DEVELOPMENT OF CONTENT ENRICHMENT PACKAGE IN PHYSICS FOR TEACHERS AT +2 LEVEL

(Sanctioned vide Principal, Regional Institute of Education, Mysore Order No.F.PS/1-5/2004/RIEM dated 3rd June 2004)

M N Bapat
Physics Section
Dept. of Education in Science and Mathematics

REGIONAL INSTITUTE OF EDUCATION, MYSORE-6
[National Council of Educational Research and Training]

2005

ACKNOWLEDGEMENT

I acknowledge with gratitude and thanks for opportunity provided to me by RIE, Mysore to undertake a small term Research Project with stress on **"Development of Content Enrichment Package in Physics"** for teachers at +2 level.

The content selection is mainly based on interaction with practicing teachers at +2 level.

I am grateful to every person who directly or indirectly helped in its persuasion.I also extend thanks to Dr.G.Ravindra, Principal and Shri.N.R.Nagaraja Rao for inspiration and help from time to time.

23.3.2005 **M N Bapat**

What to find ?
(Enrichment material in different forms)

Tool for Identification of Topics for Writing Enrichment Material in Physics

Class : 					CBSE/ STATE BOARD

[Refer to appended sheet for type of problem area]

Description of Textbook	Reference to Text/ Chapter / Page	Description of Hardness	Hard for				Reasons for hardness	Suggestions for overcoming hardness
			Teacher		Student			
			to understand	to recapitulate	to understand	to recapitulate		
1	2	3	4	5	6	7	8	9

Teaching Experience in years

State

District

School /College

Will you like to participate in developing enrichment material ? Yes / No

Signature

Name

Date

DESCRIPTION OF SOME AREAS OF HARDNESS

Teacher may add anything worth inclusion

Content	**Presentation**
Not clear Not upto the mark Language difficult Symbols not in vogue Units mixed up Not adequate Previous knowledge not enough	Lack of clarity No proper sequencing No logical connection With missing steps
Diagrams	**Examples**
Not clear Not labeled Not relevant Not catchy Not properly set Not of proper size Needed to be put	Not appropriate Not familiar Not adequate Not illustrative of principles A few to be added
Numericals	**Exercise**
Not adequate Are difficult Not of variety Are of routine type Not necessary Solutions not correct More to be provided	Not with variety No proper representation to content Not ordered Not classified Too much repetitive Too short

How to record measurements?

Generally, the results of a measurement are expressed upto a few significant figures, eg. 531.7 m. In these, except the last digit each figure should convey that the measured quantity is certainly greater than what the figures indicate. Thus, 3.78 g suggests that the mass of the object (m) is such that $3.7 < m < 3.8$. A time interval (t) 5.431 s indicates that $5.43 < t < 5.44$. A length (l) 72.5 mm indicates $72 < l < 73$. The last digits in the above examples i.e. 8 in 3.78g, 1 in 5.431s and 5 in 72.5 mm are only estimates and have an uncertainty associated with them due to limitations of the measuring instruments. For whole number, measure of 3758 units, the quantity is greater than 3750 but less than 3760.

When the measurement exceeds a particular division but is slightly less that the next division one can choose either of the last digit for their record. But it is advisable to record that division which is closer. For example if a given length lies between 72 mm and 73 mm but if one judges it to be closer to 73 mm the record can be made as 73 mm. Assuming that the measurements are made with a meter scale having 1mm divisions. Note: This judgment is applicable only to the last digit of the quantity measured.

Writing 73 does not then convey that given length is 73 mm because last digit 3 in 73 is uncertain. We write [redacted] maximum error associated as + 0.5 mm. However, length should not be recorded as 72.5 mm. Let us see then how to record. The length should be recorded as 73mm with an uncertainty of ±0.5 mm.

Some pupil try to interpolate and write the above length to be 72.6 mm as they feel that the length exceeds 72mm by more than half division. Such endeavours should be discouraged. Similarly, 23.18 mm implies length is greater than 23.1 mm and last digit 8 is as measured by screw gauge with an uncertainty to the extent of ± 0.005 mm.

