Item 1.

During an attack of rebels in a certain district, two students hid themselves at the roof top of one of the buildings, it was risky for them to observe the soldiers around the corners and gather information to make informed decisions while minimizing exposure to danger. They noticed a muzzle flash light followed by louds sounds of gun shots which was directly over a village. Some distance behind the village is a mountain. They listened carefully and realized that, for each muzzle flash, they can hear a loud sound of gunshot followed by a quieter one.

The time between seeing a flash over the village and hearing the first sound of a gun is 4 seconds.

Hint: Two plane mirrors, plastic tube, glue, craft knife and marker were available for the students at the rooftop.

Speed of sound in air = 330 ms^{-1}

Task:

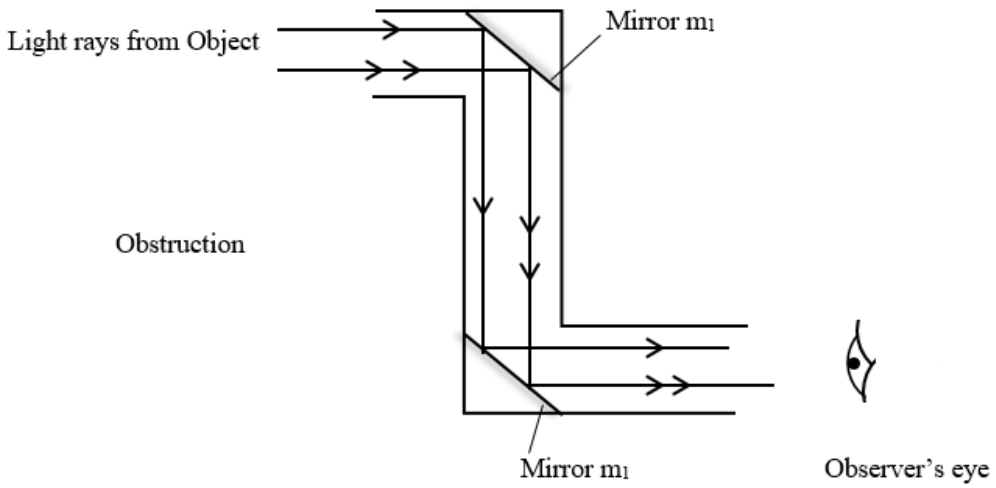
As a physics student, advise the two students to;

(a) To check for soldiers around corners and in blind spots
(b) Know why they hears two sounds for each muzzle flash?
(c) Identify how far away is the village from the students?

Answer:

(a) To check for soldiers around corners and in blind spots:

- Use the two plane mirrors m_1 and m_2 and the plastic tube to create a simple periscope.
- Attach the mirrors to the ends of the tube using glue.
- Use the craft knife to make a small hole in the top of the tube for observation.
- Use the marker to mark the direction of the mirrors for accurate alignment.



(b) Why they hear two sounds for each muzzle flash:

- The louder sound is the direct sound of the gunshot.
- The quieter sound is the echo of the gunshot reflected off the mountain.
- The delay between the two sounds is due to the time it takes for the sound to travel to the mountain and back.

(c) How far away is the village from the students:

- Use the time between the muzzle flash and the first sound of the gun (4 seconds) to calculate the distance.
- Since the speed of sound is 330 ms^{-1},
- Distance = Speed x Time = 330 ms^{-1} x 4 s = 1320 m

So, the village is approximately 1320 meters away from the students' location.

Item 3

On a national radio station, it was announced that in one of the small towns of Pakwach in Uganda, residents observed the moon block the sun completely for about seven and a half minutes, it was further communicated that in most parts of the country annual precipitation occurred, fresh water quality improved and vegetation started growing substantially.

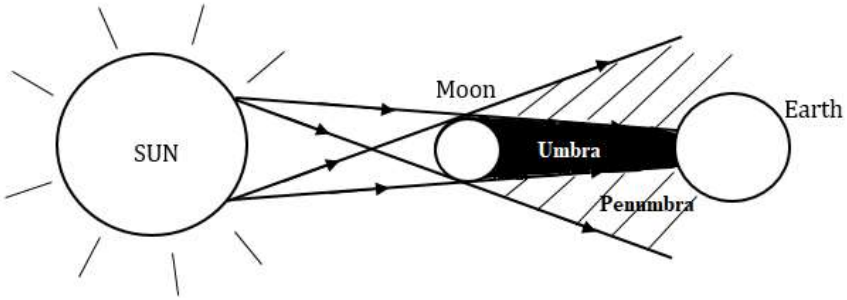
Task:

As a student of physics, help the listeners to understand:

(a) The possibility of the moon blocking the sun's light
(b) The occurrence of annual precipitation, improvement on fresh water quality and vegetation growth.
(c) How an event in one place can be communicated live to listeners in different parts of the country.

