



Topic **ELECTROMAGNETIC INDUCTION**

Class - XII

Graphic Novel - Physics



MODEL ACADEMY

The Prestigious School of MIER
Affiliated to the CBSE

ACKNOWLEDGEMENT

This novel would not have come to its completion without the hard work put in by the team. I would like to express my gratitude to our honorable Principal, Mr. Pramod Kumar Srivastava who provided help, guidance and also gave me an opportunity to do this wonderful project of Graphic Novel.

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PREFACE

- This Graphic Novel is a way for learners to look at Physics through a different lens in a more enjoyable and accessible way. The aim of this Graphic story is to make learning a fun.
- The story aims to inspire students to understand Faraday's law of Electromagnetic Induction (Self- Induction, Lenz's Law, Mutual- Induction, Eddy currents, A.C. generator and Transformer) learnt in the cocooned environment of the classroom with the real world where these concepts are applied. Each concept has been illustrated with examples from day to day life to facilitate its easy understanding.
- The story moves forward with the two children who in order to satisfy their inquisitive nature find different ways of obtaining information from their father, mother, a lineman and an electrician.
- The novel is an effective medium of integration of art with Physics. The art in the novel will make learning enjoyable and easier for readers to relate the characters and understand Physics in similar situations.

Learning Outcomes

- ❖ The students will learn the principle of electromagnetic induction, it's significance and importance in our daily life.
- ❖ The chapter introduces the terms magnetic flux and magnetic flux linkage.
- ❖ The students will understand the direction of induced current and their associated fields.
- ❖ They will understand the principle of a simple A.C. generator. and how to generate electricity using electromagnetic induction.
- ❖ They will also understand the working of a transformer.

STORY BOARD
PHYSICS XII

ELECTROMAGNETIC INDUCTION

c

MAGNETIC FLUX

FARADAY'S LAW OF EMI

LENZ'S LAW

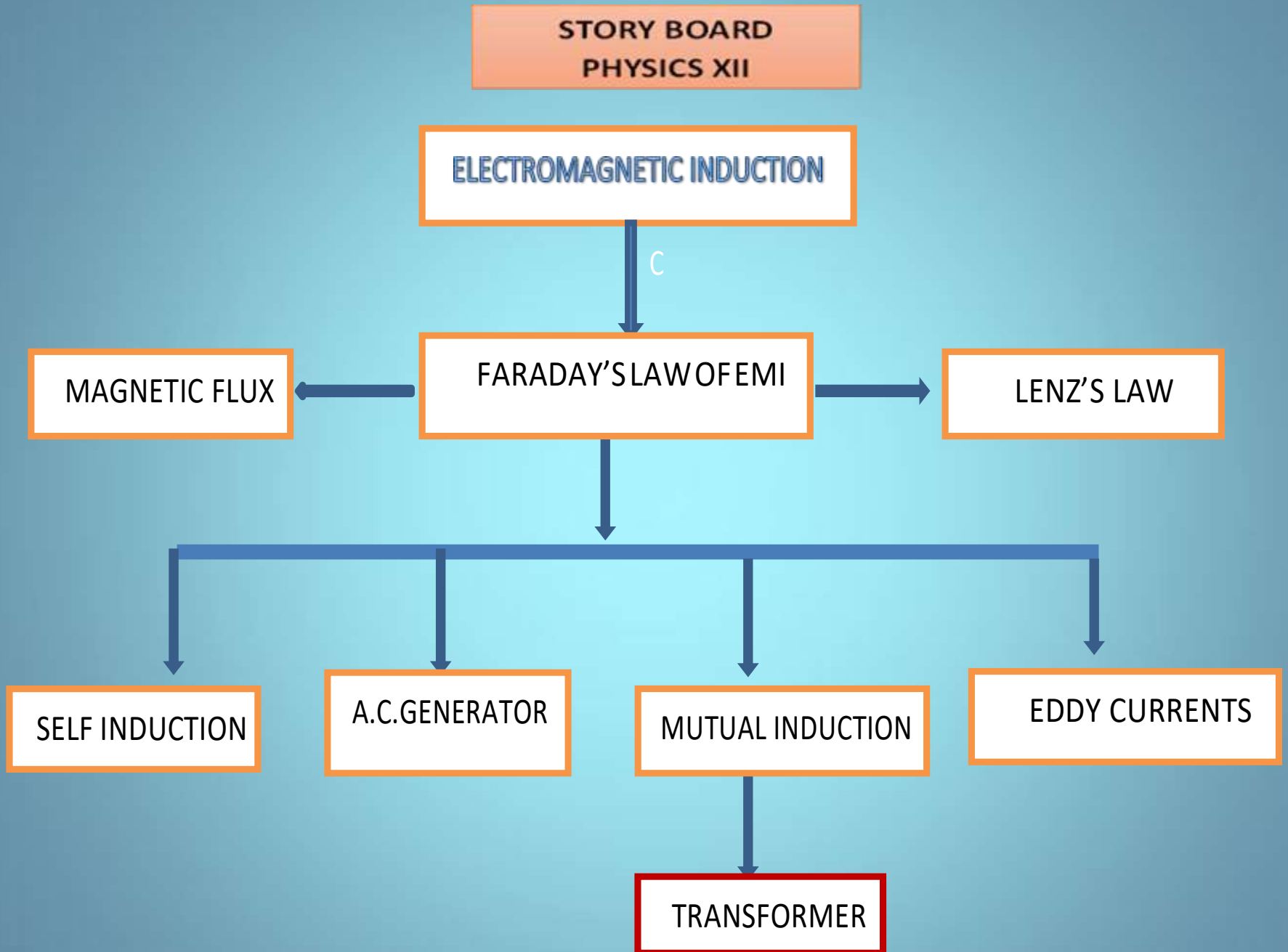
SELF INDUCTION

A.C. GENERATOR

MUTUAL INDUCTION

EDDY CURRENTS

TRANSFORMER



CHARACTERS



FATHER

Name:- Mr. Mohan Lal Sharma

Age :- 45 Years

He is a Lecturer in Physics

MOTHER

Name:- Mrs. Kamla Devi

Age:- 42 Years

She is a homemaker



Name:- Anil

Age:- 18 Years

He is studying in Class 12



Name:-Sushmita
Age:- 12 years
She is studying in Class 6

POLICE MAN

Name:- Mr. Pradeep Kumar
Age:- 45 years
Mr. Pradeep Kumar is a Sub Inspector



LINE MAN

Name:- Mr. Raman Kumar
Age:- 35 Years

ELECTRICIAN

Name:-Mr. Pawan Kumar
Age:- 35 Year
He is an engineer



Sharma family decided to visit the Taj Mahal during vacation. They took a taxi to Jammu Tawi railway station. For entering the platform, they had to cross the security check . Everyone crossed the security gate except the mother. While crossing it, an alarm rang and during checking, it was found that there was an iron knife inside the mother's bag.



Bhai, how did this police man come to know that mummy is having a knife in her bag?

There was an alarm sound while mummy was crossing the security gate.

JAMMU TAWI





Bhai, why was there an alarm sound ?



When a person carrying any heavy metallic item crosses through the security gate, an alarm sound is produced.



I know that it is a physical phenomena.



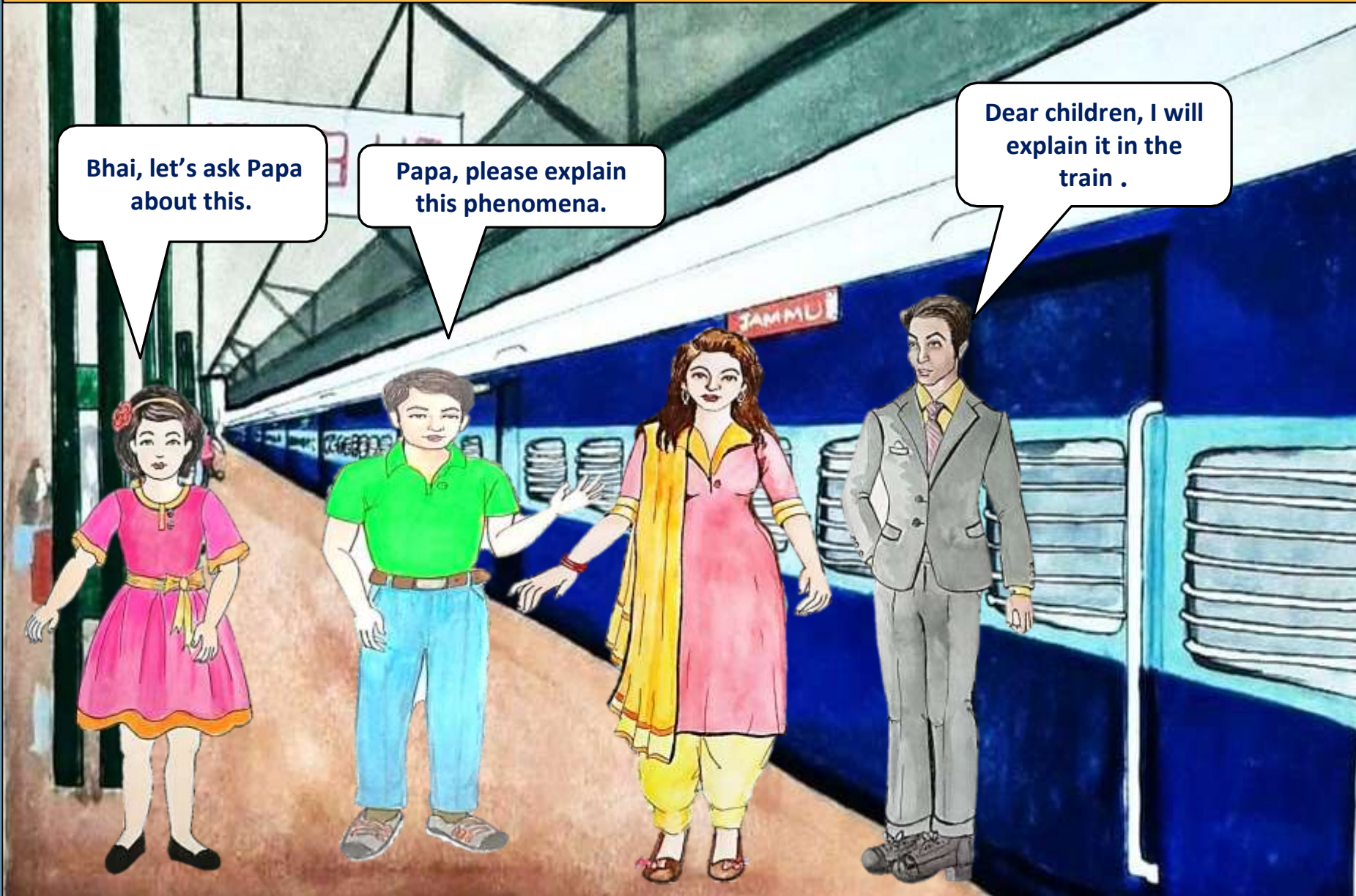
What is the phenomena ?

This is a very important and useful concept of Physics ,that's why an alarm sound is produced when a person carrying any metallic item passes through the security gate.

Bhai, let's ask Papa about this.

Papa, please explain this phenomena.

Dear children, I will explain it in the train .

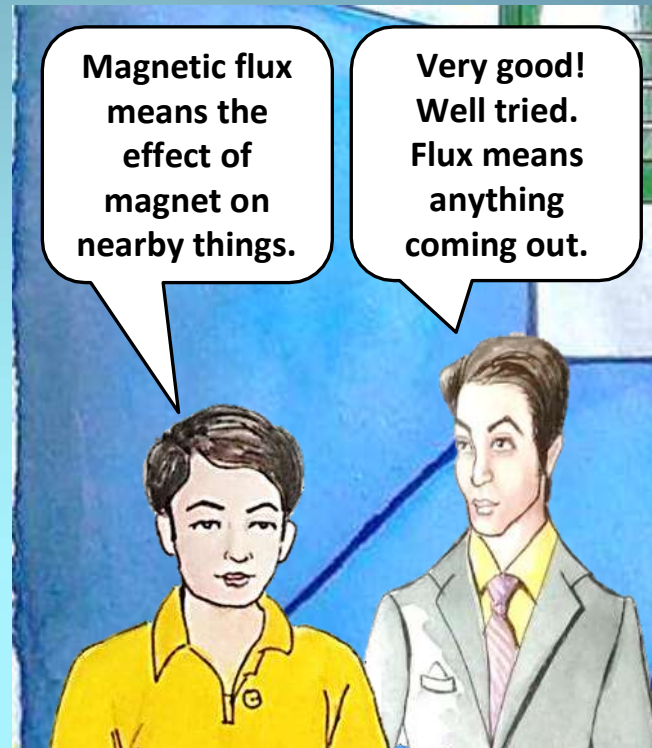
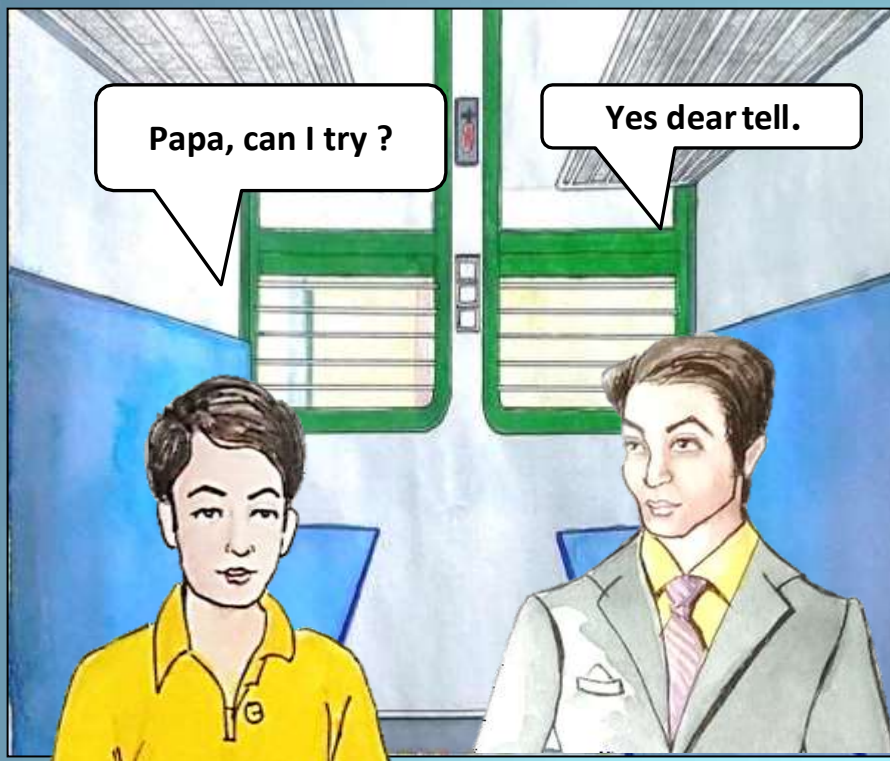




Electromagnetic induction (EMI) is a phenomena of inducing an emf (Electromotive Force) or an induced current when there is change in the magnetic flux.