HOW SHOULD A TEACHER REACT TO OBSERVATION ON EXPERIMENTS INVOLVING MEASUREMENT OF TIME PERIODS?

A number of experiments in senior secondary and UG base on the measurements of time periods and therefrom estimation of some physical quantity.

Usually teachers response on pupils observation depends on the closeness of the experimental value to the value reported in the literature

Let us inquire to what extent teacher's perception is valid,. We take simple pendulum to explore it, where pupils measure time for 10 to 50 oscillations.

Case A: Labs which can measure time and length with an accuracy of 1s and 0.1 cm respectively.

Table 1 displays value of 'g' arrived at for n oscillations when length of the pendulum is varied from 90 to 110 cm.

Sl. No.	Length	Expected time period for $g = 981\ cm\ s^{-2}$			Values of g		
	(cm)	10 osc (s)	20 osc (s)	50 osc (s)	$cm\ s^{-2}$		
		A	B	C	A	B	C
1	90.0	1.9	1.9	1.90	984	984	984
2	91.0	1.9	1.9	1.92	995	995	974
3	92.0	1.9	1.9	1.92	1006	1006	985
4	93.0	1.9	1.95	1.94	1028	966	966
5	94.0	1.9	1.95	1.94	1028	976	986
6	95.0	2.0	1.95	1.96	938	986	976
7	96.0	2.0	1.95	1.96	947	997	987
8	97.0	2.0	2.0	1.98	957	957	977
9	98.0	2.0	2.0	1.98	967	967	987
10	99.0	2.0	2.0	2.0	977	977	977
11	100.0	2.0	2.0	2.0	987	987	987
12	100.4	2.0	2.0	2.02	991	997	971
13	103.0	2.0	2.0	2.04	1017	1017	977
14	104.8	2.0	2.05	2.06	1034	984	975
15	104.9	2.1	2.05	2.06	939	985	976
16	106.0	2.1	2.05	2.06	949	996	986
17	107.0	2.1	2.1	2.08	958	958	976
18	108.0	2.1	2.1	2.08	967	967	986
19	109.0	2.1	2.1	2.10	976	976	976
20	110.0	2.1	2.1	2.10	985	985	985

Observation and Discussion :- For a range of lengths 95.0 to 104.8cm of pendulum 98, variation in length at a spacing of 0.1cm is possible but time period is the same for 10 oscillation measurements. The minimum spread is for 50 oscillations and that is from 99.0 to 100.3 i.e., 13 variations.

We have only two parameters for measurement first is length and other is time period. What happens if we measure length with more precision say 0.01 cm? Probably we may be able to have as many as thousand values of length for measurement of same time period. A scrupulous selection of lengths of 99.46 and 99.47 cm can yield values of g as 981.6 and 981.7 units whereas full range would be from 938 to 1034 which amounts to ~ 10% of standard value.

Before getting into precision for time periods we see that with 10 oscillations an experimenter is expected (ignoring other errors) to measures 'g' from 938 to 1034 unit whereas with 50 oscillations he can measure 'g' between 966 and 987 which amounts to only ~ 2%.

Case B:- Let us see what works out to be better: ten told increase in precision or 10 fold increase in oscillations? (10 oscillations with an accuracy of 0.1s or 100 oscillations with an accuracy of 1s ?) Table 2 display it.

Table 2

Sl. No.	**Length**	**Expected time period for 10 osc**	**100 osc**	**Value of g**	
	cm	(a) (s)	(b) (s)	(a) **cm s^{-2}**	(b) **cm s^{-2}**
1	98.0	1.99	1.99	977	977
2	99.0	2.00	2.00	977	977
3	100.0	2.00	2.01	987	977
4	101.0	2.02	2.02	977	977
5	102.0	2.03	2.03	977	977

Inspection of table suggest that increased precision in time measurement though yield better results are not consistently better than the ten fold increase in number of oscillations.

Tables should provide hints to the teacher that although the value of 'g' taken for calculations was strictly 981 units, a truthful observation does not reflect it through experiments and quite a significant error is possible even if several other inherent and human errors are neglected. Hence teacher's titude to observations should be to see sincere effort and careful presentation and not to closeness to reported values.