Solution

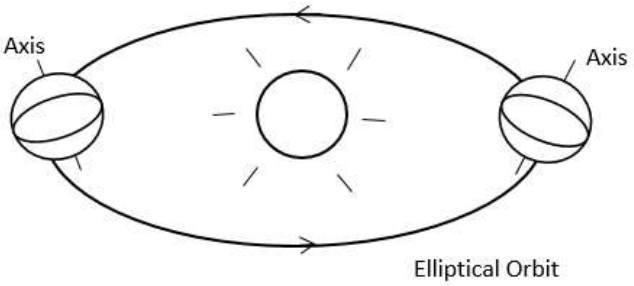
(a) The possibility of the moon blocking the sun's light: This is a rare astronomical event known as a *total solar eclipse*! The *moon's orbit aligns with the sun* (Sun, Moon and Earth), casting a shadow on Earth, blocking direct sunlight for a short period. It's only visible from a specific path on Earth, known as the *path of totality*. Thus forming a *penumbra and Umbra* as shown below.



(b) Annual precipitation is a natural cycle, and improved water quality and vegetation growth could be due to various environmental factors like *seasonal changes*,

Seasons are caused by the combination of two main factors:

1. **Earth's Axial Tilt**: The Earth rotates on its axis, which is *tilted at an angle of about* 23.5 degrees relative to its orbit around the Sun. This tilt causes *the amount of sunlight* that reaches the Earth's surface to *vary throughout the year*.



2. **Earth's Orbit:** The Earth orbits the Sun in *an elliptical path*, which means that the *distance between the Earth and the Sun varies* throughout the year.

As the Earth rotates and orbits the Sun, *different parts of the planet receive different* amounts of sunlight, *leading to changes in temperature*, weather patterns, and the seasons. Here's a brief overview of each season:

- **Spring:** The Northern Hemisphere begins to tilt towards the Sun, increasing sunlight and temperatures.

- **Summer:** The Northern Hemisphere is fully tilted towards the Sun, receiving the most direct sunlight and experiencing the warmest temperatures.

- **Autumn:** (Fall): The Northern Hemisphere begins to tilt away from the Sun, decreasing sunlight and temperatures.

- **Winter:** The Northern Hemisphere is fully tilted away from the Sun, receiving the least amount of sunlight and experiencing the coldest temperatures.

For countries in the *equatorial region*, they experience two seasons i.e. *wet season* (winter) and *dry season* (summer)

(c) Radio live broadcasting works through a process called "over-the-air" transmission, where audio *signals are transmitted* through radio waves *from a studio* to *a broadcast tower*, and then *received by listeners* with radios or streaming devices. Here's a simplified overview:

1. **Audio source:** The broadcast starts with an audio source, like a microphone or a pre-recorded audio file, in a studio.

2. **Mixing and processing**: The audio is mixed, edited, and processed to prepare it for broadcast.

3. **Encoding**: The audio is encoded into a format suitable for radio transmission, like FM or AM.

4. **Transmission:** The encoded audio is transmitted from the studio to a broadcast tower through a high-power antenna.

5. **Broadcast tower:** The broadcast tower receives the signal and amplifies it to cover a wider area.

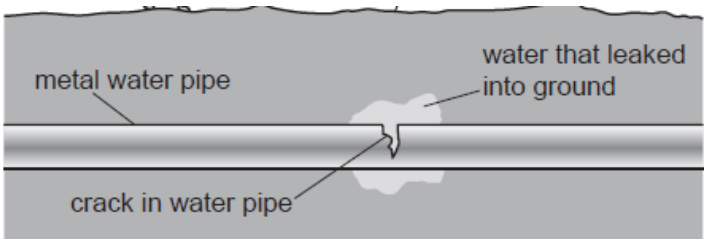
6. **Radio waves:** The amplified signal is broadcast as radio waves into the air.

