SOLUTIONS TO SEMINAR QUESTIONS HELD AT HOLY CROSS LAKE VIEW ON 28TH SEPTEMBER 2024

ITEM ONE

a)A rainbow is formed when there is a lot of water droplets in the atmosphere before or after a drizzle. A rainbow is formed due to the refraction, dispersion, total internal reflection, and scattering of light as it enters and comes out of a water droplet. When sunlight passes through raindrops in the atmosphere, the light is refracted as it enters the droplet, which causes it to split into its constituent colors **(**dispersion) because different colors have different refractive indices in water / different speeds in water. The light then undergoes total internal reflection inside the droplet, and when it exits, it is refracted again, further separating the colors. The result is a spectrum of colors that appears as a circular arc in the sky because the sky is spherical as it surrounds a spherical earth. Note that, it is possible to have two rainbows, one faint and another one clear. (Further research)

b) it is difficult to differentiate the colors in the rainbow because it is an impure spectrum**.** An impure spectrum is where the colors overlap each other. Therefore, it becomes difficult to differentiate the colors by counting

c) The mother was able to communicate with the grandmother through a telephone or mobile phone, which uses electromagnetic waves **(**specifically radio waves). When the mother speaks, sound energy is converted into electrical signals by the telephone sender which are then converted to radio waves by the phone which are then sent to the communication satellite through the uplink dish. The satellite then sends the radio waves to the downward link which then sends to the receiver phone. Through the above process, the mother can communicate to the grandmother.

d) A single string can produce different sound notes depending on the vibrating length and tension applied to the string. When a musician presses a string at different points, the vibrating portion of string changes which makes the string to produce sound notes of different pitches due to the difference in the frequency of the vibrations. A shorter vibrating length produces a higher pitch, while a longer vibrating length produces a lower pitch. This enables the musician to produce different sound notes using one string.

ITEM TWO

a) Solid concrete blocks are made entirely of concrete and have no voids. They are denser, heavier, and generally stronger, making them ideal for load-bearing structures like walls that must support significant weight. Solid brocks can also be reinforced

Hollow concrete blocks, on the other hand, have hollow spaces (voids) within them. They are lighter, easier to handle, and provide better insulation against heat and sound. Hollow blocks are typically used for non-load-bearing walls or partition walls and can reduce the overall weight of the structure. Therefore, they are suitable for constructing top floors of storeyed structures or bungalows

b) Durability: Concrete is strong and long-lasting, able to withstand weathering, erosion, and natural elements like wind, rain, and sunlight.

Fire resistance: Concrete is non-combustible and does not burn, making it an excellent material for fire-resistant buildings.

Energy efficiency: Concrete has good thermal mass, meaning it can store heat and help regulate building temperature, improving energy efficiency.

Low maintenance: Once set, concrete requires little maintenance compared to other construction materials like wood or steel.

Versatility: Concrete can be molded into various shapes and structures, making it highly versatile for construction projects.

c) A machine is said to be perfect if it operates without any losses, meaning its efficiency is 100%. To check if this machine is perfect, we shall determine the efficiency.

$$V.R = \frac{Distance\ moved\ the\ effort}{Distance\ moved\ by\ the\ load}$$

$$V.R = \frac{2.0m}{0.5m}$$

V.R =4

Mechanical Advantage

$$M.A = \frac{Load}{Effort}$$

$$M.A = \frac{200N}{62.5N}$$

$$M.A = 3.2$$

Calculating the Efficiency

$$Efficiency = \frac{M.A}{V.R}\ x\ 100\%$$

$$Efficiency = \frac{3.2}{4.0}\ x\ 100\%$$

$$Efficiency = 80\%$$

Since the efficiency is less than 100%, the machine is not perfect. Losses such as friction reduce its effectiveness.

d) To determine the temperature, rise of the axle, we shall use the concept of heat energy from friction being converted into thermal energy. The heat generated is related to the change in temperature as:

$$\mathbf{Q} = \mathbf{M}.\mathbf{C}.\Delta T$$

Where

Q is the quantity of heat

C specific heat capacity of copper

ΔT is the temperature change

$$18000J = 15Kg\ x\ 400\ x\ \Delta T$$

Re-arranging the formula

$$\Delta T = \frac{18000}{15\ x\ 400}$$

$$\Delta T = 3^{o}C$$

After a day's work, the temperature of the machine rose by $3^{o}C$

e) Wear and tear: Friction leads to wear on the axle's surface, reducing its lifespan and requiring frequent maintenance or replacement.

Heat generation: As seen above, friction generates heat, which can cause the axle to overheat. This weakens the axle which may lead to mechanical failure.