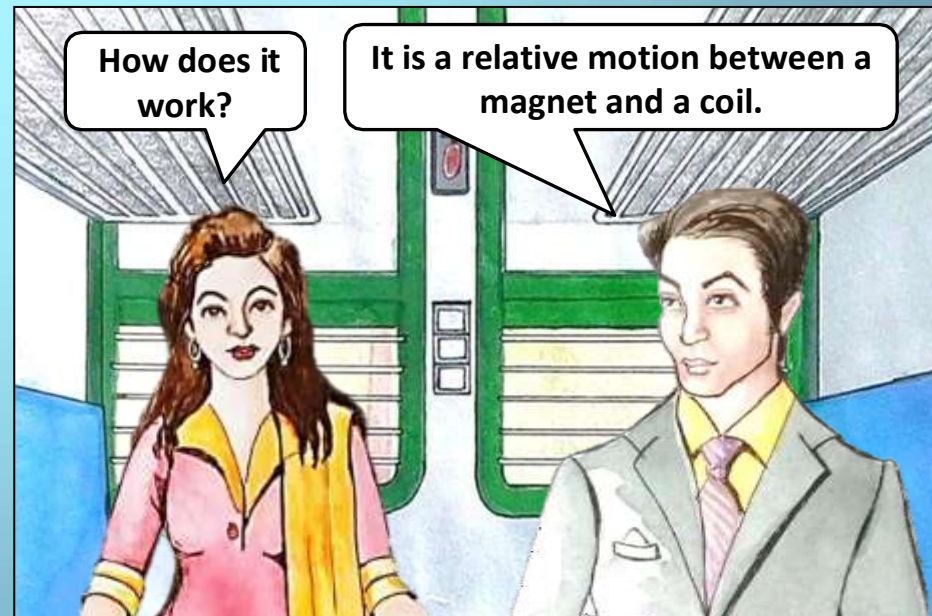
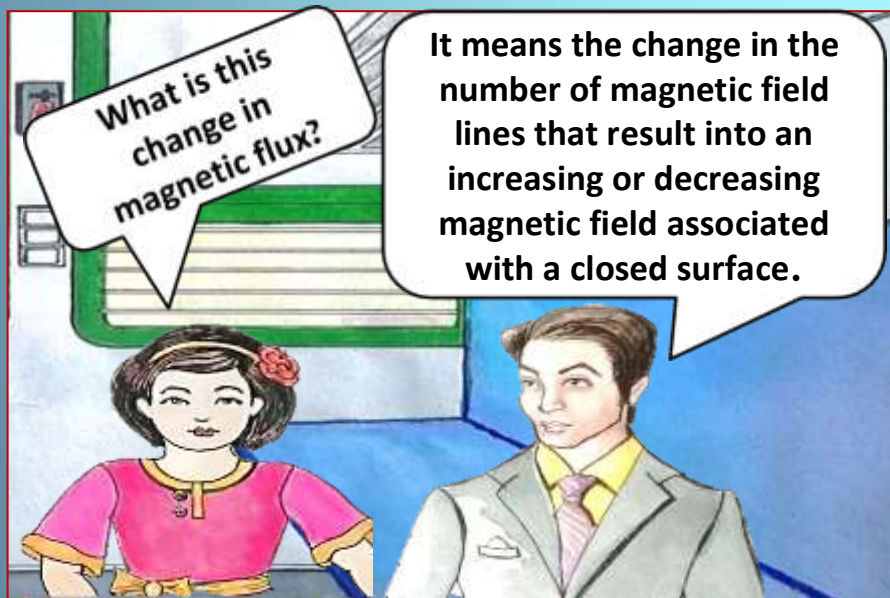
This phenomena is electromagnetic induction.

What is the meaning of magnetic flux?



Magnetic flux
When a magnetic field of magnetic flux density B passes perpendicular to an area A , the magnetic flux, ϕ passing through the area is given by
$$\phi = BA$$

→ It is a scalar quantity.
→ It is measured in Weber (wb).





Methods of producing induced e.m.f. :

- Induced e.m.f. by changing the strength of magnetic field.
- Induced e.m.f. by changing the area (Motional e.m.f.).
- Induced e.m.f. by changing the orientation of the coil with respect to the magnetic field.

Dear children, when a person carrying a knife or any heavy metallic object crosses the magnetic field, it changes the magnetic flux, which produces an induced EMF across the coil itself, this is self induction.



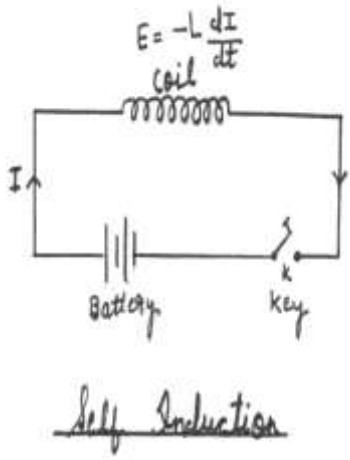
Both the children are very excited as they know the fact and phenomena behind this security check.

See, there is a security man for checking.

Mama, please check your bag again.



Anil narrates and explains this phenomena to his classmates and they enjoy the whole story and get knowledge of EMI.



Self-Induction

As $\phi \propto I$

$\therefore \phi = LI$, L is known as
Coefficient of self Induction
According to Faraday's law

$$E = - d\phi / dt$$

$$E = - d/dt (LI)$$

$$E = -L dI / dt$$

SI unit of self inductance is
Henry (H).

Faraday's Law

It states that the induced
emf is proportional to the
rate of change of flux.

$$\text{Formula} \rightarrow E = - d\phi / dt$$

Negative sign indicates that
direction of induced emf is
opposite to the cause which
produces it (Lenz's law).

Dear friends,
today I will
explain you the
phenomena of
electromagnetic
induction.



CHECK YOUR KNOWLEDGE

(I) Multiple Choice Questions:-

- Q1. Due to the relative motion of a magnet with respect to a coil, an emf is induced in the coil, identify the principle involved-
- (a) Ampere's circuital law (b) Faraday's law of EMI
(c) Gauss law (d) Biot-Savart law
- Q2. In Faraday's experiment on electromagnetic induction, more deflection will be shown by the galvanometer, when-
- a) Magnet is in uniform motion towards the coil.
b) Magnet is in uniform motion away from the coil.
c) Magnet is in accelerated motion towards the coil.
d) Magnet is at rest near the coil.
- Q3. If both, the number of turns and core length of an inductor is doubled keeping other factors constant, then its self-inductance will be-
- (a) Unaffected (b) doubled
(c) halved (d) quadrupled
- Q4. The direction of induced current is such that it opposes the very cause that has produced it. This is the law given by:-
- (a) Lenz (b) Faraday
(c) Ampere (d) Joseph Henry

(II) True/False Type Questions:-

- Self-inductance of a coil increases when an iron core is introduced in the core of the coil.
- The rate of change of magnetic flux through a coil is maximum when a magnet is held stationary near the coil.

(III) Units of following quantities are

TABLE A (Quantities)

- a) Magnetic field
b) Magnetic flux
c) Induced e.m.f.
d) Inductance

TABLE B (Units)

- 1) volt (V)
2) tesla (T)
3) weber (Wb)
4) henry (H)

Answer Key

Multiple choice question:

1. (c) 2. (b) 3. (a) 4. (a)

True/False:

1. True 2. False

Table:

a. 2

b. 3

c. 1

d. 4

SUB TOPIC:- A.C. GENERATOR



Dear children, today we are going for a picnic.

Wow! Maa.

Hurray! But where are we going ?

Sharma family is planning to visit the Salal Dam in tehsil Reasi of district Jammu and nearby hydropower station through their car. The main purpose of the visit is to explain the production of the electricity.



let's ask Papa, he
must have a very
good plan.

Papa, where
are we going
today?



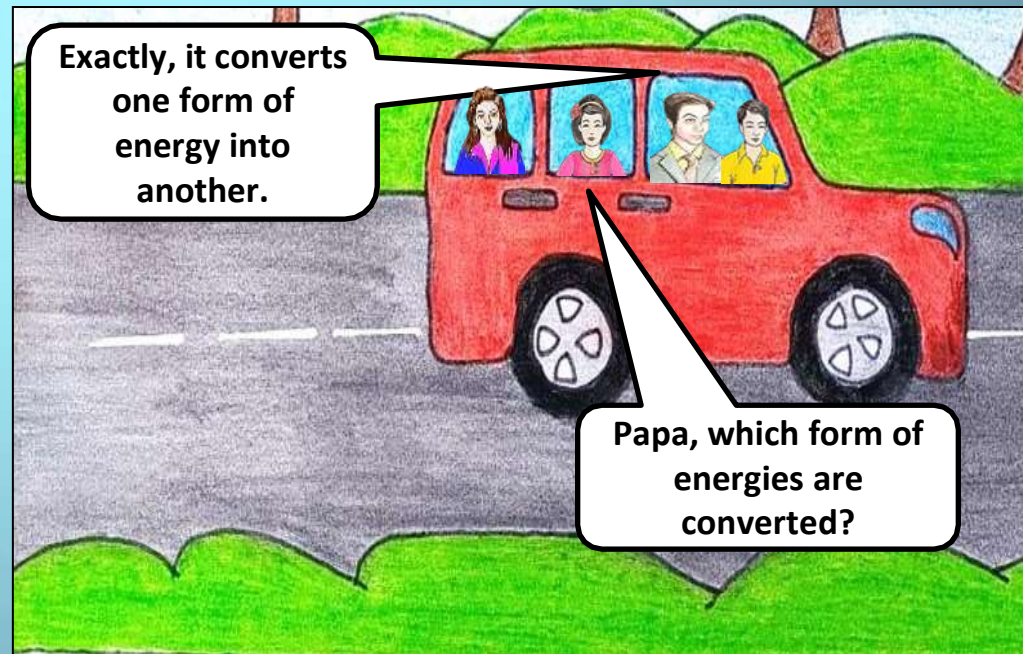
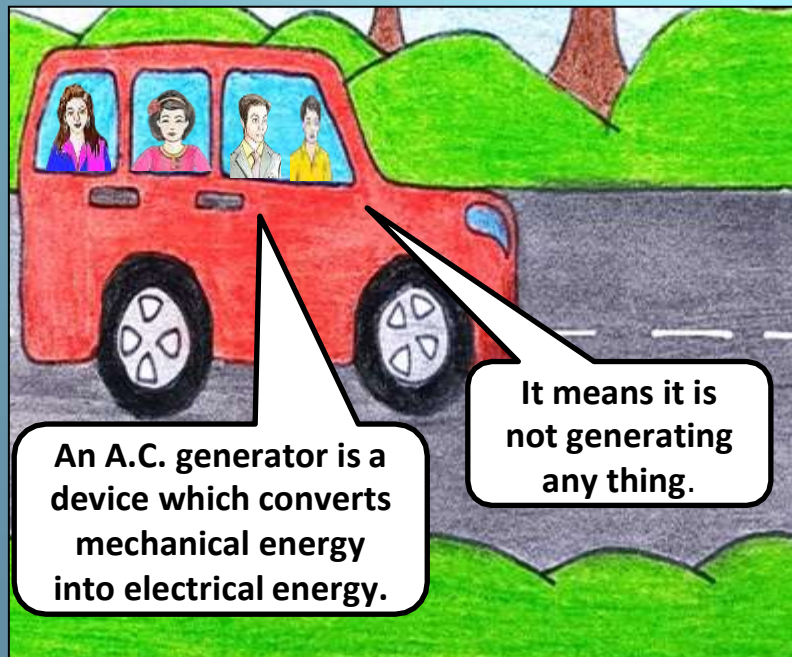
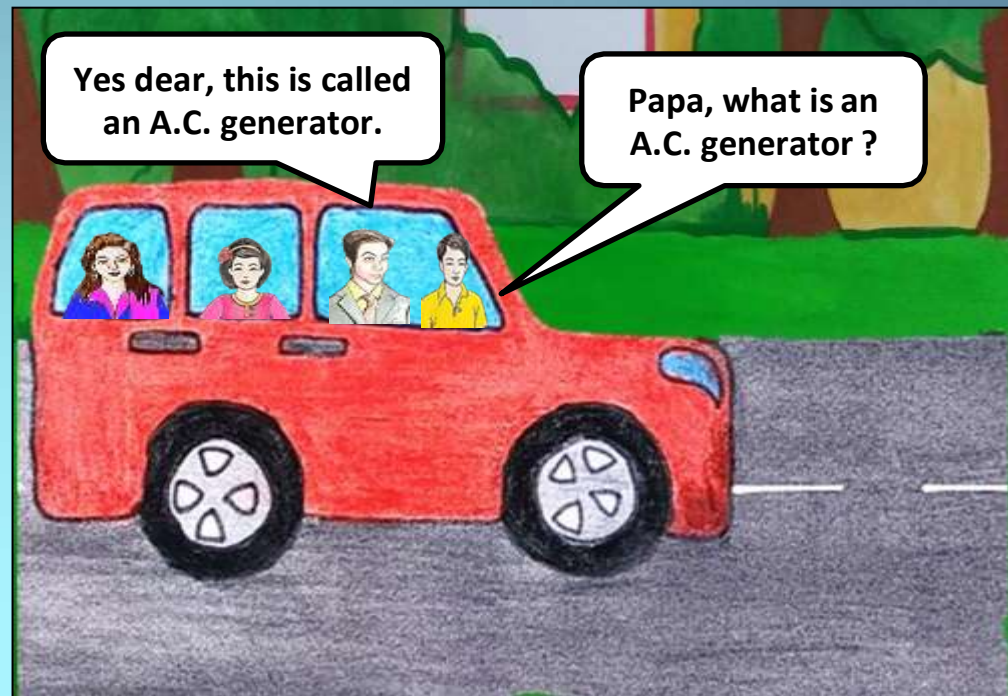
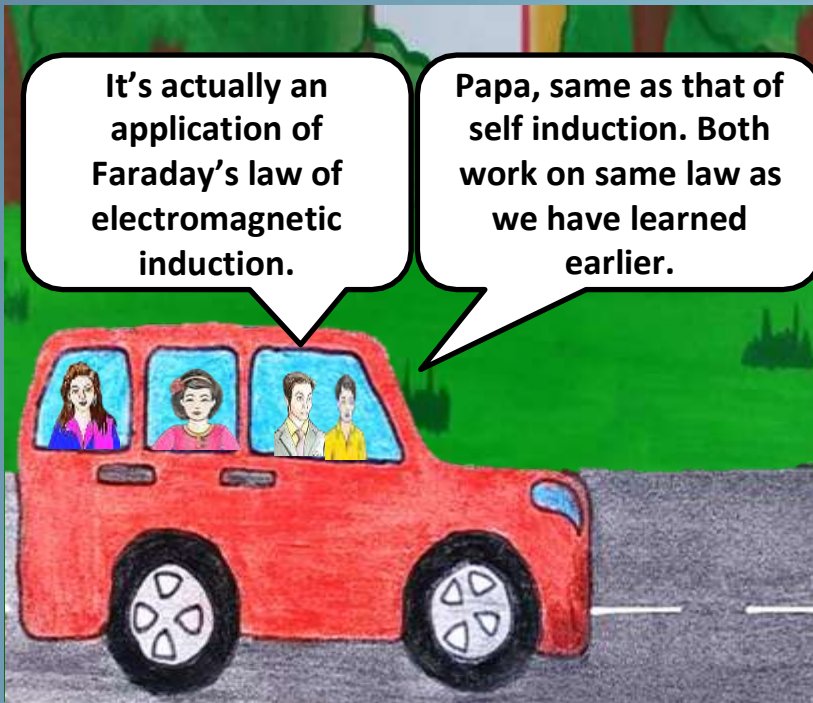