7. **Reception:** Listeners with radios or streaming devices tune into the specific frequency to receive the broadcast.

8**. Decoding:** The received signal is decoded and played back as audio.

Item 2

An underground water pipe in the school compound cracked and water gradually leaks into the surrounding ground. The school laboratory is well stocked with various radioactive materials. The school compound prefect tries to locate an actual point where water leaks but fails. The school hires a technician who introduced a radioactive isotope of half-life 6hours of 8g from the laboratory into the water supply and the water that leaks from the crack is radioactive.



Hint: Assume the safety desired level of radiation is 6.25%

Task:

As a student of physics;

(a) Explain the type of radiation that was emitted by the isotope for the leak to be detected.

(b) Explain to the compound prefect why an isotope of half-life 6 hours is suitable for use.

(c) Write a message to sensitise the members of the school about the risks associated with radioactive materials in the school laboratory and how such materials should be handled.

(d) How long shall it take for the water to be ready for use again?

(a) The type of radiation emitted by the isotope to detect the leak is *beta radiation or gamma radiation*. Beta radiation consists of high-energy electrons that can *travel several millimeters* in tissue, while gamma radiation consists of high-energy electromagnetic waves that can *travel several centimeters (Higher penetration power)* in tissue. Both types of radiation can penetrate the soil and be detected using a Geiger counter or other radiation detection instruments, helping to locate the source of the leak.

(b) An isotope with a half-life of 6 hours is suitable for this purpose *because it decays quickly enough to produce a strong signal for detection*, but not so quickly that it becomes too weak to detect. A shorter half-life would result in a stronger signal, but the radiation might decay too *quickly to be useful for detection*. A longer half-life would result in a weaker signal, *making detection more difficult*. The 6-hour half-life allows for a balance between signal strength and detection time.

(c) Message to sensitise school members:

"Dear students and staff,

We want to bring to your attention the potential risks associated with the radioactive materials in our school laboratory. These materials require proper handling and safety precautions to avoid exposure and potential harm.

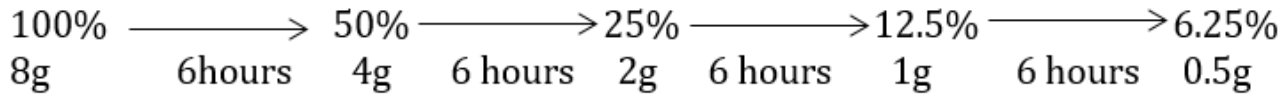
Radioactive materials *emit ionizing radiation*, which can *cause damage to living tissues* and *increase the risk of cancer*. It's crucial to follow proper protocols when handling

these materials, including *wearing protective gear (lead coats)*, using *appropriate storage and disposal methods*, and *minimizing exposure time*.

Let's work together to ensure a safe and responsible use of these materials in our pursuit of scientific knowledge.

Thank you for your attention to this matter."

(d) To determine how long it will take for the water to be ready for use again, we need to consider the half-life of the radioactive isotope and the maximum percentage present after for safety.



$6\text{hours} \times 4 = 24$ hours
Therefore, it will take approximately 24 hours for the water to be ready for use again,

Item 4

Your family hires three vehicles for a convoy to attend a wedding ceremony of one of your relatives. The hiring company charges a fee according to the distance moved. On a hot day, the team sets off from home with inflated balloons at 7:00am and attains a maximum velocity of 72km/hr. in 60 minutes. On reaching the highway road, it maintains this velocity for 90 minutes, finally it reaches the reception at 10:00am. It was observed that some balloons burst and only a few were left. Later in the evening it rained heavily and cars failed to reach back home due to slippery roads.

Task:

As a physics student;

(a) Help your family members compute the distance from home to church.
(b) Explain to your relatives the reason(s) why most of the inflated balloons burst.
(c) Provide guidance to the car owners to avoid the problem faced during the return journey.

(a) To compute the distance from home to the church:
Method 1
We can break down the journey into two segments:
Acceleration phase (0-60 minutes):
The convoy accelerates from 0 to 72 km/h in 60 minutes. We can calculate the distance covered during this phase using the equation of motion:

$$s = ut + \frac{1}{2}at^2$$

where s is the distance, u is the initial velocity (0 km/h), t is the time (60 minutes = 1 hour), and a is the acceleration.