ITEM 3

a) To determine if the available string will work, we need to calculate the maximum tensile force the string can withstand based on its Young's modulus, and then compare it to the weight of the rim.
The formula for Young's modulus is:

$$\text{Young's modulus} = \frac{stress}{strain}$$

$$\text{Young's modulus} = \frac{F/A}{\Delta L/L}$$

$$P = \frac{F.L}{A.\Delta L}$$

Where

- E is the Young's modulus ($1.7x10^{4}Nm^{-2}$)
- F is the force applied (weight of the rim, 300N)
- L is the original length of the string (1m)
- A is the crossectional area of the string
- ΔL is the extension of the spring

$$E = \frac{300.1}{0.02.0.3(3)}$$

On simplifying

$$E = 16{,}666Nm - 2$$

Basing on the above calculations, the young's modulus obtained 0f 16,666 Nm^{-2} is approximately equal to the young's modulus of $1.7x10^{4}Nm^{z}$ of the spring required·

b) Heat from the sun is transferred by radiation and convection to the rim which absorbs heat by conduction. This increases its temperature

The heat absorbed (Q) by an object can be calculated using the formula:

$$\mathbf{Q = M.C.}\Delta T$$

Where

Q is the absorbed heat

M is the mass of the rim

ΔT is the temperature change

C is the specific heat capacity of aluminum

To find the mass of the rim, we use the formula relating weight and mass

$$W = m.g$$

$$300N = m.10$$

$$m = 30Kg$$

calculating the quantity of heat absorbed

$$\mathbf{Q = 30\ x900\ x\ 20}$$

$$\mathbf{Q = 540,000J}$$

The heat absorbed by the aluminum rim is 540,000J

Basing on the calculation above, the rim absorbed 540kJ of heat energy, which caused its temperature to rise by 20 K.

ITEM 4

a) The age of the bone can be determined using carbon-14 dating. Carbon-14 is a radioactive isotope of carbon that decays over time. The ratio of carbon-14 in a living organism remains constant while it is alive, but after the organism dies, the carbon-14 begins to decay at a known rate, described by its half-life (the time it takes for half of the carbon-14 to decay). The half-life of carbon-14 is 5,600 years.

In this case, the bone of the animal has 5 grams of carbon-14 remaining, while a living animal has 20 grams. The reduction in the carbon-14 mass indicates that some time has passed since the animal died

20g to 10g takes 5600 years and from 10g to 5g takes 5600 years
The total time taken will be 5600 x 2= 11,200 years

Thus, the bone is approximately 11,200 years old.

b) The soil particles that caused a reduction in mass and made fluorescent materials glow are likely to be radioactive materials. This can be inferred because:

The mass of the particles reduced by 3/4 in 20 days, indicating rapid radioactive decay, which is typical of materials with a short half-life.

The fluorescent materials in the store glowed, suggesting they were exposed to ionizing radiation from the radioactive particles. Radioactive substances emit radiation (alpha, beta, or gamma) that can excite atoms in fluorescent materials, causing them to glow.

Given these observations, the soil particles are likely radioactive isotopes, possibly naturally occurring radioactive materials (NORM) such as radon, uranium, or thorium, which can be found in certain soils and rocks.

c) Precaution with radioactive materials: The fact that the soil particles are radioactive suggests that the area may contain hazardous materials. Radioactive substances can be harmful to human health if ingested, inhaled, or through prolonged exposure. The local government and the community must take precautions by:
Restricting access to the affected area,
Wearing protective clothing and masks when handling the soil,
Monitoring radiation levels in the surrounding environment.
Consult with environmental and radiation experts: The presence of radioactive materials in the soil should be investigated further by professionals. Experts can assess the level of radioactivity, determine the source of the radiation, and recommend proper disposal or containment strategies.
Ensure proper storage of radioactive materials: If radioactive materials are discovered, they should be properly stored in containers that can block radiation (such as lead boxes) to prevent exposure to people and animals.
Awareness and education: The community should be informed about the potential risks of radioactive materials and educated on safety measures to avoid harmful exposure. The government should ensure proper communication about the situation and any ongoing remediation efforts.
By following these safety precautions and consulting experts, the risks associated with the radioactive soil particles can be minimized

ITEM 5

a) The time difference between the two countries is caused by the Earth's rotation on its axis. The Earth is divided into 24 time zones, and as it rotates, different parts of the Earth face the Sun at different

times. When one side of the Earth is facing the Sun, it experiences daylight, while the opposite side experiences nighttime. Since the Earth rotates 360 degrees in 24 hours, every 15 degrees of longitude corresponds to a 1-hour time difference. The country where your friend is studying is ahead of Uganda in terms of time because it is further east, meaning it experiences sunrise and daytime earlier than Uganda. At the time your friend's local time was 9 am (morning), Uganda, which is further west, the time was 8 pm (evening). This is why there's a significant difference in time.

b) The moon has phases because of its orbit around the Earth, which causes different parts of the moon to be illuminated by the Sun as seen from Earth. The main phases of the moon from the new moon to the full moon are as follows:

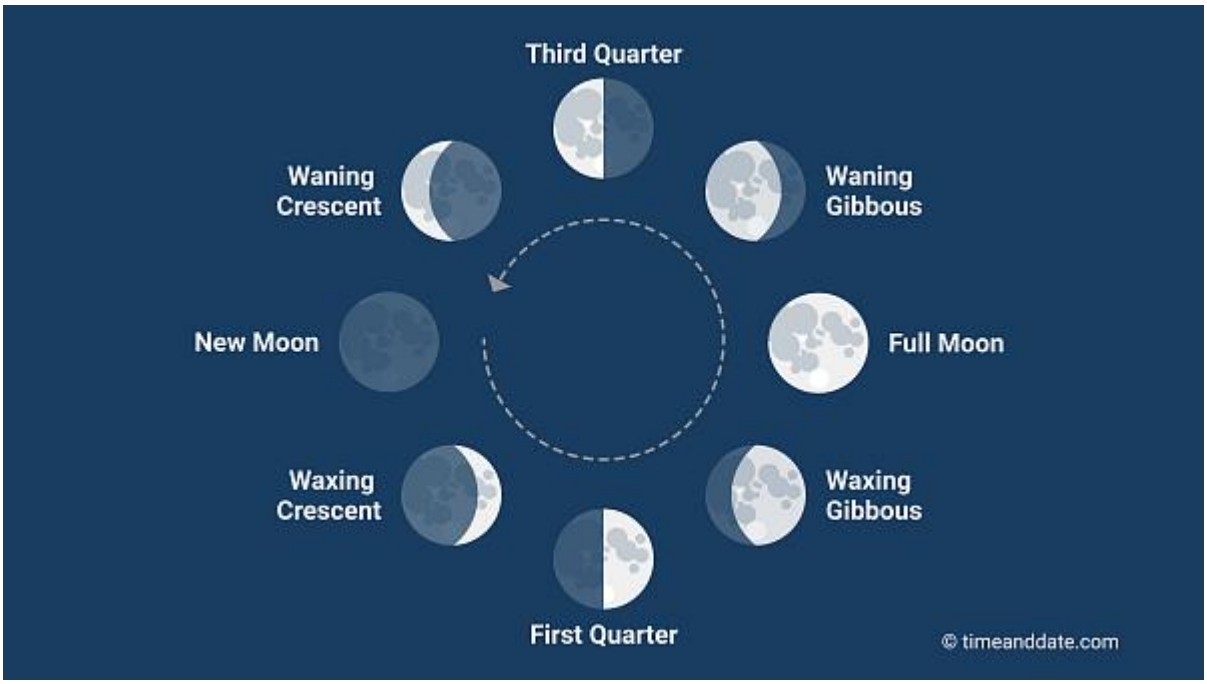
New Moon: The moon is between the Earth and the Sun, and the side of the moon facing the Earth is not illuminated, making it invisible.

Waxing Crescent: A small sliver of the moon becomes visible after the new moon, as the illuminated portion begins to increase.

First Quarter: Half of the moon’s disk is illuminated, and it appears as a half-moon.

Waxing Gibbous: More than half of the moon is illuminated as it approaches the full moon.

Full Moon: The entire face of the moon is illuminated by the Sun as the Earth is between the moon and the Sun. After the full moon, the phases reverse (waning gibbous, last quarter, waning crescent) as the illuminated portion decreases, eventually returning to the new moon.



c) The life cycle of a star depends on its mass, but in general, it follows these stages:

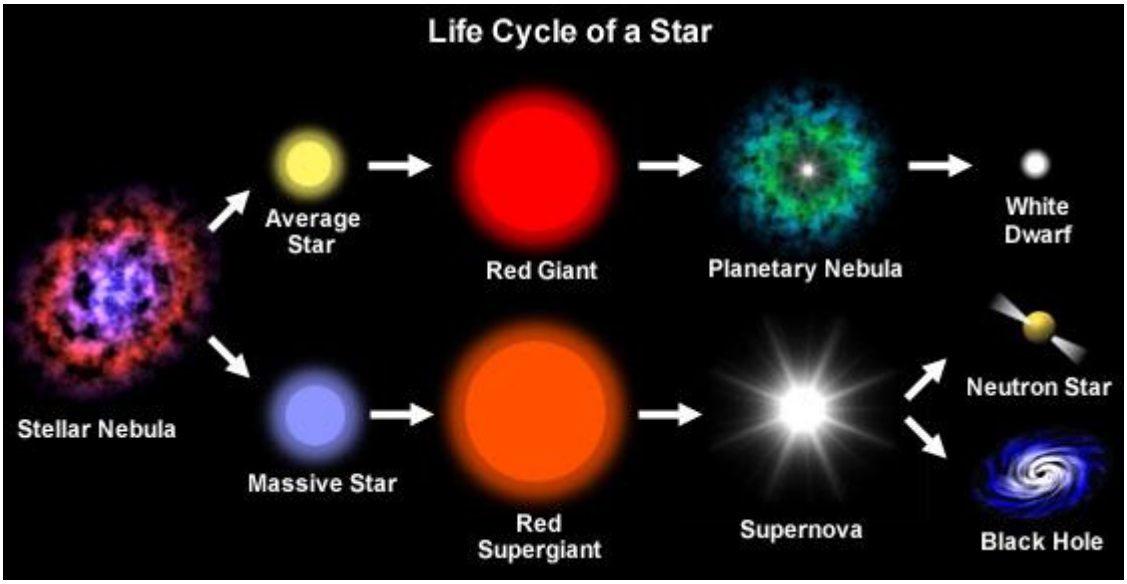
Nebula: A star begins its life in a cloud of gas and dust called a nebula. Gravity pulls the gas and dust together to form a protostar.