Sharma family started their journey towards the Power Station. (Conversation in the car).



Anil, do you know on which law is an A.C. generator based on and how does it work ?

No papa.

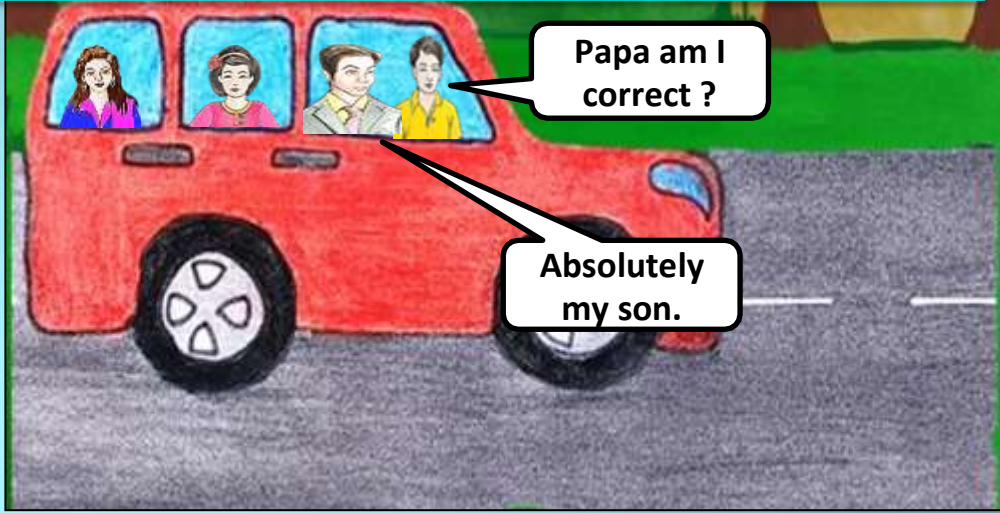




Papa, can I answer?

Yes, my dear.

Water up in the dams store potential energy, when water starts falling downward through pipes this potential energy is converted into kinetic energy and into another form of energy that is electrical energy.



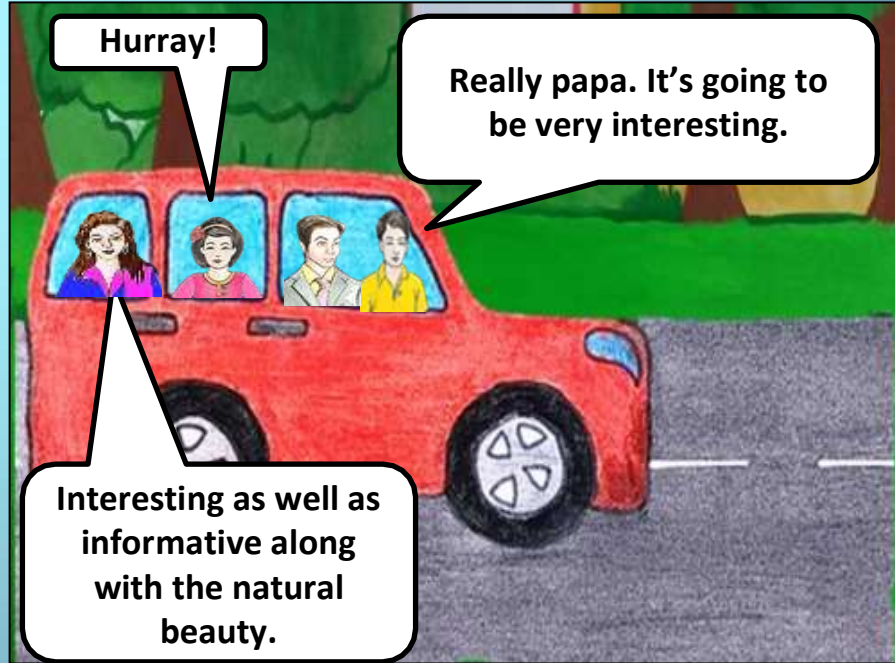
Papa am I correct?

Absolutely my son.



Thanks papa.

I have explained you that in Faraday's law of EMI, when water falls with kinetic energy on turbine, it rotates because of that magnetic field which changes due to orientation inside the device which produces Alternating electricity.



Hurray!

Really papa. It's going to be very interesting.

Interesting as well as informative along with the natural beauty.





Good, water moves downwards through these pipes.

This moving water will have Kinetic Energy now.

Mohan Lal Sharma taking permission from the electrician to go inside the hydropower station.

Hello! How can I help you?

Sir, we want to visit the generator room if you could please permit.

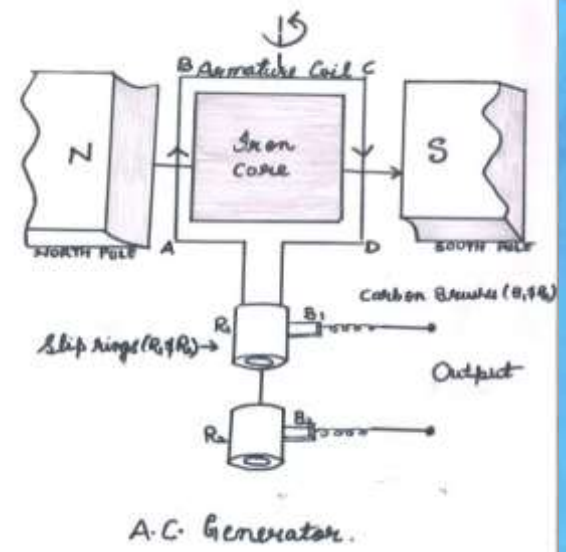
We are from Jammu.
I am a lecturer in Physics and I want to explain the working of an A.C. generator to my children.

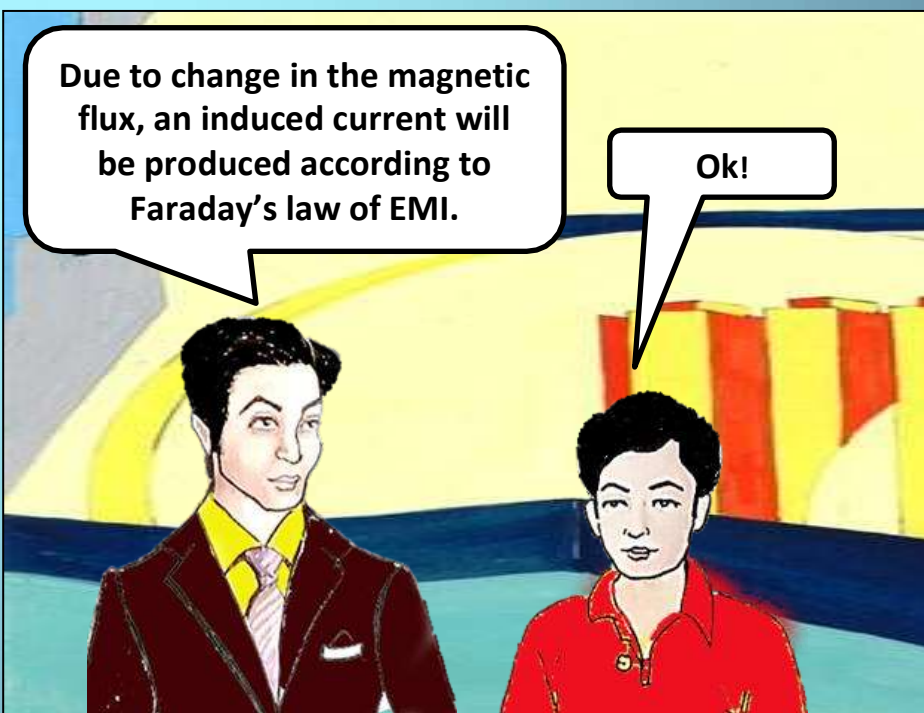
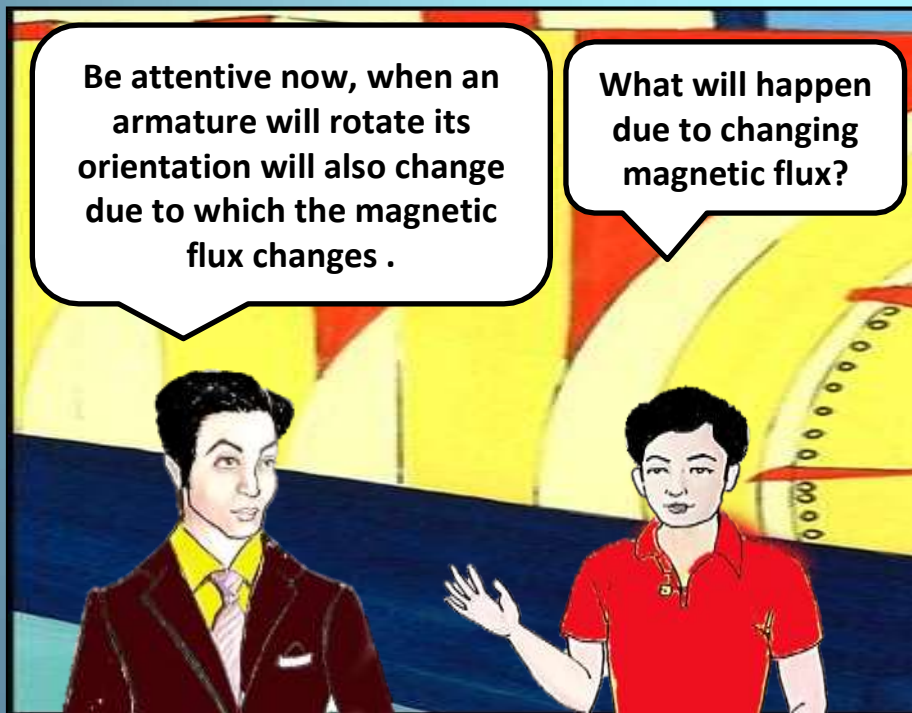
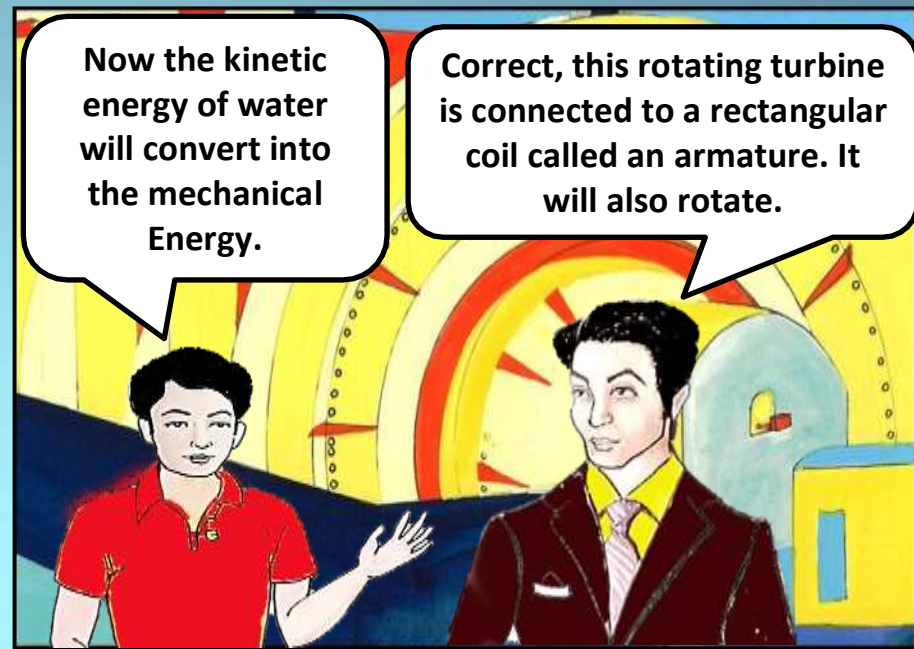
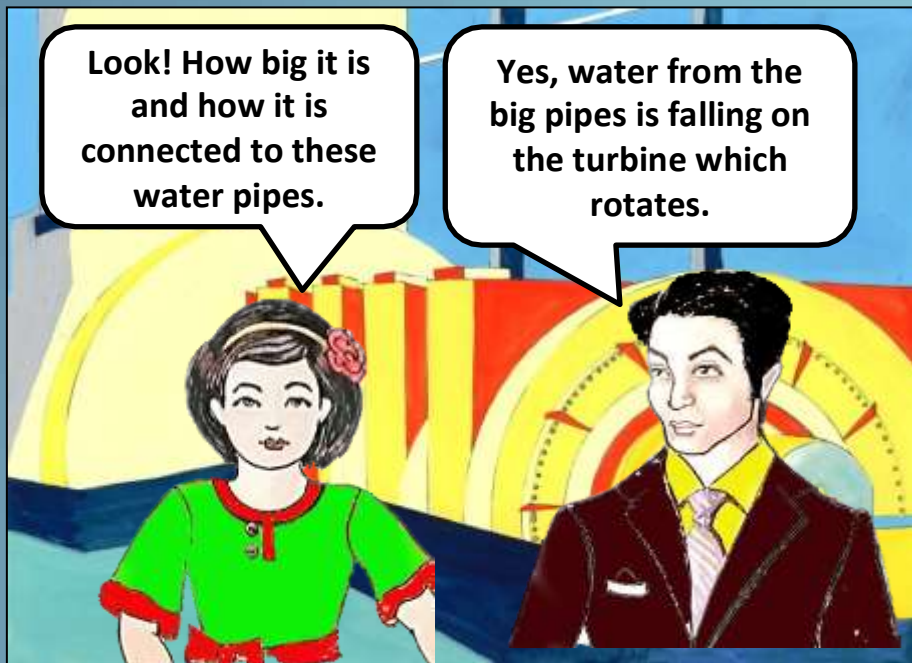
Okay Sir, please take care of the safety also.