First, let's find the acceleration:

a = $\frac{v-u}{t}$ = (72 kmh^{-1} - 0 kmh^{-1}) / 1 hour = 72 kmh^{-2}

Now, plug in the values:

$$s = 0 \times 1 + \frac{1}{2}72(1)^2$$

So, the convoy covers 36 km during the acceleration phase.

Constant velocity phase (60-150 minutes):

The convoy maintains a constant velocity of 72 kmh^{-1} for 90 minutes (1.5 hours). We can calculate the distance covered during this phase using the equation:

$$s = vt$$

Where v the velocity (72 kmh-1) and t is is the time (1.5 hours):

s = 72 kmh^{-1} × 1.5 hours = 108 km

Adding the distances from all phases, we get:

Total distance = 36 km + 108 km +36km = 180 km

Therefore, the distance from home to the church is 180 km.

Method 2

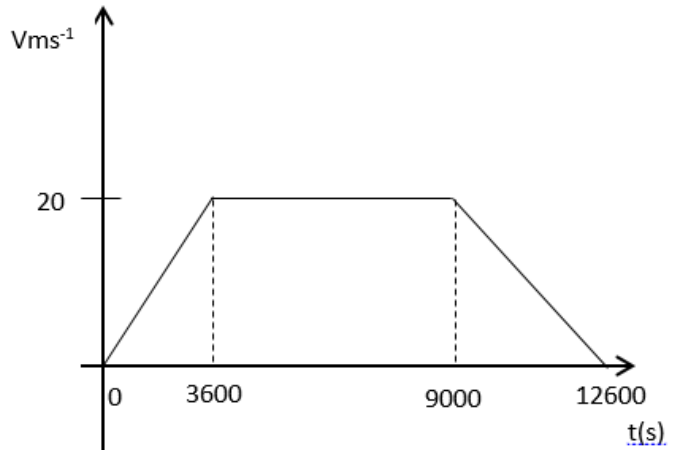
1 minute = 60 seconds

60 minutes = 3600s [phase 1]

90 minutes = 5400s [phase 2]

60 minutes = 3600s [phase 3]

72$kmhr^{-1}$ = $\frac{72\times1000}{3600}$ =20ms^{-1}



$$\text{T.D.C} = \frac{1}{2}bh + lxw + \frac{1}{2}bh$$

$$= \frac{1}{2}(3600)(20) + 5400 \times 20 + \frac{1}{2}(3600)(20)$$

$$180{,}000m$$

$$= 180km$$

(b) Why most of the inflated balloons burst:
As the convoy accelerates and reaches higher speeds, the *air pressure inside* the balloons increases due to air *molecules gaining kinetic energy*. The molecules *collide more frequently* with themselves and the *inner walls* of the balloon due to *increased temperature* from the sun. This increase in pressure causes the *balloons to expand* and eventually *burst*.

(c) Guidance to avoid the problem during the return journey:

- *Reduce speed*: Drive at a slower pace to maintain control and avoid skidding on slippery roads.
- *Use appropriate tires*: Ensure that the vehicles are equipped with tires that provide good traction on wet surfaces.
- *Increase following distance*: Maintain a safe distance from the vehicle in front to allow for extra stopping time in case of sudden braking.
- *Use low gear:* When driving uphill or on slippery roads, use a lower gear to maintain control and avoid wheel spin.
- *Avoid sudden movements:* Sudden turns or braking can cause loss of control on slippery roads, so make smooth and gradual movements instead.

Item 7

In a certain village, electricity is normally supplied at 240V and 5A, electricity normally blacks out on weekends. On working days, a business man normally uses electricity to charge community batteries and also listens to radio programs. Later his radio failed to work and he noticed it had specifications 100V, 5A and 50Hz, Which he couldn't interpret, he checked in the empty box of the radio and found two devices labelled 20Ω and 8Ω which he couldn't use either. He wishes to work throughout the week and was advised to purchase a suitable generator of required specifications for weekend purpose. The business man does not know what a generator is, how it works and is bothered by the type of the generator that should be purchased.

Hint: The 20Ω and 8Ω devices must be connected either in series or parallel to lower the input voltage of the radio from 240V to 100V.

Task:

As a student of physics,

(a) Describe the specifications of the radio

(b) Help the business man to connect the devices to have his radio working.
(c) Advise the business man to solve the weekend problems.