When to compromise?

If oscillations die out quickly time measurement should be precise Otherwise one should go for record of time for large number of oscillations.

How to Interpret?

(Standard for those who speculate past, Based on paper by G A Cowan Sci.. America 1976)

Observation

a) In Gabon (West Africa) some ^{235}U samples had abundance as low as 0.44% of natural uranium.

b) To day ^{235}U constitute 0.72% of natural uranium. This abundance is same in all terrestrial samples, samples from moon and that found in meteorites too.

Tentative inference- At some time in past ^{235}U was partially consumed by the operation of a fission reactor (why not by other process?).

Fact $\Rightarrow$ ^{235}U has a half life of 0.704×10^9

$\Rightarrow$ ^{238}U has a half life of 4.47×10^9 y

$\Rightarrow$ i.e. ^{235}U decays 6.4 times fast

$\Rightarrow$ in the remote past the abundance of ^{235}U was not 0.72%

$\Rightarrow$ To have fission materialized the abundance of ^{235}U should be > 3%

Plausible Inference- About 2 billion years age, the abundance of ^{235}U in natureal uranium could be 3.8% just the one to be called an enriched uranium. Hence a fission reactor worked.

Probabilities:- (a) Two billion years ago, the highest order form of life could be blue green algae. i.e., the human or other living species did not enrich uranium.

(b) If fission had occurred, the fission fragments whose stable isotopes that are ultimately produced, must still be found in the locality.

Directive- Seek further data.

(c) ^{142}Nd the dominent isotope in natural Nd is totally absent in fission product of ^{235}U

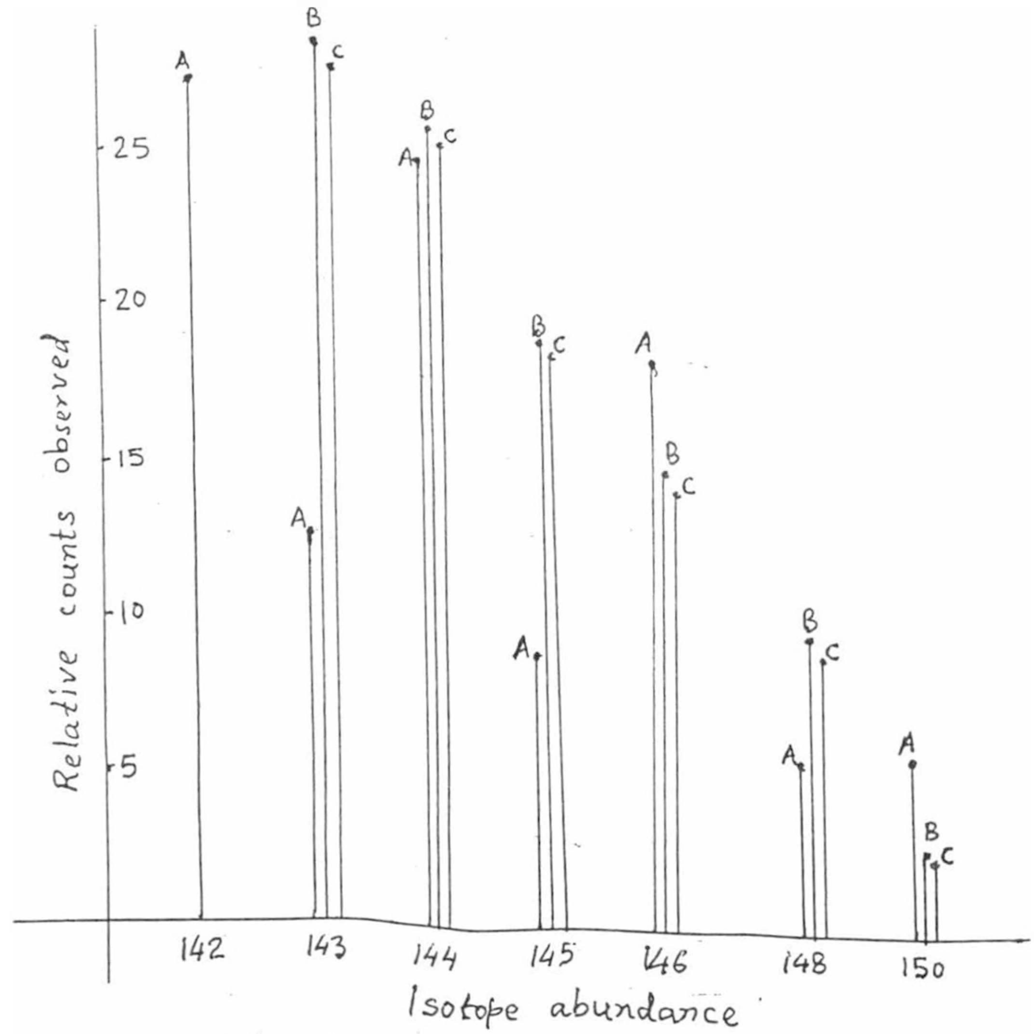
(d) The abundance of Nd isotopes worked out for fission reactor differ considerably from the Nd isotope abundance of natural samples. (i.e. that found in samples after supernova explosions).