Main Sequence: The protostar contracts and heats up, and nuclear fusion begins in its core, converting hydrogen into helium. The star enters the main sequence stage, where it spends most of its life. Our Sun is currently in this stage.

Red Giant or Supergiant: As the star exhausts its hydrogen fuel, it expands into a red giant (for medium-sized stars) or a red supergiant (for massive stars).

White Dwarf or Supernova: For medium-sized stars, the outer layers are shed, leaving behind a dense core called a white dwarf. For massive stars, they explode in a supernova, scattering their outer layers into space.

Black Hole or Neutron Star: After a supernova, the core of a massive star may collapse into a neutron star or, if the core is very massive, into a black hole.



d) As my friend talked, the mouth piece of her phone converted the sound energy to electrical energy and in the process, the phone converted the electrical energy to electromagnetic waves which are sent to the uplink dish that eventually sends the electromagnetic waves (radio waves) to the communication satellite. The satellite then sends the waves to the downward link dish which sends them to the telephone receiver of the parents that are converted to sound waves.

ITEM 6

a) Bright full moon with dark spots: The moon is seen by reflection of light from the sun. The darker areas are due to craters, valleys or depressions on the moon formed by ancient volcanic activity on the moon's surface. These regions reflect less light than the surrounding areas, making them appear darker.

Groups of stars forming specific patterns: The groups of stars that form specific patterns are called constellations. Over time, humans have noticed patterns in the arrangement of stars and named them after animals,

mythological figures, or objects. These patterns are not actually related to each other in space but appear grouped due to our perspective from Earth.

Some stars are brighter than others: The brightness of a star, as seen from Earth, depends on two main factors:

Intrinsic brightness (or luminosity): Some stars are naturally brighter than others due to their size, temperature, and stage in the stellar life cycle.

Distance: Stars closer to Earth appear brighter, even if they are less luminous than distant stars. Stars further away seem dimmer because their light has to travel a greater distance.

Some stars are of different colors: The color of a star is determined by its surface temperature. Blue stars are the hottest, with temperatures exceeding 25,000°C, White and yellow stars (like the Sun) are cooler, with temperatures around 6,000°C, Red stars are the coolest, with surface temperatures around 3,000°C. The color differences are due to blackbody radiation, where hotter objects emit more blue light and cooler ones emit red light.

Changing sky colors during sunrise: The change in the sky's color as the sun rises (from red to orange, yellow, and then blue) is due to the scattering of sunlight by the particles in Earth's atmosphere. When light is scattered, the red light with a long wavelength and low frequency is less scattered and is the first to be seen as the sun comes out of the horizon followed by orange and yellow in that order. The sky appears blue during day time because blue is more scattered by the particles, water droplets and clouds in the atmosphere

The sky seems to touch the ground: This is a common optical illusion caused by the curvature of the Earth. The horizon appears as the point

where the sky meets the ground, but this is simply the limit of our line of sight. The sky covers a spherical earth , and therefore the sky is spherical.

b) To locate the home accurately and with ease, the chief guest can use GPS (Global Positioning System) technology. This method is highly accurate and relies on satellites to determine the precise position on Earth.