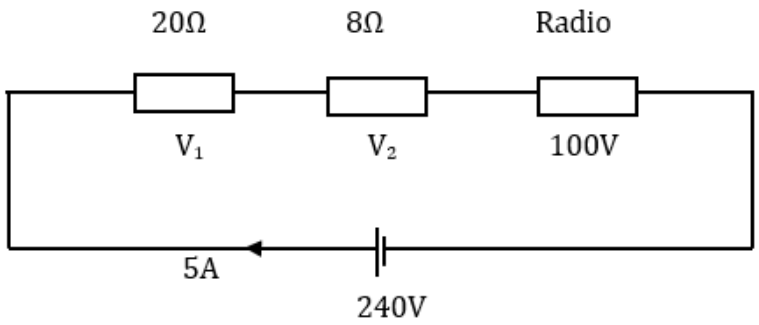
(a) The radio specifications are:

- Voltage: 100V
- Current: 5A
- Frequency: 50Hz

These specifications indicate that the radio is designed to operate at a lower voltage than the available grid voltage (240V).

(b) To connect the devices (resistors) to lower the input voltage from 240V to 100V, we can connect them in series:

240V → 20Ω → 8Ω → Radio (100V)



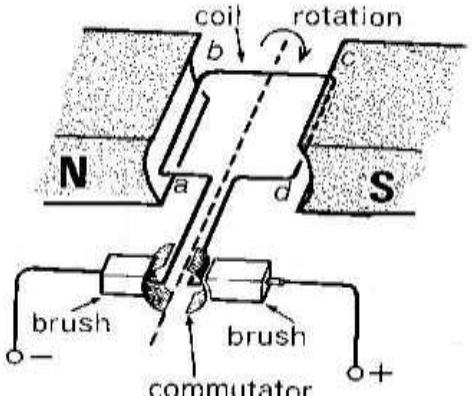
Using the voltage divider formula, we can calculate the output voltage:

V_out = (R2 / (R1 + R2)) × V_in
= (8Ω / (20Ω + 8Ω)) × 240V
≈ 100V (required voltage for the radio)
OR
V1 +V2 +100V =240V
V=IR
V1= 5X20 = 100V (p.d across the 20Ω resister)
V2 =5X8 =40V (p.d across the 8Ω resister)
Therefore 100V +40V +100V =240
This enables the radio to operate normally at 100V and 5A.

(c) To solve the weekend problem (electricity blackout), the businessman needs a a D.C generator that can provide a stable voltage and frequency to power the radio and battery charging. Based on the radio's specifications, a D.C generator should have the following characteristics:

- Output voltage: 100V (or adjustable to 100V)
- Output current: at least 5A (to accommodate the radio and battery charging)
- Frequency: 50Hz (to match the radio's specification)
- Power rating: sufficient to handle the total power requirement (radio + battery charging)

How the dc generator works



- The coil is rotated in the magnetic field, the magnetic linking it changes and an emf is induced in the coil.
- The resulting current is led away through carbon brushes B1 andB2 to the load.
- In the vertical position, emf is zero, the commutators change contact with the carbon brushes and the emf reverses in the coil but the out put emf maintains current in the same direction hence direct current

Recommendation:
- A portable inverter generator with an output voltage of 100V, 5A, and 50Hz would be a suitable option.
- Look for a generator with a sufficient power rating (e.g., 500W or higher) to handle the total power requirement.

By purchasing and using this generator during weekends, the businessman can continue to charge community batteries and listen to radio programs without interruptions.

Item 6

A certain team of sailors was navigating along Lake Victoria. The team was involved in a series of violent storms thunderstorm at the lake. They lost the direction of their journey. Some members thought of sailing any how until they meet the lake shore while others refused because they knew fuel would get used up before arriving.

Hint: A sewing needle, 2 bar magnets, cork, medium sized bowl and water were available for the sailors.