Hypothesis- Two billion year ago a natureal fission reactor operated in Gabon, if Gabon samples of Nd isotopes have abundance which would represent appropriate average of reactor samples and natural samples.

Directive-Seek further data.

(e) The abundance of Nd isotopes from Gabon virtually tally the hypothesis(see the bar diagram).

Ultimate Inference- In the view of today's scientific philosophy a natural fission reactor existed in Gabon some two billion years ago which ran probably for about a million years. But should this contention hold, the abundance of ^{235}U at the time of supernova explosion is 30%. This may influence any final verdict. Hence the hypothesis may even undergo a radical change if certain other evidence or theory directs us to do so.

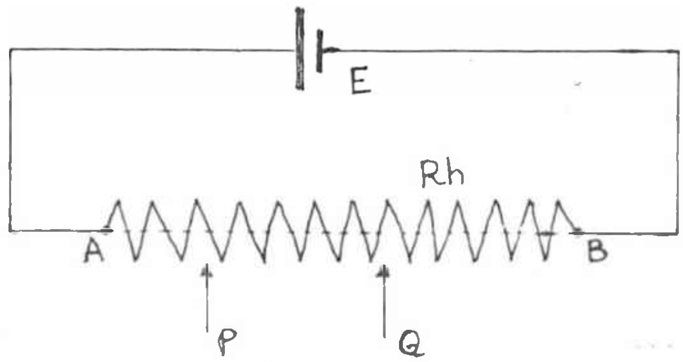


A ⇒ Natural sample, B ⇒ sample from reactor
C ⇒ Gabon sample

A comprehensive note on

The Power Supply

It is usually a secondary source of dc power, equipped with essential circuitary. Ideally its internal resistance is zero, yet specifications are given for maximum current that can be drawn from it. The simplest power source is a rheostat or a potentiometer connected across a stack of cells (Battery) as shown.

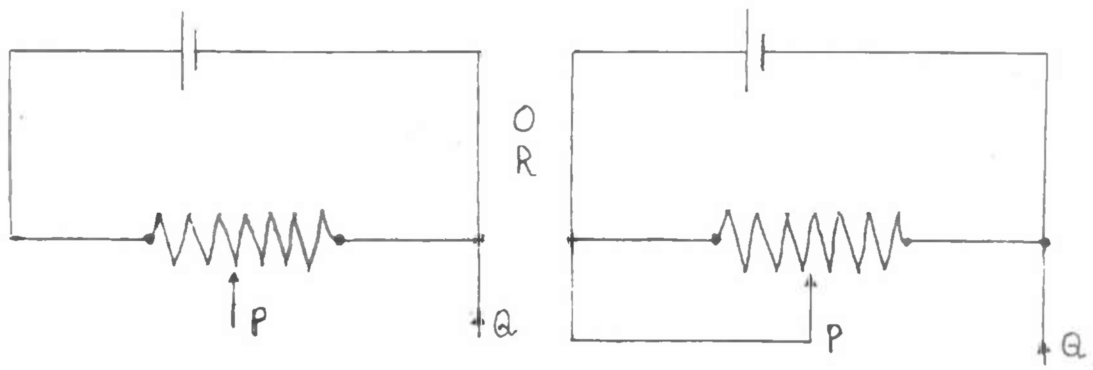


The value of Rh (Rheostat Range) depends on the anticipated load across PQ and current capability of Battery E.