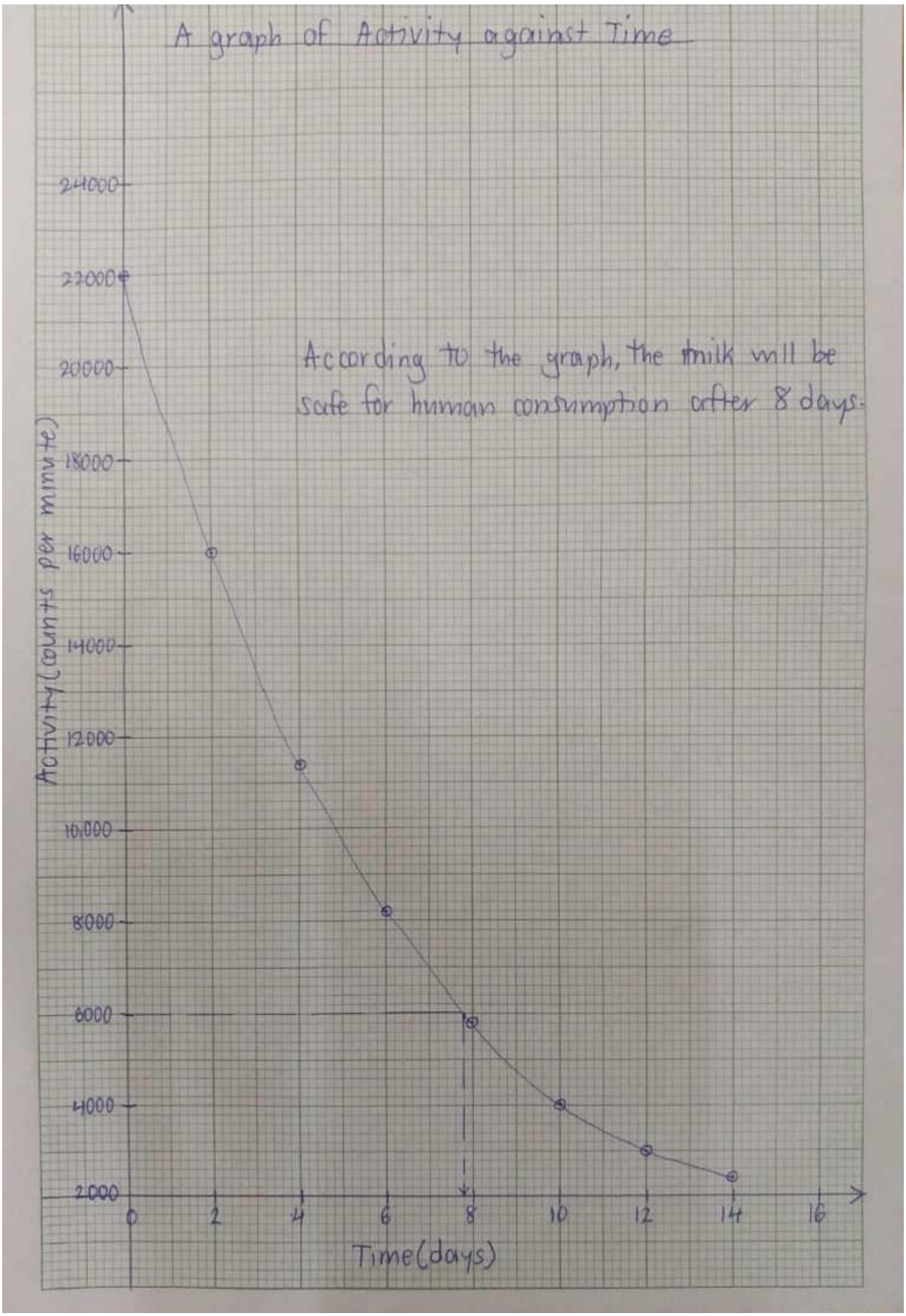
How GPS Works:

Satellites orbiting the Earth continuously send out signals with their exact time and position.

A GPS receiver (in the guest's smartphone or navigation device) picks up signals from at least three satellites.

By calculating the time, it takes for the signals to reach the receiver, the device can determine its distance from each satellite.

Using a process called triangulation, the GPS receiver can calculate the exact location of the receiver (in this case, the chief guest's location) in terms of latitude and longitude.


A graph of Activity against Time
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
Activity (counts per minute)
0
2
4
6
8
10
12
14
16
Time (days)
According to the graph, the milk will be safe for human consumption after 8 days.

b)

Health hazards/dangers of radioactivity:

- ✓ Radiations cause skin burns.
- ✓ Radiations cause blood cancer.
- ✓ Radiations cause sterility [inability to produce].
- ✓ Radiations cause low body resistance to normal diseases.
- ✓ Radiations cause genetic changes [mutation].
- ✓ Radiations destroy body cells.
- ✓ Radiations damage eyesight and body tissues.

Safety precautions when handling radioactive elements:

- ➢ They should be transported in thick lead containers.
- ➢ They should be handled using long pair of tongs.
- ➢ You should avoid unnecessary exposure to the radiations.
- ➢ You should wear protective clothing when handling radioactive elements.
- ➢ You should not eat or drink where radioactive sources are in use.
- ➢ You should cover any wound before using radioactive source.

c) The reading of the GM- tube is due to background radiations. These background radiations may come from different sources which may include, cosmic radiations, radioactive sources around us or terrestrial radiations (from soil and locks) or carbon-14 that is found in the body tissues.

d) X-rays carry no charge and they least ionize the air molecules and yet the GM-tube works on the principle of a radiation ionizing air molecules. Therefore, a GM-tube cannot easily detect X-rays

ITEM 8

a) A hydraulic press works on Pascal's Principle, which states that pressure applied to a confined fluid is transmitted equally in all directions. Here's how it operates:

A small force is applied to a small piston (input piston) within a cylinder containing hydraulic fluid.

The fluid transmits the applied pressure uniformly to a larger piston (output piston).

The force on the larger piston is amplified because the pressure remains constant, but the larger piston has a greater surface area than the smaller piston. This amplified force is then used to compress materials like concrete for making pavers, blocks, and bricks.

Mathematically, the relationship between force and area in the hydraulic press is:

$$\frac{F1}{F2} = \frac{A1}{A2}$$

Where

- F1 is the input force on the small piston
- F2 is the output force on the large piston
- A1 area of the small piston
- A2 area of the large piston

b) Oil is used instead of air in hydraulic presses for several reasons:

Incompressibility: Oil is virtually incompressible, meaning it efficiently transmits force through the system without losing energy due to compression. Air, being compressible, would lead to energy loss and inefficient force transmission.