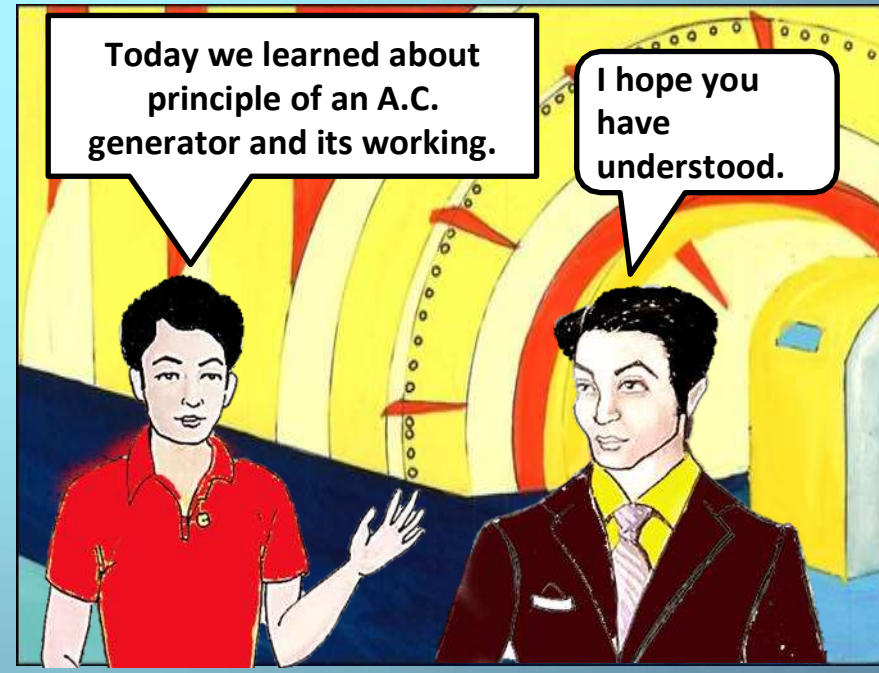
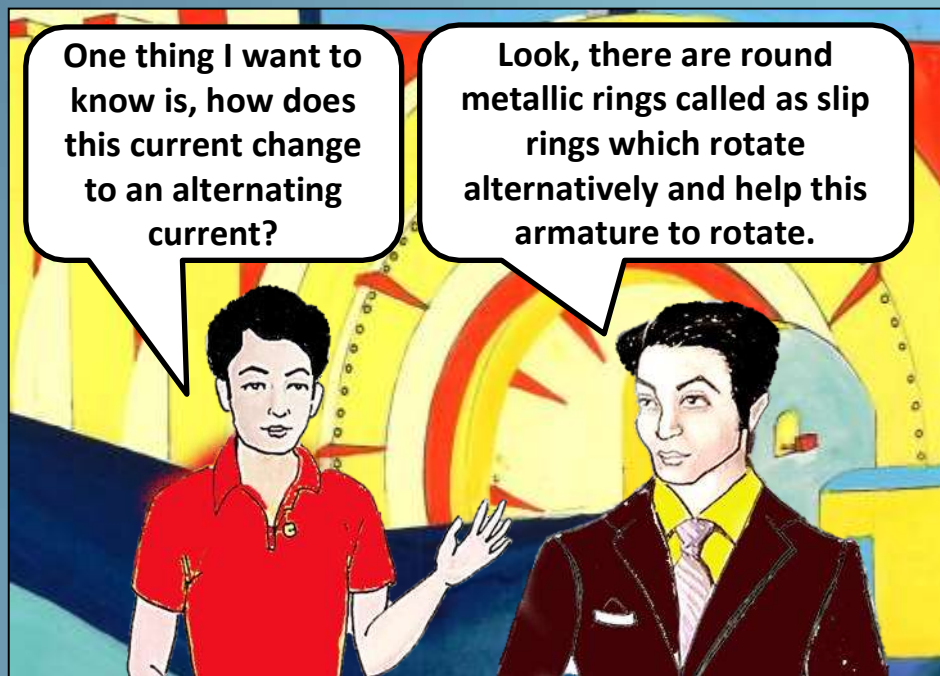


Papa, what is this big machine?

This is an A.C. generator dear.







LET'S REVISE

(I) True/False Type Questions:-

1. The magnetic flux passing through a plane surface area, which is held perpendicular to a magnetic field is maximum.
2. The rate of change of magnetic flux through a coil is maximum when a magnet is held stationary near the coil.
3. The magnetic flux passing through a coil becomes twice when the number of turns becomes two times.
4. An A.C. generator is based on the principle of electromagnetic induction.

(II) Fill in the blanks:-

1. An A.C. generator is based on the phenomena of
2. In A.C. generator, we use to determine the direction of
3. In hydro power station, of falling water is converted into

Answer Key

True/False:

1. True 2. False 3. True 4. True

Fill in the blanks:

1. Faraday's law of EMI 2. Fleming's right hand rule; induced current 3. kinetic energy; electrical energy

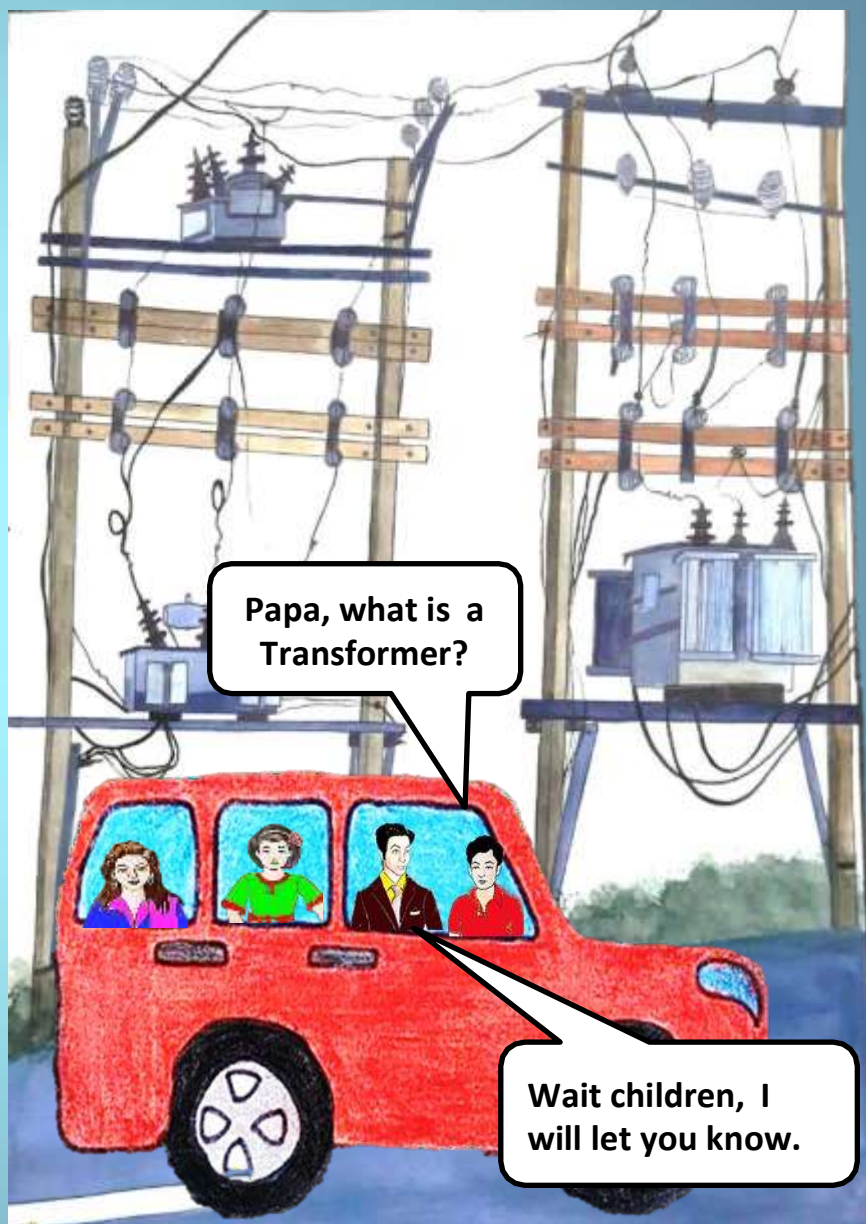
SUB TOPIC:- TRANSFORMER (MUTUAL INDUCTION)

While sitting inside the car Anil saw a huge device and got curious to know about it.



Papa, what is this big thing or an equipment hanging on the poles?

Dear son, this is a Transformer.



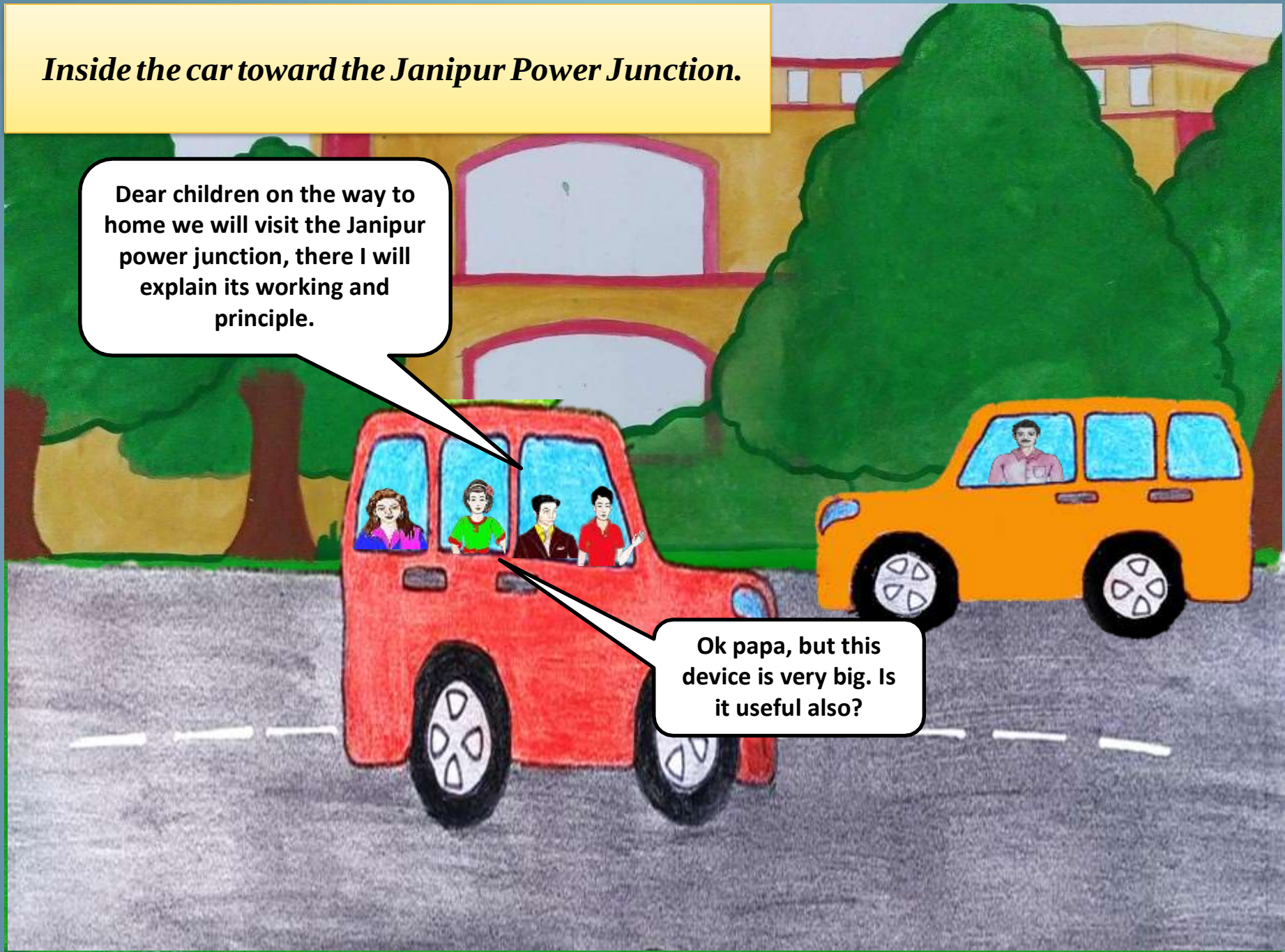
Papa, what is a Transformer?