For convenience either point P is connected to end A and Q is varied by slider movement as per voltage requirements (note that P is at higher potential and Q is on diminishing potential side) *or* Q is connected to end B and P is slided away from B to get required potential difference (here P will acquire successively larger potentials with respect to B as it is moved towards A. Try to verify whether two cases of tapping of power are equivalent). This arrangement is known as potential divider arrangement and is widely used for getting continuously varying potential difference.

+ Points

i) Simple in construction for obtaining a continuously varying potential difference between P and Q by the slider movement.



ii) Range of Rheostat can be chosen as per current requirements.

- Points

i) Each kind of requirement needs a rheostat of different specification.
ii) For very low value of load resistance PQ is almost shorted which in turn damages the source supply, (as also the potentiometer).
iii) For very high value of load resistance across PQ transfer of power is very low.

Remedy

i) Choose Rh value such that

$$\mathbf{Rh \cong R_L >> r}$$

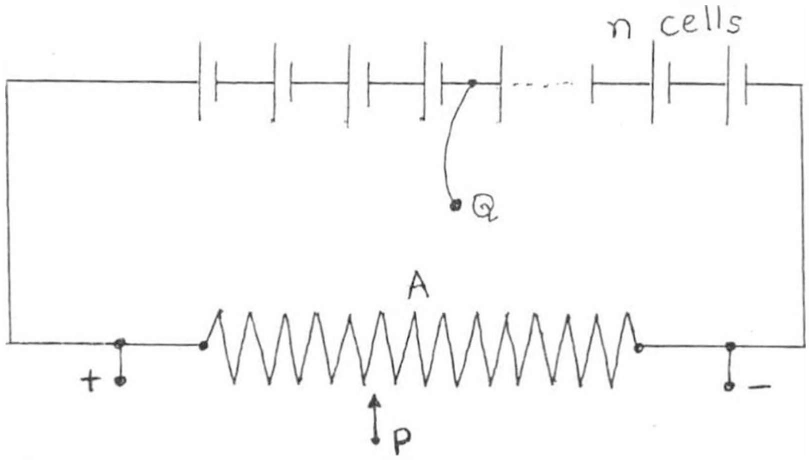
Where R_L is resistance of load and r is internal resistance of (primary) source E.

ii) Use PQ section of this supply to provide biasing to a power transistor, to regulate its output. This will accordingly regulate supply voltage.

The Dual Polarity Power Supply.

Digital circuits, transistor biasing circuits, difference amplifiers, op-amps as also few investigatory experimental circuits need power supply that can supply simultaneously a positive as well as a negative potential with reference to some conveniently chosen ground voltage.

Such power supplies again can be easily constructed using again a rheostat and a stack of batteries as shown.



This sequencing enables us to set the location A i.e. of zero potential difference between P and Q. If then slider is moved toward -ve terminal, P becomes more negative with respect to Q. But if slider moves towards +ve terminal P acquires a positive potential status with respect to Q. Such supply is used to advantage for studying photoelectric effect (see Halliday, Resnick and Krane). If chosen point Q is such that n cells of emf E lie left to it and m similar cells lie right of it then the potential of P can be varied from –mE through 0 to + n E (Task -fabricate a power supply that will allow variation of voltage from - 1.5 V to + 9V).