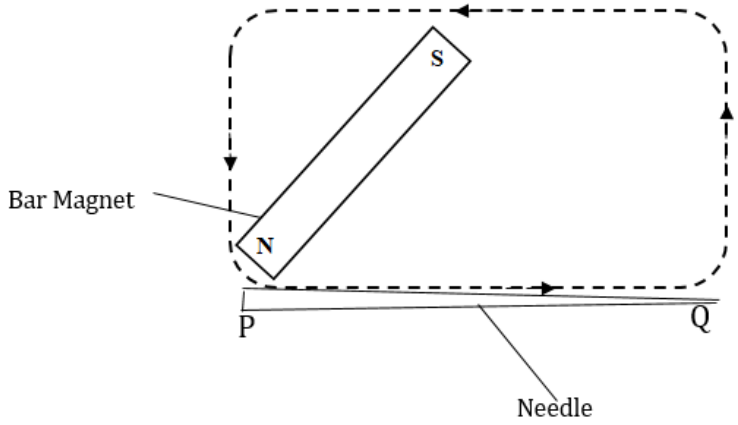
Task:

As a student of physics:

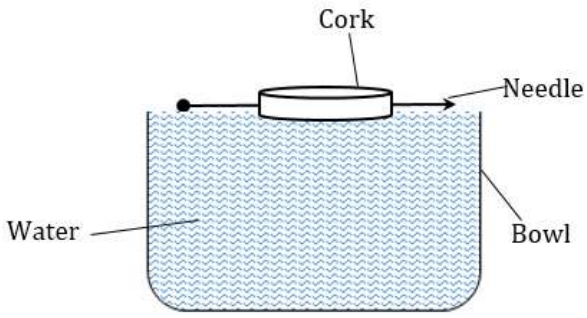
(a) (i) Help the sailors to determine the direction for their journey.
(ii) Comment on the effectiveness of what you have designed.
(b) How can sailors stay safe in a thunderstorm?
(c) Provide guidance how the bar magnets can be safely stored.

(a) (i) To help the sailors determine the direction of their journey, we can create a makeshift compass using the available materials:

- Fill the medium-sized bowl with water.



- Stroke the needle from one end P to end Q and lift the bar magnet when reached end Q
- Repeat the procedure several times
- End P becomes north while Q becomes South Pole
- Mark ends P and Q
- Place the cork in the water, and gently push the sewing needle through the cork, making sure it's straight and not touching the bowl's bottom or sides.
- Mark the direction the needle points as the north direction
- Use this compass needle to determine the direction of their journey.



Accept Double touch method

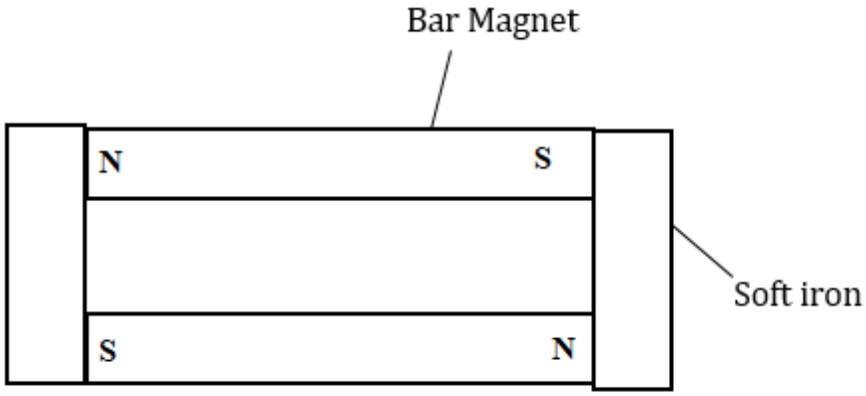
(ii) Effectiveness: This makeshift compass is effective because the sewing needle, being *ferromagnetic*, aligns itself with the earth's magnetic field created by the bar magnet. This allows the sailors to determine the north direction, which can help them navigate their way back to shore.

(b) To stay safe in a thunderstorm, sailors should:

- Monitor weather forecasts and warnings
- Avoid sailing during thunderstorms
- Keep a safe distance from tall objects (e.g., masts, trees)
- Avoid being in open water or near metal objects (e.g., anchors, chains)
- Stay low and away from windows if inside a boat or building
- Avoid using electrical equipment or metal objects that can conduct electricity

(c) To safely store the bar magnets:

- Store them in a dry place, away from direct sunlight and moisture
- Keep them separated from other magnetic materials and electronic devices to prevent interference or damage
- Handle them carefully to avoid accidental droppings
- Use magnetic keepers



The bar magnets are arranged parallel to each other with pole as shown above

The free ends are attached to soft iron pieces
Magnetic fields produced are kept in a continuous loop, thus keeping the strength of the bar magnets for a longer period of time.

END