Wait children, I will let you know.

Inside the car toward the Janipur Power Junction.

Dear children on the way to home we will visit the Janipur power junction, there I will explain its working and principle.

Ok papa, but this device is very big. Is it useful also?

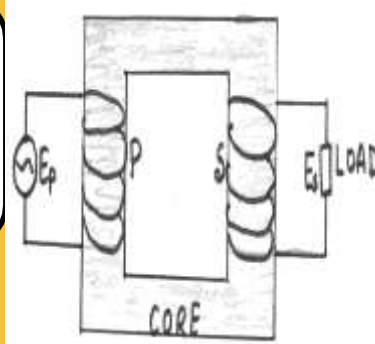


Anil trying to explore the concept of transformer .



The Transformers are made up of a primary coil, a secondary coil and an iron core. The lay out diagram will be demonstrated.

Let's watch this video.



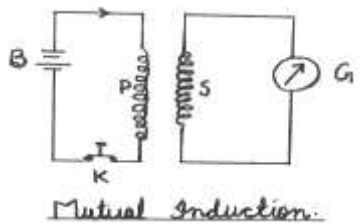
Show it to me also.

Pausing the video inbetween.



Papa, which material is used to make these coils?

These are made up of copper but can be of any good conductor metal like aluminum, silver, etc.



Are there two such coils?

Yes, one to which input is given, is called the Primary Coil and the other one from which output is taken is called the Secondary Coil.

Papa explained the process of Self induction in train.

When another coil is brought near the secondary coil, again flux changes and induced current is produced, this is called as mutual induction.

They reached the Janipur Power Junction.

What is the principle of a transformer?

A transformer is based on the principle of mutual induction

Principle of Mutual Induction

Inducing e.m.f. in a coil due to change of current with time in a nearby coil.

$$\phi_s \propto I_p$$

$\phi_s = M I_p$ Where M is coefficient of Mutual Induction.

$$\therefore \varepsilon_s = - \frac{d\phi_s}{dt}$$

$$\varepsilon_s = - \frac{d}{dt} (M I_p) = M \frac{dI_p}{dt}$$

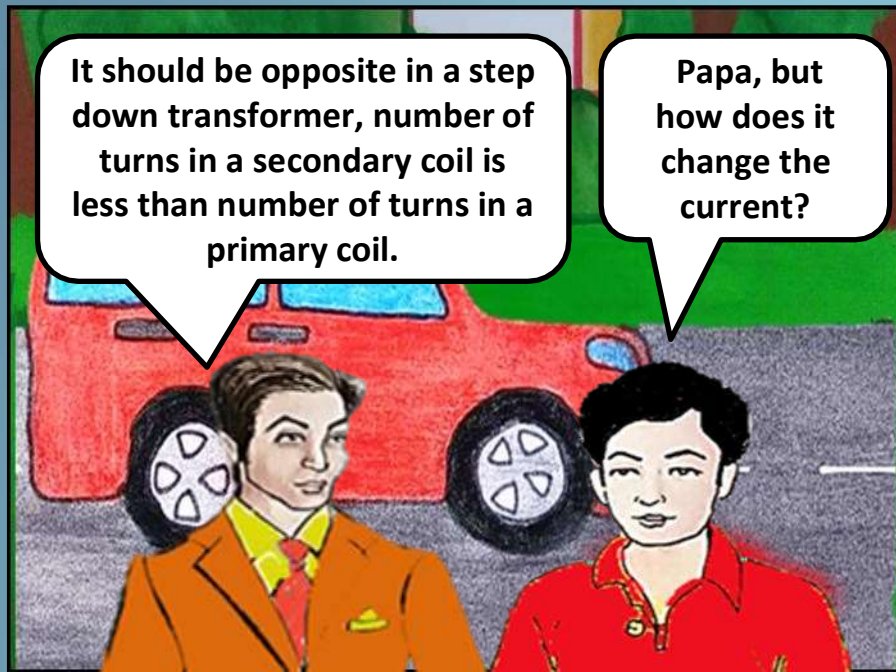
S.I. Unit of Mutual Induction is Henry (H).

Papa, there are two types of transformers in this video i.e. step up and step down.

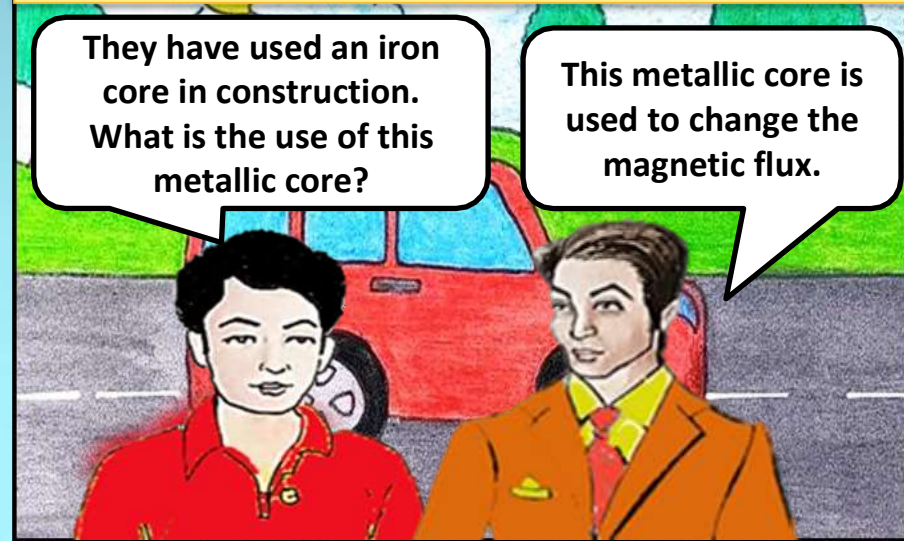
Absolutely right.

What is a step up transformer?

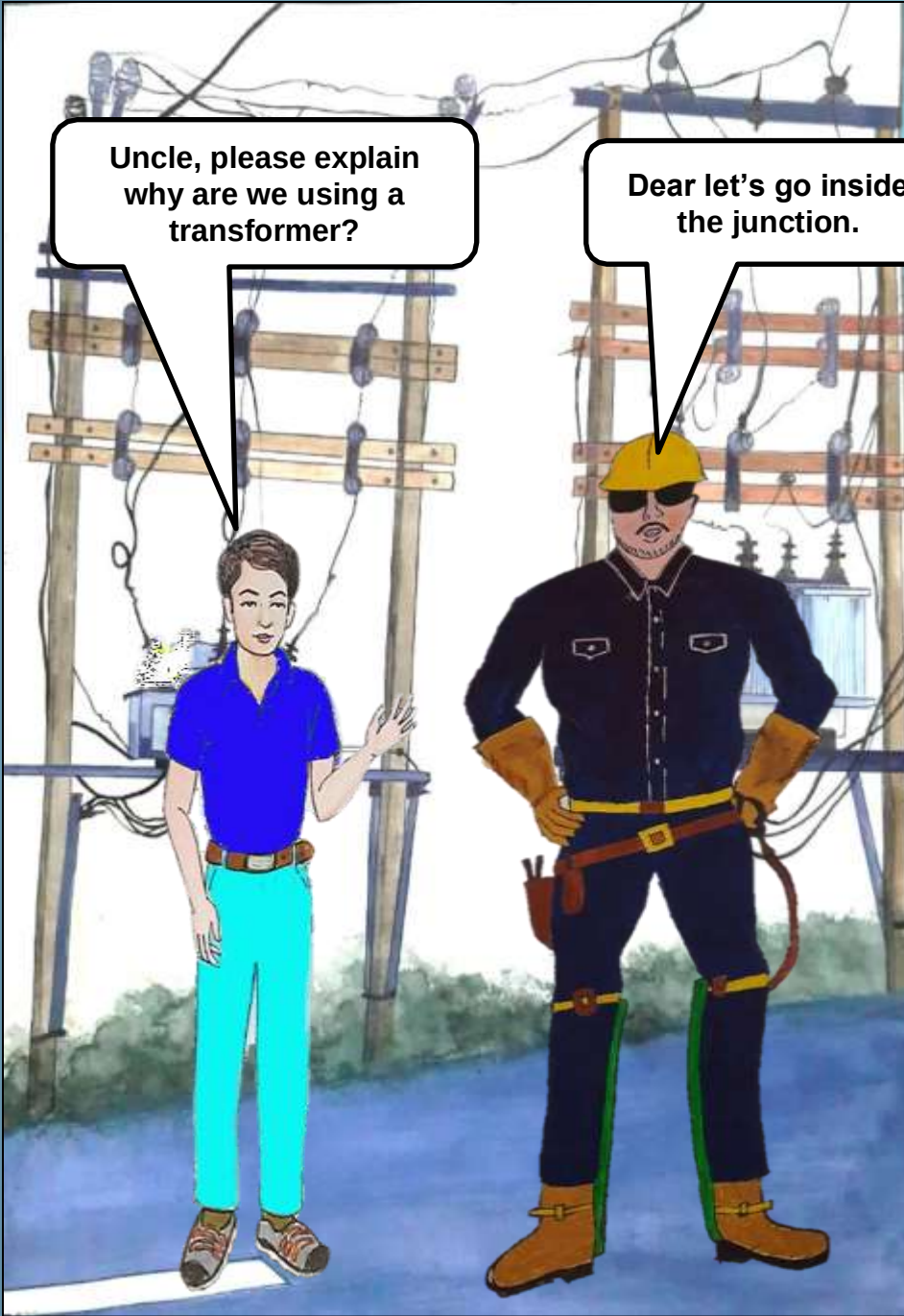
In a step up transformer, number of turns in a secondary coil is greater than number of turns in a primary coil.



This is because of Faraday's law of EMI in which induced e.m.f. depends upon change in the flux and the number of turns.







Uncle, please explain
why are we using a
transformer?

Dear let's go inside
the junction.



Ok. But do not
touch anything, be
careful.



Look at the wires coming from the power station. They carry the current.

The current has to travel a distance of 28 kms. How is this possible?

Very good observation. This is possible with the help of a transformer.

We use step up transformer, which converts low alternating voltage at high current into high alternating voltage at lower current.

Here at junction we decrease voltage with the help of step down transformer for distribution.

Otherwise high voltage will destroy our electrical equipments at home.

Very correct.

So transformer is used for long distance transmission of electrical signals.

Thank you so much Uncle and Papa for valuable information.

LET'S REVISE

(I) Fill in the blanks:-

1. The S.I. unit of mutual inductance is
2. The energy stored in a coil carrying current I is u . If current is halved, then energy stored in the coil will be
3. In a primary winding of a transformer, if we connect a D.C. supply we get no.....output.
4. In a transformer, the no. of turns of a primary and a secondary coil are 500 and 400 respectively. If 220 V is supplied to the primary coil, then ratio of currents in primary and secondary coils is

(II) Multiple choice Question:-

1. A Transformer is an electrical device used for
 - a) producing direct current.
 - b) producing alternating current.
 - c) changing D.C. into A.C.
 - d) changing alternating voltages.
2. Choose the wrong statement out of the following:-
 - a) A transformer cannot work on D.C.
 - b) A transformer cannot change the frequency of A.C.
 - c) A transformer can produce A.C. power.
 - d) In a transformer, when alternating voltage is raised n times, the alternating current reduces to $1/n$ time.

Answer Key

Fill in the blanks:

1. Henry 2. $U/4$ 3. Power 4. 4:5

Multiple choice questions:

1. (d) 2. (c) 3. (d)