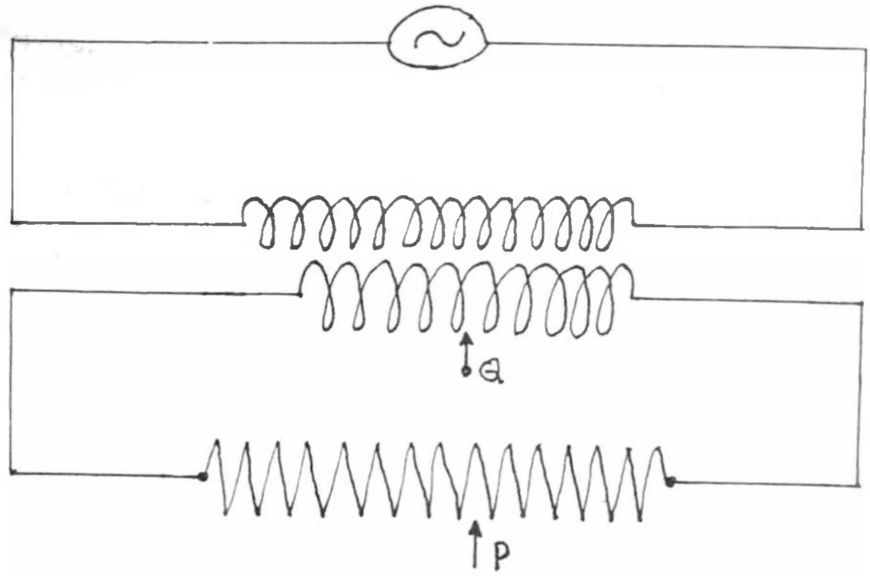
Other investigations.

i) Ground P. The terminals +ve and P form a power supply of potential difference 0 to $\cong$ + (m+n)E whereas terminals -ve and P form a power supply of potential difference 0 to $\cong$ - (m+n)E. In short it is not different from simple potential divider power supply. But it can be used as dual power supply where variation in one voltage hardly affects gain of the circuit whereas variation in another gives desired response for studying some parameter. An example is study of transistor characteristics where $V_C \geq 2V$ if maintained produce negligible change in I_c with V_c but variation in V_B gives desired change in I_B and I_C.

ii) Join PQ and ground. Then the terminals +ve and P form a power supply of constant potential difference $\cong$ n E while the terminals -ve and P form a power supply of potential difference $\cong$ mE (why not exact n E and mE respectively ?). Sliding P either way will alter only current sending capabilities of the power supplies.

What if stack of cells is replaced by Transformer?

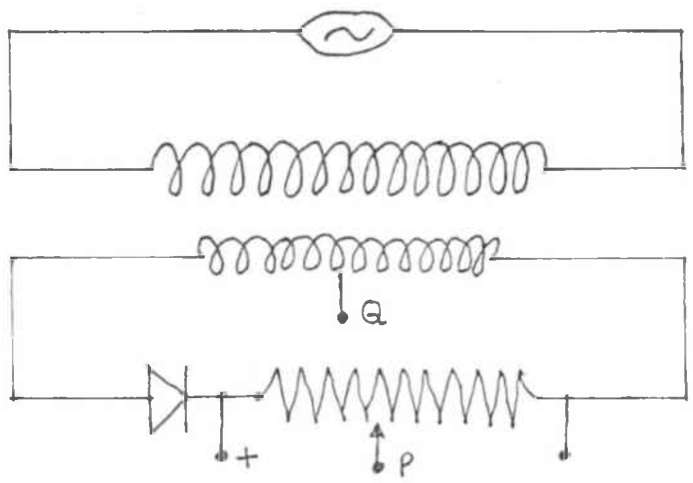
Let us consider following circuit



Again one can expect varying A C potential difference across P and Q with no definite *say* on the state of polarities on either side of null. Hence applicability of such circuitary does not go beyond the fact that a continuously variable A C output is available when proper rheostat is used.

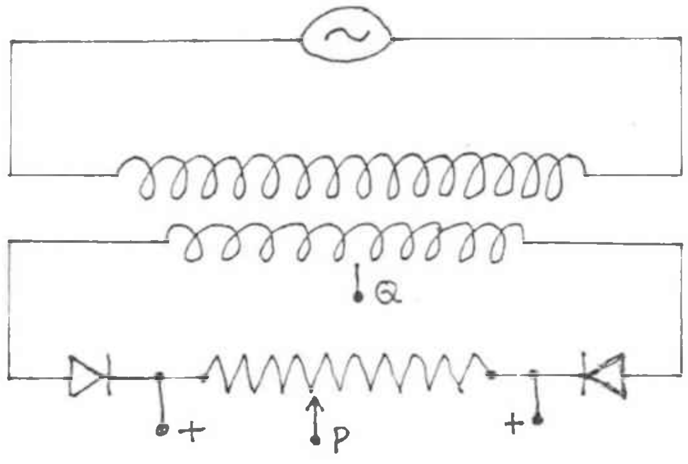
Other investigations.

i) Connect a diode on LHS of Rh as shown below.