Lubrication: Oil serves as a lubricant for moving parts, reducing friction and wear on the press components.

Cooling: Oil absorbs and dissipates heat, which helps prevent overheating of the hydraulic press during operation, maintaining its efficiency.

Contaminant Control: Oil can trap particles and contaminants, preventing damage to the machinery. Air does not provide the same protective qualities.

c) To determine if the system will remain effective after generating 340,000 J of heat, we need to calculate the temperature rise in the hydraulic fluid.

Given the following

- The specific heat capacity of the hydraulic fluid is 1750 $\boldsymbol{Jkg^{-1}K^{-1}}$
- The minimum energy input for the press to start working is ***1600 J***
- 1liter=$\boldsymbol{0.001m^3}$
- Density of hydraulic fluid = $\boldsymbol{800\ kgm^{-3}}$
- Heat generated Q =340,000J
- Maximum allowable temperature rise, =20^{o}C

The mass of the fluid will be given by

$$mass\ = density\ x\ volume$$

$$mass\ = 800\ x\ 0.01$$

$$mass\ = 8Kg$$

calculating the temperature change

$$\mathbf{Q} = \mathbf{M}.\mathbf{C}.\Delta T$$

$$\Delta T = \frac{\boldsymbol{Q}}{\boldsymbol{MC}}$$

$$\Delta T = \frac{\mathbf{340,000}}{\mathbf{8\ x\ 1750}}$$

$$\Delta T = 24.3^{o}C$$

Since the temperature rise is 24.29°C, which exceeds the allowable 20°C limit, the hydraulic system may overheat and will not remain fully effective under these conditions. Additional cooling mechanisms or heat dissipation methods should be considered

d) The hydraulic press has an efficiency of 80%, and it needs to produce 2000 J of output work. To determine if it can operate, we calculate the input energy required for this output:

Efficiency is given by

$$efficiency = \frac{work\ out\ put}{work\ input}\ x\ 100\%$$

$$80 = \frac{2000}{work\ input}\ x\ 100$$

$$Work\ input = \frac{2000}{0.8}$$

$$Work\ input = 2500J$$

Since the press needs 2500 J of input energy and the minimum energy required to start operating is 1600 J, the press will not be able to start operating because 2500 J exceeds the 1600 J minimum threshold

ITEM 9

a) The radio has the following specifications:
   Voltage: 100V, meaning the radio requires 100 volts to operate.
   Current: 5A, meaning it draws a current of 5 amperes.
   Frequency: 50Hz, meaning it operates on alternating current (AC) with a frequency of 50 hertz.
   When the radio is connected to a 100V supply, it draws a current of 5A from the system at a frequency of 50Hz

b) The businessman should connect the resistors 20 ohms and 8 ohms in series with the radio because, in a series connection, all appliances receive the same current(5A). But the P.d is different for different resistors.
   The P.d across the 20Ω