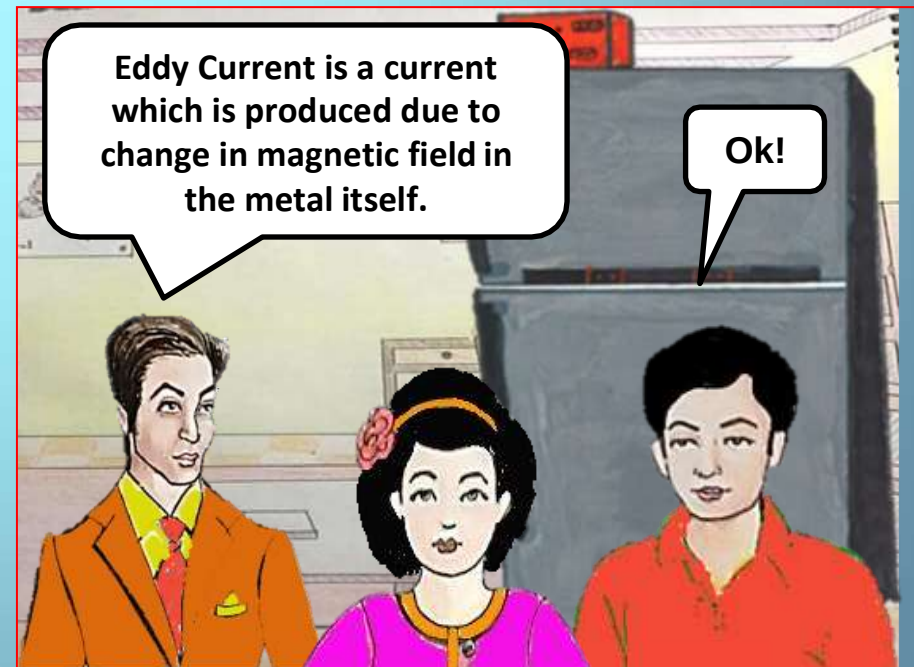
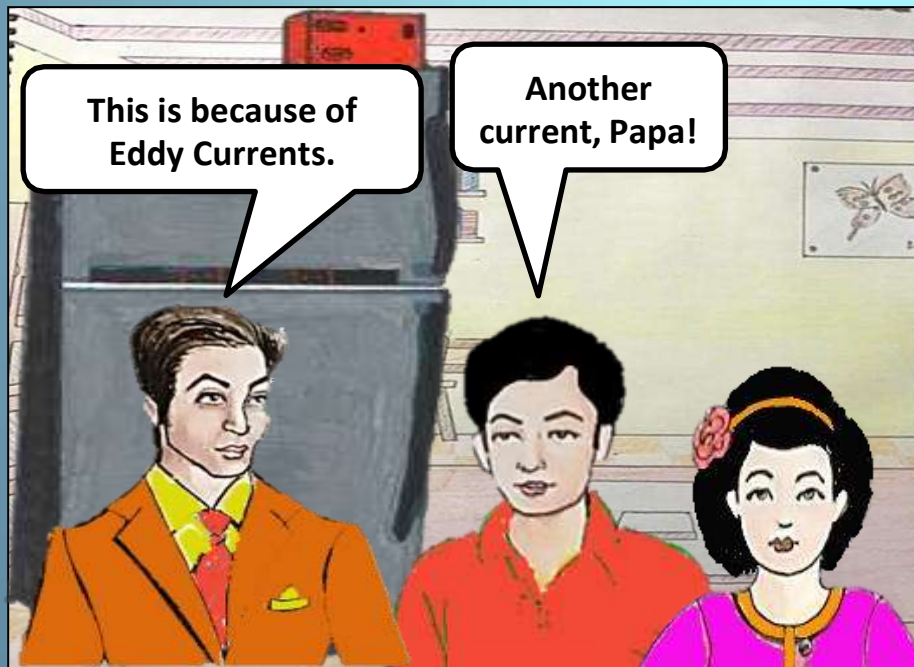
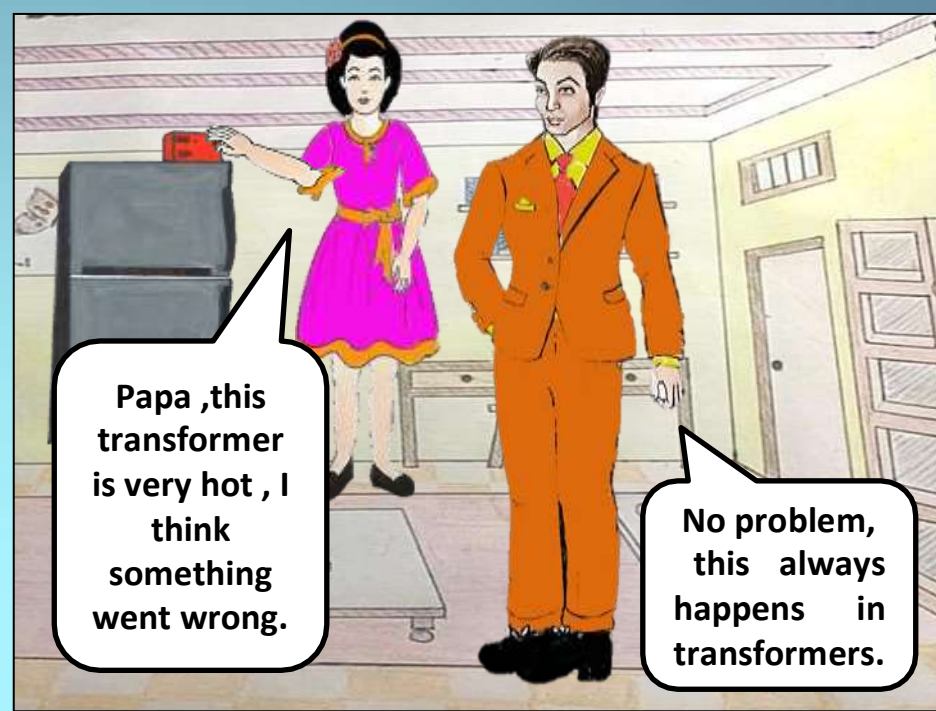
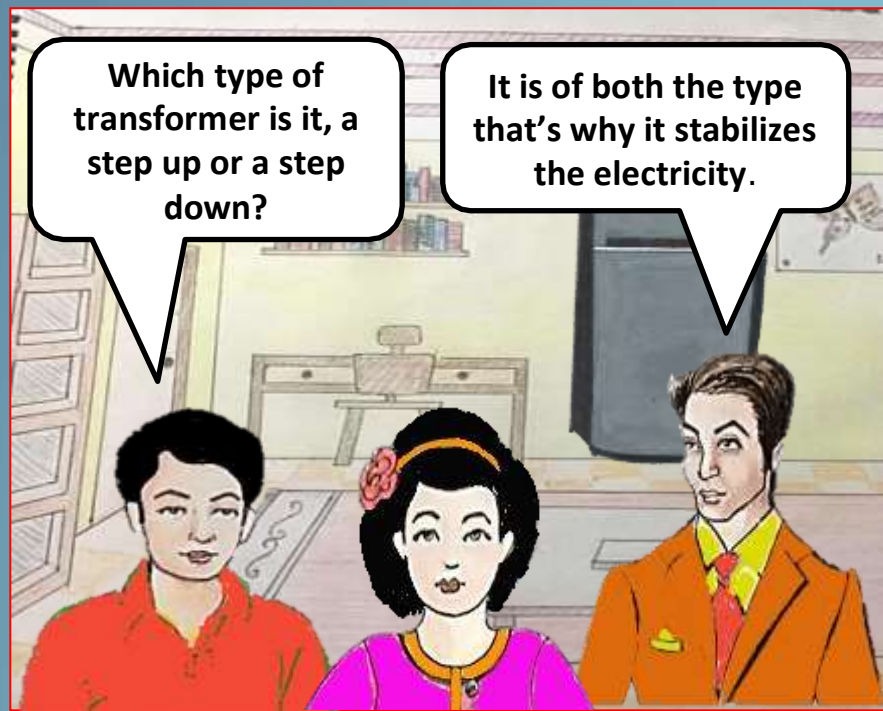
SUB TOPIC:- EDDY CURRENTS

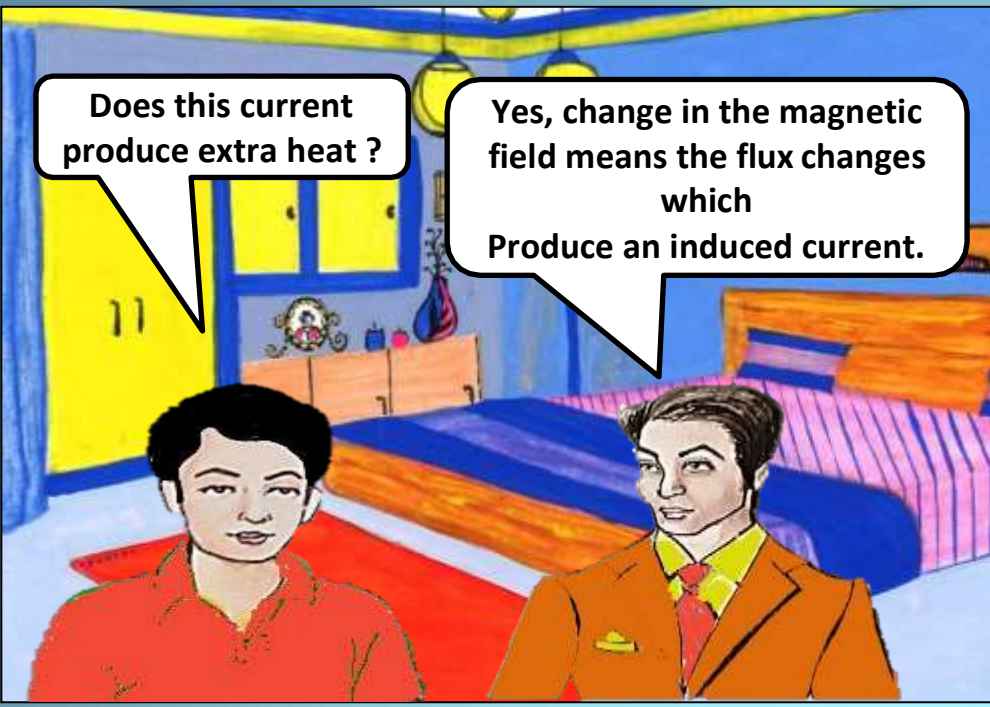
They all came back home.

Papa, is transformer also present in a stabilizer?

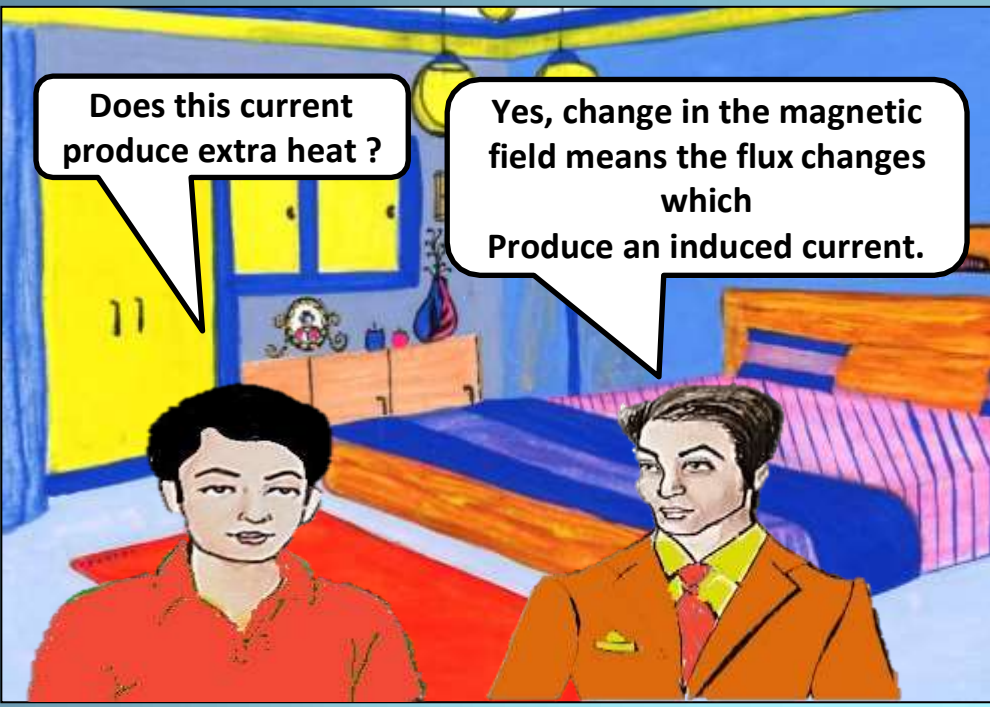
Yes my dear.



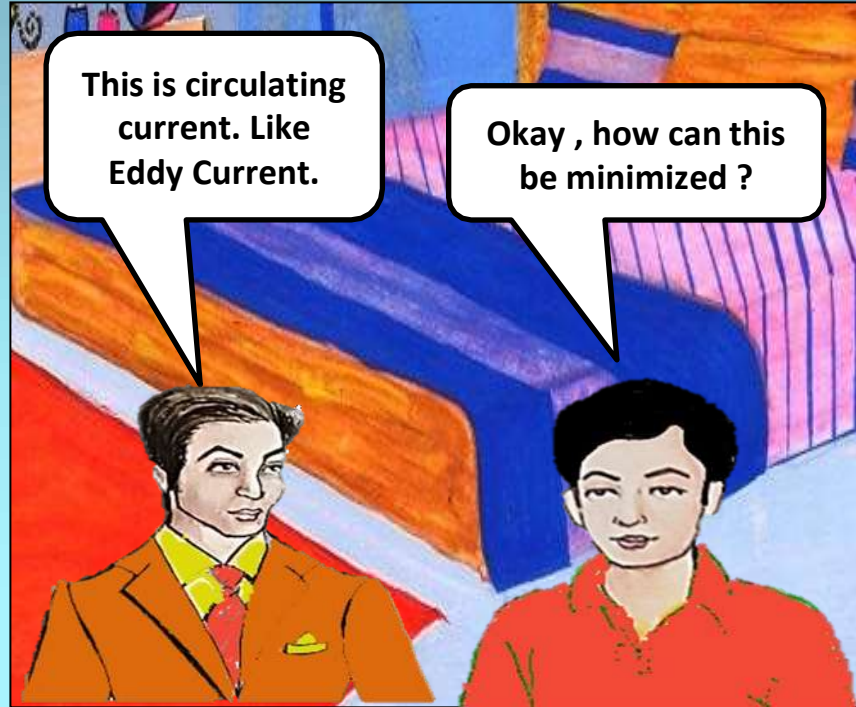




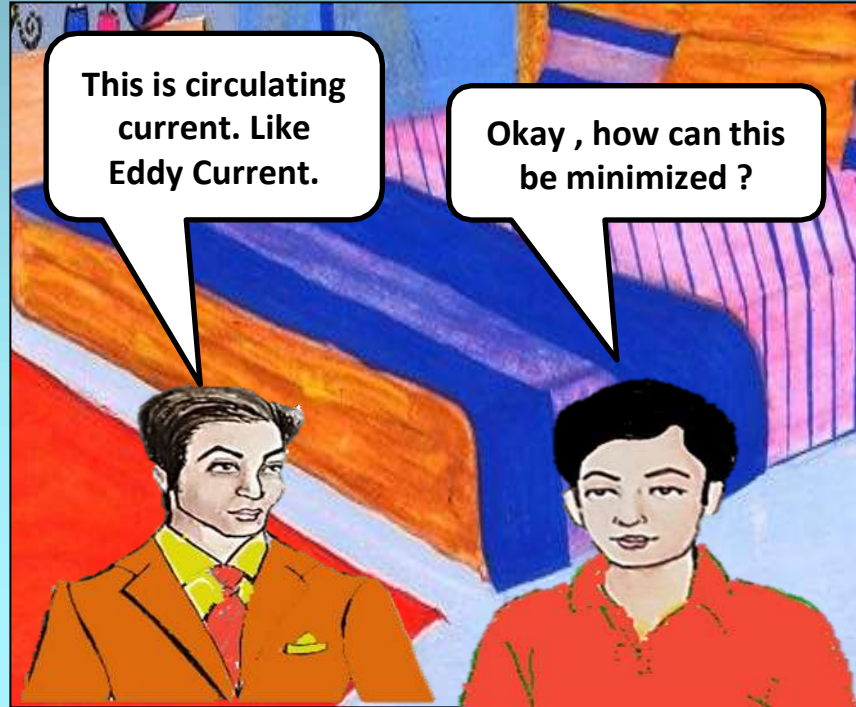
Does this current produce extra heat ?