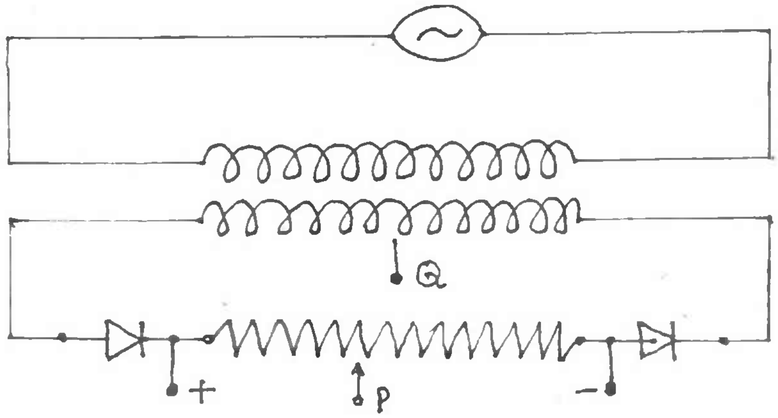
It allows to tap +ve supply across +ve terminal and Q (investigate if this is so between +ve terminal and P. Change position of P for further exploration).

ii) Connect another diode at the other end of Rh as shown below.



It is simply a full wave rectifier (verify the circuitary) allowing us to tap dc power between P and Q. Location of P on the rheostat will only determine the extent to which signal gets diminished. Connect load across P and Q and also see response of rectifier on CRO.

iii) Connect the other diode differently, as shown



Clearly the situation is complicated but can be made a little understandable if P and Q are joined and grounded. This device is a dual polarity power supply. But …

To enable you to find words that should follow But…, do the following activity.

Connect an npn transistor in common emitter configuration to this supply. There is no passage of collector currents, though it appears to be almost the same as the dual polarity power supply discussed in investigation i), that worked quite well.
(Hint – A measurable current flows in the circuit if a capacitor of a few microfarad is connected between transformer terminal and diode. For further explanation see 'phase dependent biased transistor' discussed elsewhere in this write-up).

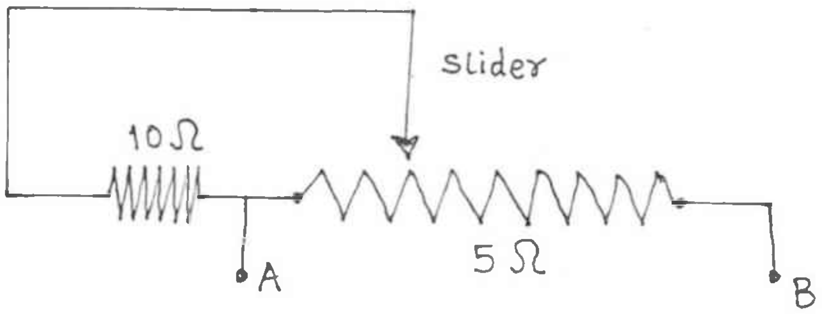
Some Questions

1. Why do we bother about filtering circuits in power supply units?

2. There is always a drop of potential across diodes, yet the rectified potential difference obtained is higher than the rated value on the transformer.

3. We do not use two or three diodes in series (in same sense) for more reliable unidirectional current.

4. A few rheostats give variations like from 10 Ω to 15 Ω as shown.



What is the advantage of such a rheostat?

5. For a 10 Ω load with specification 10V, 2W; choose an appropriate rheostat to connect to 15 V, 3A supply.
6. What should be the value of capacitor connected before the diode whose forward resistance is 1500 Ω ?
7. Where would you use A C dual polarity power supply? What are its limitations?