$$V = IR$$
$$V = 5\ x\ 20$$
$$V = 100V$$

   The P.d across the 8 Ω

$$V = IR$$

$$V = 5\ x\ 8$$

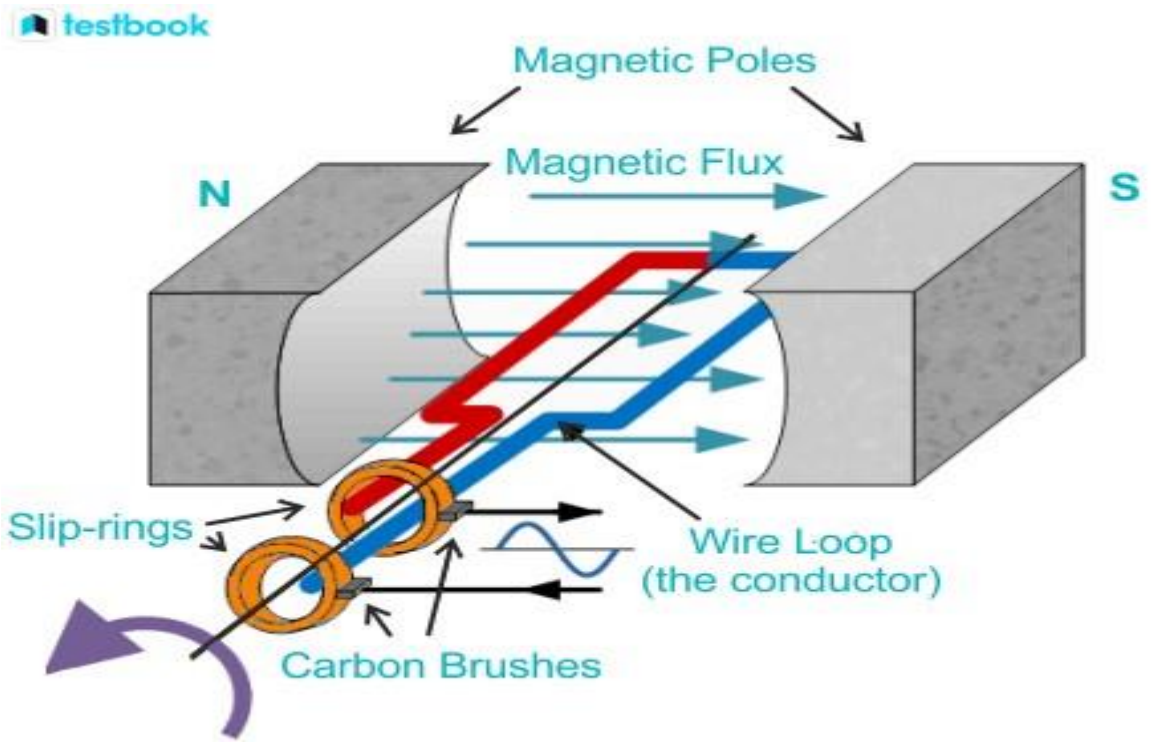
$$V = 40V$$

The P.d across the radio is 100V,

Total P.d across the resistors and radio will be 100V+40V+100V=240V

Therefore, a series connection will enable the radio to work normally

c) A generator is a device that converts mechanical energy (from fuel like diesel or petrol) into electrical energy. It is used as an alternative power source when grid electricity is unavailable.



An AC generator works on the principle of electromagnetic induction, where mechanical energy is converted into electrical energy. It consists of a coil of wire (armature) that rotates in a magnetic field, usually created by magnets or electromagnets. As the coil rotates, the magnetic flux linked with it changes, inducing an electromotive force (EMF) according to Faraday's law of induction. This changing magnetic field causes the current to alternate direction, generating alternating current (AC). The magnitude of the induced EMF depends on the speed of rotation, the strength of the magnetic field, and the number of turns in the coil. Slip rings and brushes are used to transfer the alternating current from the rotating coil to the external circuit. This process continues as long as the coil keeps rotating, providing a continuous AC output.

ITEM 10

AIM:

To determine the force constant of the spring to replace the damaged spring in the toy gun.

HYPOTHESIS:

The force constant of the spring is 20 Nm^{-1} and it can be used to replace the damaged spring in the toy gun.

VARIABLES:

Independent Variable – Mass loaded on the spring

Dependent Variable – Extension of the spring

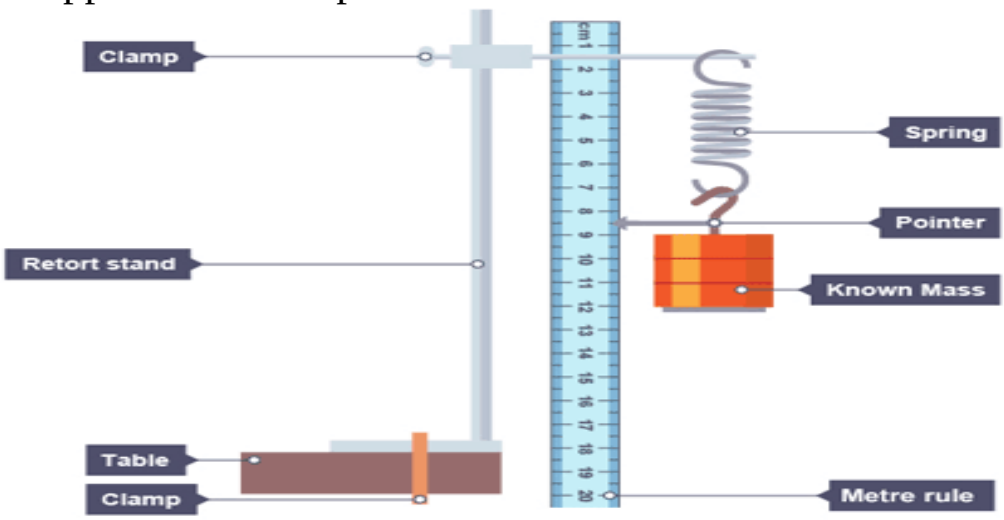
Controlled Variable – initial position of the pointer, the original length of the spring, Cross-sectional area of the spring.

LIST OF APPARATUS:

Meter rule, small wooden blocks, retort stand, pointer, known masses, spring

PROCEDURES:

a) The apparatus is set up as shown below.



b) Without any masses, the position of the pointer is read and recorded as, L_0.
c) A mass, m=0.100 kg is attached to the lower end of the spring.
d) The new position of the pointer is read and recorded as L.
e) Procedures (c) and (d) are repeated for values of m=0.200 kg, 0.300 kg, 0.400 kg, 0.500 kg, and 0.600 kg.

f) The results are tabulated in a suitable table including values of Force, F(N), and extension, e(m) where F = m x 10 and e = L – L_0.
g) A graph of F against e is plotted.
h) The slope of the graph is determined and it will be the force constant.

