object contains. Your mass will be the same on the earth and moon.
Weight is a measurement of the gravitational force on an object. It not only depends on the object's mass, but also on its location. Therefore, weight is a measure of force. The moon is much smaller than the earth and its gravitational force is around six times smaller. Your weight on the moon would be six times smaller than on earth.

58. **ANSWER: B**

Earth's tilted axis causes the seasons. Throughout the year, different parts of Earth receive the Sun's most direct rays. So, when the North Pole tilts toward the Sun, it's summer in the Northern Hemisphere and winter in the Southern Hemisphere. South Africa will not receive direct sunlight in this position.

59. **ANSWER: A**

Extrapolating the point for Mercury on the graph to the X-axis shows that it is the shortest distance from the sun.
Extrapolating the point for Mercury on the graph to the Y-axis shows that it is orbiting at the highest speed.

60. **ANSWER: C**

It takes the Earth one year, or 365 1/4 days, to completely orbit the Sun.
As the Earth orbits the Sun, the Moon orbits the Earth. The Moon's orbit lasts 27 1/2 days, but because the Earth keeps moving, it takes the Moon two extra days, 29 1/2, to come back to the same place in our sky.
The Earth's axis runs from the North Pole to the South Pole. It takes the Earth 24 hours, or one day, to make one complete rotation around this invisible line.