Yes, change in the magnetic field means the flux changes which produce an induced current.



This is circulating current. Like Eddy Current.



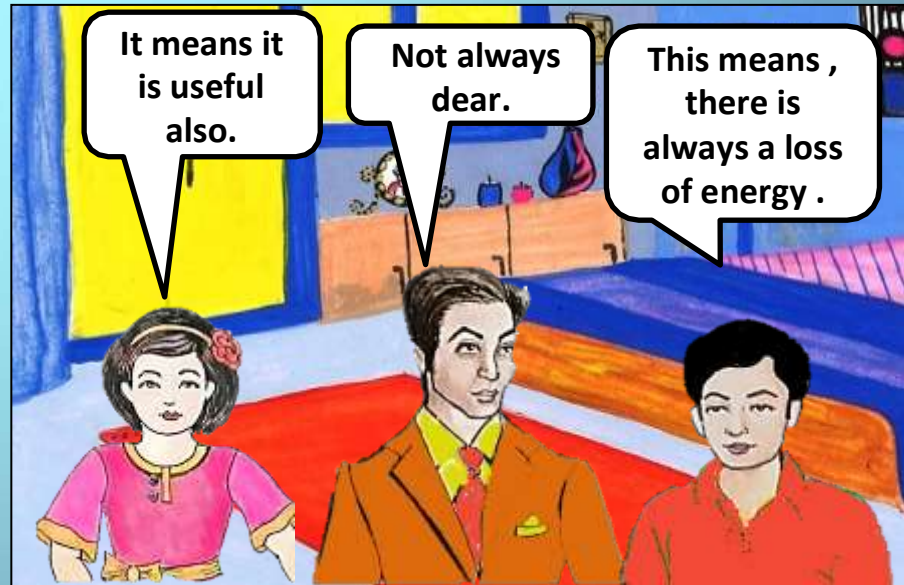
Okay , how can this be minimized ?



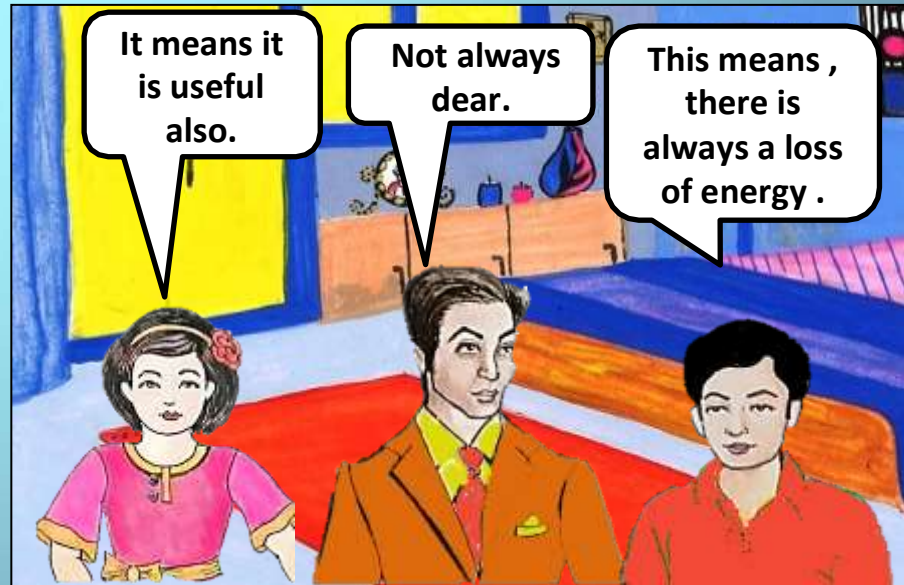
By cutting the metallic sheet and lamination.



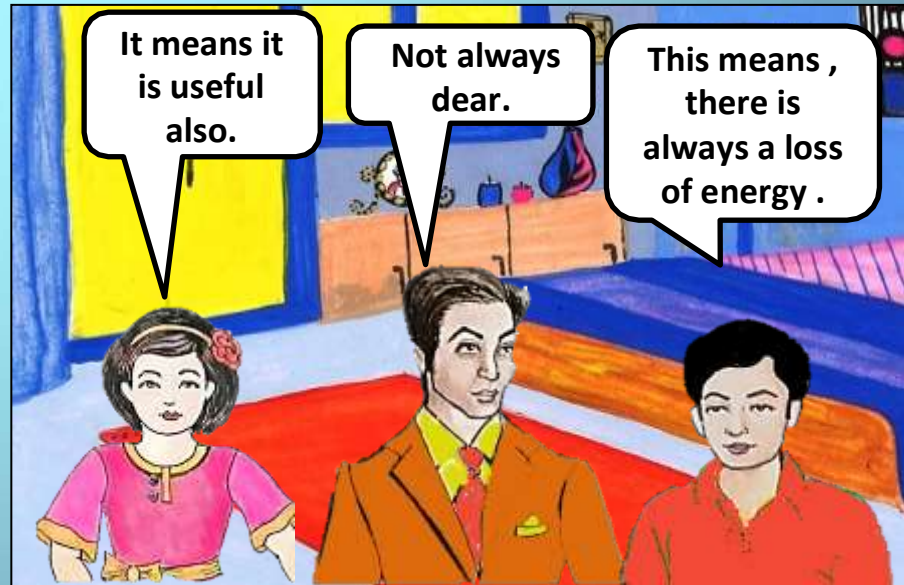
Ok , cutting and lamination will decrease this circular current.



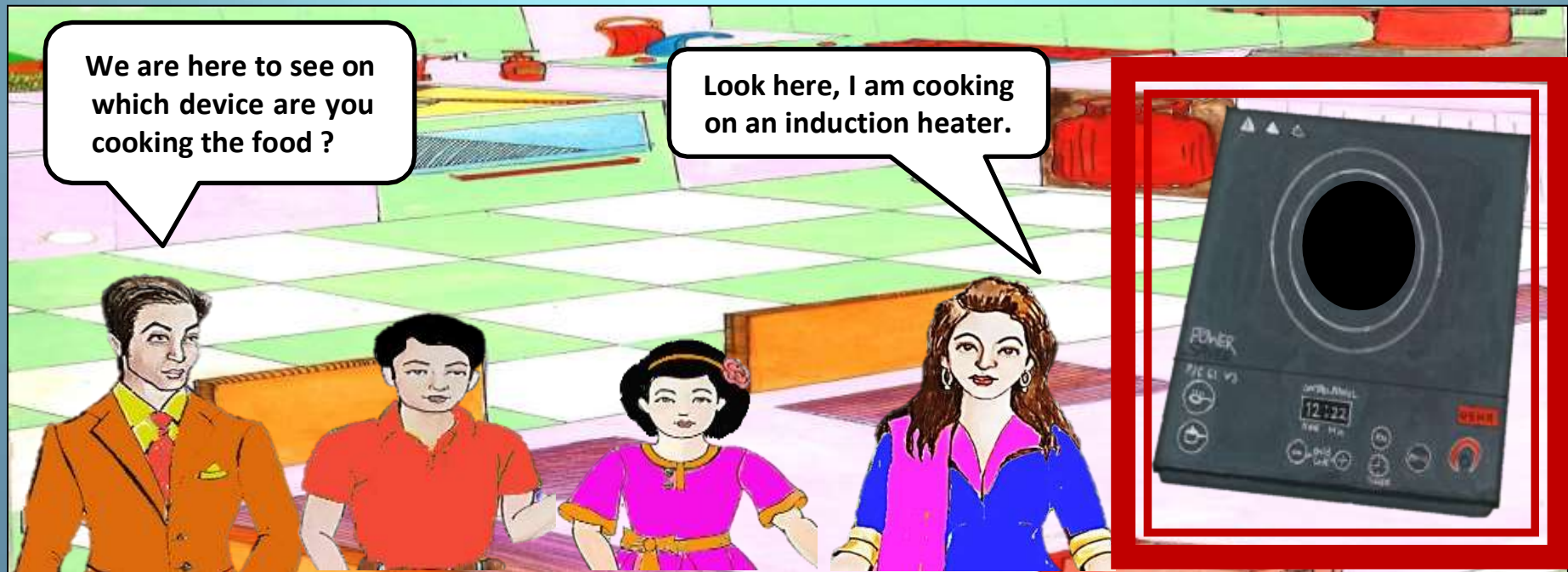
It means it is useful also.

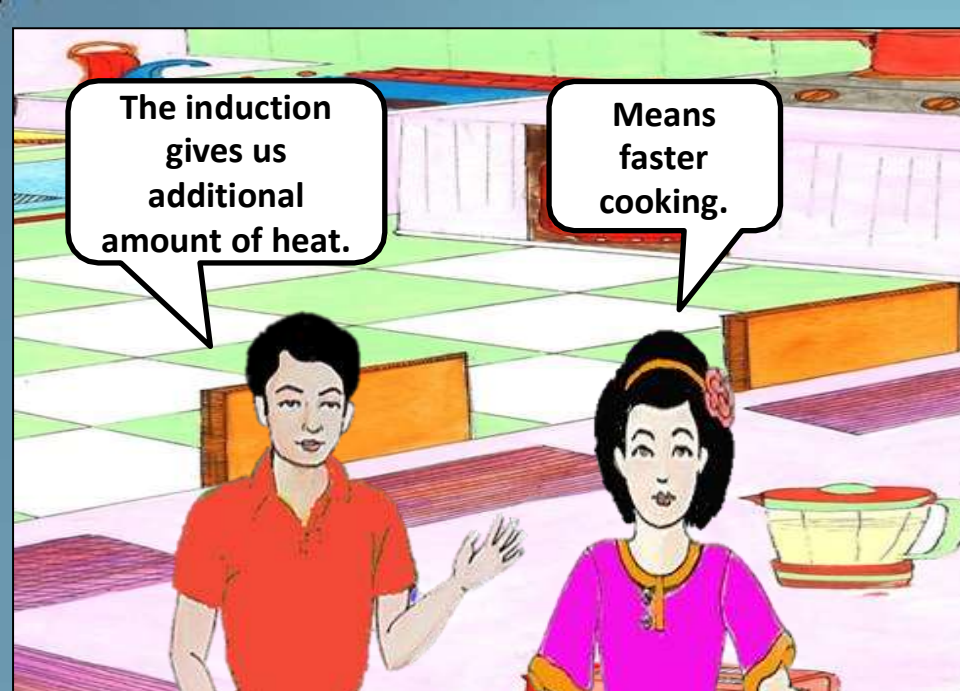


Not always dear.



This means , there is always a loss of energy .





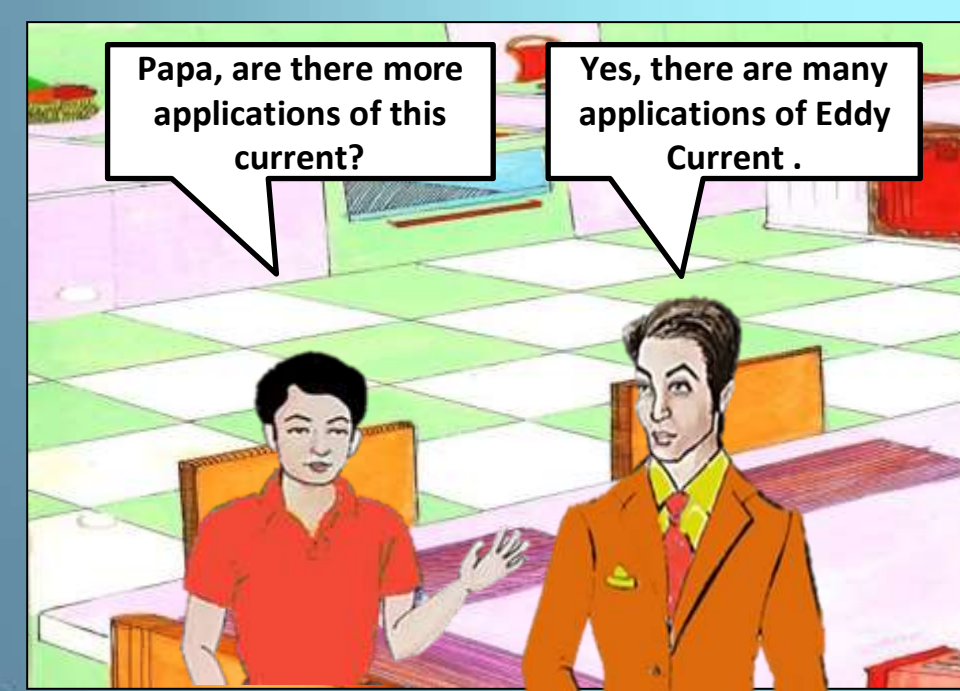
The induction gives us additional amount of heat.

Means faster cooking.



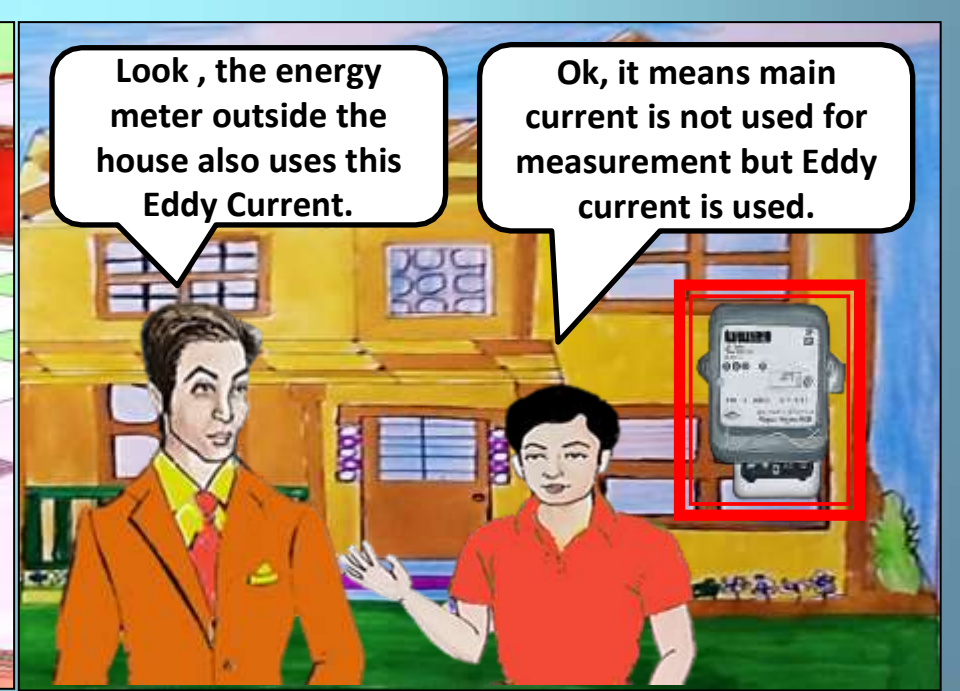
This is an application of Eddy Current.