ERRORS AND PRECAUTIONS:

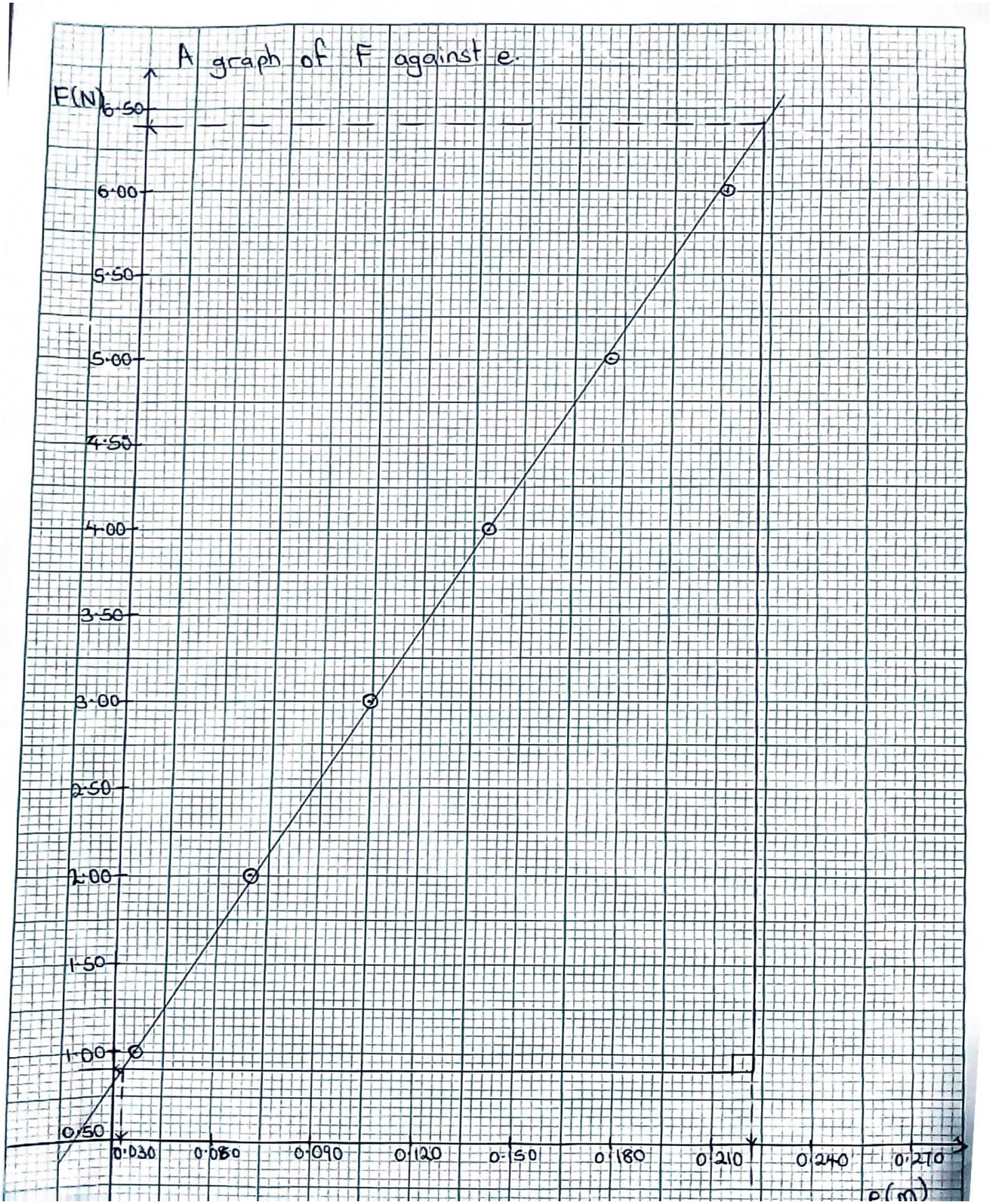
Parallax errors: Position your eyes such that they are perpendicular to the point that is to be read.

DATA PRESENTATION AND RECORDING:

Table of results

L_0 = 0.373 m

m (kg)	L(cm)	L(m)	e(cm)	e(m)	F(N)
0.100	40.9	0.409	3.6	0.036	1.00
0.200	44.2	0.442	6.9	0.069	2.00
0.300	47.7	0.477	10.4	0.104	3.00
0.400	51.2	0.512	13.9	0.139	4.00
0.500	54.2	0.542	17.6	0.176	5.00
0.600	58.4	0.584	21.1	0.211	6.00


A graph of F against e.
F(N)
6·50
6·00
5·50
5·00
4·50
4·00
3·50
3·00
2·50
2·00
1·50
1·00
0·50
0·030
0·060
0·090
0·120
0·150
0·180
0·210
0·240
0·270
e(m)

DATA ANALYSIS AND INTERPRETATION:

$$\text{slope} = \frac{6.40 - 0.90}{0.222 - 0.033}$$

$$= \frac{5.50}{0.189}$$

$$= 29.1\ \text{Nm}^{-1}$$

CONCLUSION:

The force constant of the spring is 29.1 Nm^{-1}, therefore it cannot be used to replace the damaged spring in the toy gun.