Very interesting, this induction saves energy also.



Papa, are there more applications of this current?

Yes, there are many applications of Eddy Current .



Look , the energy meter outside the house also uses this Eddy Current.

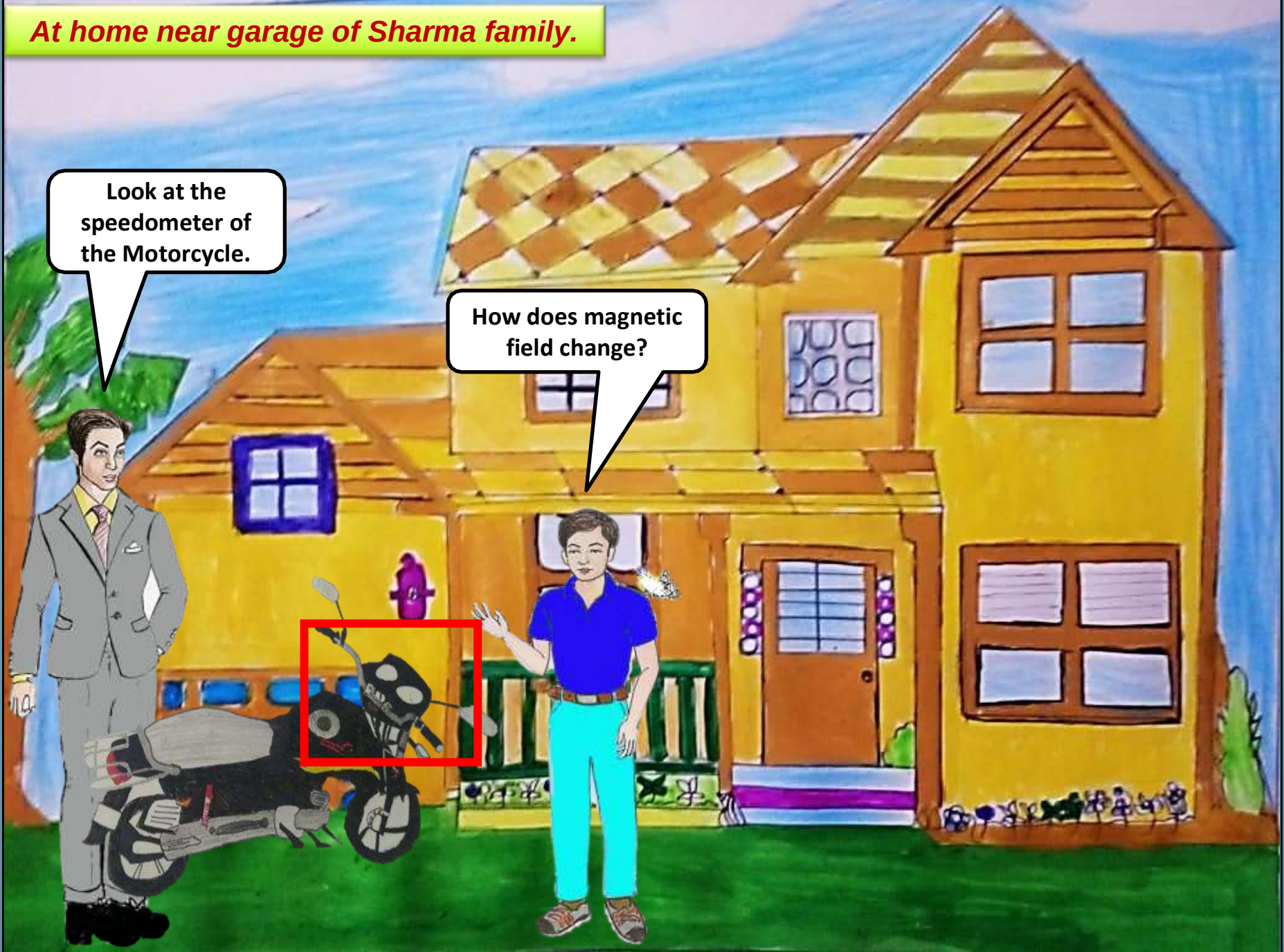
Ok, it means main current is not used for measurement but Eddy current is used.



At home near garage of Sharma family.

Look at the
speedometer of
the Motorcycle.

How does magnetic
field change?

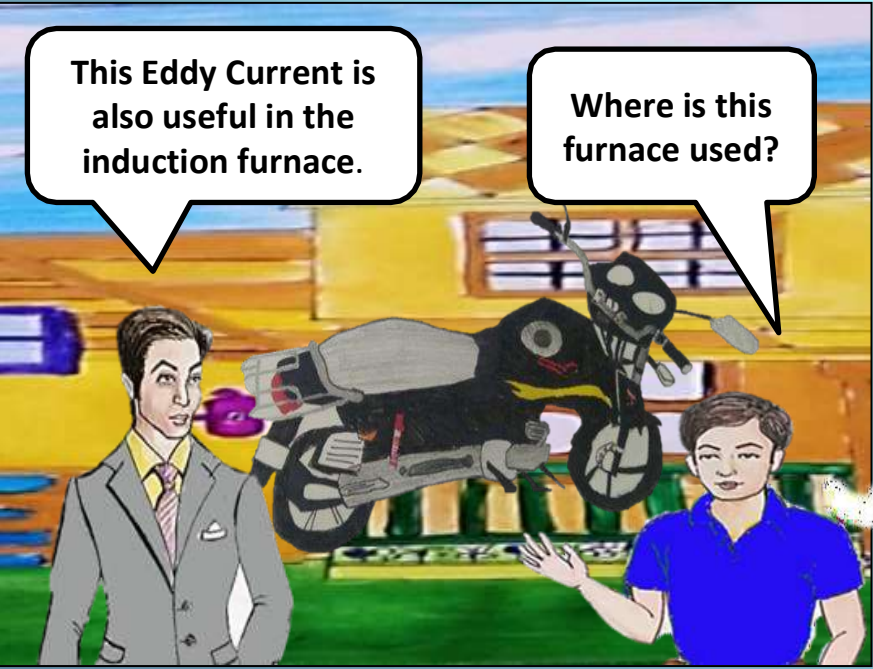




Near the axle of the tyre, there is a magnetic drum .

Ok!

Due to the rotation of the magnet, magnetic flux linked with the drum changes and hence Eddy Currents are produced in it. Thus the speed is measured which corresponds to the deflection of the pointer.



This Eddy Current is also useful in the induction furnace.

Where is this furnace used?

It is used to produce high temperatures for preparing alloys by melting the constituent metals.

Ok! How is the temperature increased in the furnace?

A high frequency alternating current is passed through a coil which produces large eddy currents . Hence high temperature is produced which is sufficient to melt the metals.

Ok!

Dear I hope you have understood this Faraday's Law.

Yes papa thanks a lot.

CHECK YOUR KNOWLEDGE

Fill in the blanks:-

1. Eddy currents are the currents when changes.
2. A light metal disc on the top of an electromagnet is thrown up as the current is switched on due to.....

Multiple Choice Questions:-

1. Which of the following does not use the application of eddy currents?
 - a) Electric power Meters
 - b) Induction Furnance
 - c) LED lights
 - d) Jumping Disc
2. Identify the wrong statement
 - a) Eddy Currents are produced in a steady magnetic field.
 - b) Eddy Currents can be minimized by using laminated core.
 - c) Induction furnance uses eddy current to produce heat.
 - d) Eddy current can be used to produce breaking force in moving trains.
3. The core of a transformer is laminated, so as to
 - a) Make it light weight.
 - b) Make it robust and strong.
 - c) Increase the secondary voltage.
 - d) Reduce energy loss due to eddy current.

Answer key Fill

in the blanks:

1. Induced in the body of a current ; magnetic flux linked with the conductor
2. eddy currents_

Multiple Choice questions:

1. (c)
2. (a)
3. (d)

GLOSSARY

Magnetic Flux: Total number of magnetic field lines passing through the surface.

Electromagnetic Induction/ Induced current: Whenever there is a relative motion between a closed coil and a magnet, induced e.m.f is set up across the coil or induced current flows through the coil.

Self- induction: It is the property of the coil by virtue of which it opposes the growth or decay of the current by inducing an e.m.f in itself. Self-induction is the inertia of electricity.

Lenz's Law: The polarity of induced e.m.f is such that it opposes the cause which produces it. Lenz's law is in accordance with the law of conservation of energy.

Fleming's Right hand Rule: If we stretch the thumb and first two fingers of our right hand mutually perpendicular to each other and if the fore finger points in the direction of magnetic field, thumb in the direction of motion of conductor then the central finger points in the direction of current induced in the conductor.

Eddy currents: The induced circulating currents produced in a conductor itself due to change in magnetic flux linked with the conductor.

Hydropower: The power derived from the energy of falling or fast running water, which may be harnessed for useful purposes.

A.C Generator: An electrical machine used to convert mechanical energy into electrical energy.

Mutual induction: It is the property of producing induced e.m.f in a closed circuit due to the flow of changing current in a nearby circuit.

Transformer: It is a device used to increase or decrease the input alternating voltage. It works on the principle of mutual induction. It is an economical device to transmit electric power to long distances.

Step up transformer: The transformer which converts low alternating voltage at high current into a high alternating voltage at lower current.

Step down Transformer: The Transformer which converts high alternating voltage at lower current into a low alternating voltage at higher current.

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SUMMARY

Whenever the magnetic flux linked with an electric circuit changes, an e.m.f. is induced in the circuit. This phenomenon is called electromagnetic induction.

1. The magnetic flux through a surface of area A placed in a uniform magnetic field B is defined as

$$\phi_B = B.A = BA \cos\theta$$

2. Faraday's Laws of Electromagnetic induction

- a) Whenever the magnetic flux linked with a circuit changes, an induced e.m.f. is produced in it.
- b) The induced e.m.f. lasts so long as the change in magnetic flux continues.
- c) The magnitude of induced e.m.f. is directly proportional to the rate of the change in magnetic flux.

$$E = -N (d\phi)/dt$$

Where N is the number of turns, negative sign indicates Lenz's Law.

3. Lenz's Law: The direction of induced e.m.f or induced current is always in such a way that it opposes the cause due to which it is produced.

Lenz's Law is in accordance with the conservation of energy.

4. Fleming's Right Hand rule: The direction of induced current in any conductor can be obtained from Fleming's right hand rule.

5. A rectangular coil moves linearly in a field when coil moves with constant velocity in a uniform magnetic field, flux and induced e.m.f. will be zero.

An e.m.f. is induced.

- a) When a magnet is moved with respect to a coil.
- b) When strength of current flowing in a coil is increased or decreased, induced current is developed in the coil.

6. Self-Induction: The phenomenon of production of induced e.m.f. in a circuit due to change in current flowing in its own, is called self-induction. The self-induction e.m.f. is given by $E = -L di/dt$.

Where L is coefficient of self-Induction, it is measure of the inertia of the coil against the change of current through it.

7. Mutual Induction: The phenomena of production of induced e.m.f. in a circuit due to the change in magnetic flux in its neighbouring coil, is called mutual induction .

The induced e.m.f. in the secondary coil is $E = -M \frac{dI}{dt}$

Where $\frac{dI}{dt}$ is the rate of change of current through Primary coil and M is coefficient of mutual Induction.

8. Eddy currents: When a conductor is moved in a magnetic field, induced currents are generated in the whole volume of the conductor. These currents are called eddy currents.

9. A.C. generator: It is a device by which mechanical energy is converted into electrical energy. It is based on the principle of electromagnetic Induction.

10. Transformer: It is a device which changes the magnitude of alternating voltage or current.

It consists of an iron core on which primary coil having number of turns N_s and a secondary coil having number of coils N_p are bounded. If the secondary coil has a greater number of turns than the primary, the voltage is stepped-up. This is called a Step-up transformer.

If the secondary coil has number of turns less than the primary, the voltage is stepped-down. This is called as Step-down transformer.

FROM THE PRINCIPAL'S DESK

Dear readers

'Change is the only constant', so said a wise man from the past. And so true indeed! With the coming of the National Education Policy 2020, the focus of education is shifting to more student centric education, and thus the need to produce the content in a way which can be easily understood by the students. The Central Board of Secondary Education has also brought in alterations in the way education was being imparted in the classrooms of the nation. Art Integration with the curriculum, competency based education, stress on Physical Fitness are all endeavors to prepare the students for the future.



I would like to express sincere gratitude to **Mr. Sandeep Sethi (Director Education, M.S.M.S. II, Museum Trust)** without whose unconditional support and persistent guidance, this would have not been accomplished so compellingly. I hope this aesthetic, artistic and edifying piece of work will fulfill its purpose of making learning enjoyable and effective.

I am very sure that this will change the way topics are taught in the classrooms. Using comic strip as a tool, concepts will be explained in a simple way, more relatable to the students. Graphic Novel is an ongoing feature which supports the reading of a chapter in an effective manner. Building comprehension and critical thinking skills is one amongst the myriad benefits of this innovative and unique pattern for students. The combination of dedication, pragmatic approach and innovative thinking enabled us to fabricate this effective teaching tool. The readers will definitely find it useful in learning a complex subject matter.

My sincere thanks are also due to the team of gifted teachers and students who in a time-bound frame produced creatively endowed content which will be a visual extravaganza for the students.

Dr. Pramod Kumar Srivastava
Principal
Model Academy, Jammu



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