Investigations exhorted

1. Find difference between performance of a transformer and A C dual polarity power supply.
2. Use dual polarity power supply for obtaining transistor characteristics.
3. Connect different kinds of diodes for fabricating a full wave rectifier. In what aspect it differs from the conventional one?
4. Use two, three … diodes in series and find the response of the combination in respect of voltage and current. Do these just add forward resistances? If not Why? If Yes Why?
5. Use LC combination before diode and study the phase response on CRO between +ve terminal and P.

(BASED ON PRINCIPLES OF PHYSICS BY H.C.OHANIAN, W.W NORTON & Co. NY 1994)

A course in Thermodynamics

Thermodynamics deals with conversion of thermal energy into other forms of energy (in most cases mechanical energy).

It describes physical processes in terms of macroscopic quantities such as temperature, pressure, density, heat capacity etc.

Two fundamental laws of Thermodynamics govern the energy conversion, viz.

First Law of Thermodynamics (also known as law of Conservation of energy which denies fabrication of any device that can supply an endless output of work without providing requisite input of energy, i.e., perpetual motion machines of first kind are impossible to build)

Second Law of Thermodynamics (that tells about limitations to the maximum efficiency attainable in the conversion of heat into work. Thus there can be no engine that takes heat from a reservoir and converts it completely into work. i.e., perpetual motion machine of second kind is impossible to construct).

First Law of Thermodynamics:-

Whenever a process involves heat and work to change a system characterized by a certain set of macroscopic parameters into a system characterized by another set of macroscopic parameters, change in its internal energy is given by

$$\Delta U = Q - W$$

This change does not depend on the details of the process carried out for the said purpose.

By Convension

ΔU is change in internal energy

+Q is amount of energy supplied to the system and **+W** is amount of work done by the system.

-W and –Q would therefore suggest work done on the system and energy released (given out) by the system respectively.

Notice that as total energy is conserved, change in internal energy of an isolated system is equal heat given minus its part that has gone for conversion into work. So first law tells us (i) that energy of the system can be determined from the knowledge of macroscopic parameters and (ii) heat can be converted into work.

Second Law of Thermodynamics:-

It is an empirical Law and tells about limitation to the conversion of heat into work and to the conversion efficiency attainable. As we will see shortly no engine can convert all heat it takes into useful work, without some other effects on its surroundings. Unlike first law, it tells from where heat is to be taken for performing work.

The corollary of this law is Carnot's Theorem " No engine operating between two temperatures (heat reservoirs) can have efficiency greater than the efficiency of Carnot engine".

Clausius formulation of second law is even simpler 'An inaided engine cannot transfer heat from a cold reservoir to a hot reservoir'.

The other versions can be

a. An isothermal cyclic process cannot produce work.

b. Heat conversion into work can only be partial i.e., heat $\longrightarrow$ work is partial but work $\longrightarrow$ Heat is 100% possible. It also says that sink temperature cannot be O K.

c. Cooling sink for getting work is impossible.

d. No work possible by cooling by cooling the working substance below coolest surrounding.

e.

$$-\int_{\text{closed cycle}} \frac{\delta S}{T} \leq 0$$

Reversible Processes:

A Thermodynamic process is said to be reversible when -

1. Various stages of operation can all be reversed back in reverse order

2. The amount of heat transferred has the same magnitude in either direction .

3. At any stage, an infinitesimal change in one of its thermodynamic coordinates brings about reversal.

No process can ideally be reversible. An infinitesimally slow process in the absence of any energy dissipative effects can be taken as reversible for all practical purposes.

For a cyclic process over closed cycle $\int \mathbf{dU = 0}$ i.e., all energy given to an unaided system is converted into equivalent work. In the process the system does not undergo a permanent change.

In thermodynamics the cyclic processes with $\int_{\text{Closed cycle}} \mathbf{dU = 0}$ is called an engine. More useful engines are those where cyclic process are reversible.

Heat Engines.

Any device that convert heat continuously into mechanical work by means of a cyclic process is called a heat engine.

It consists of -

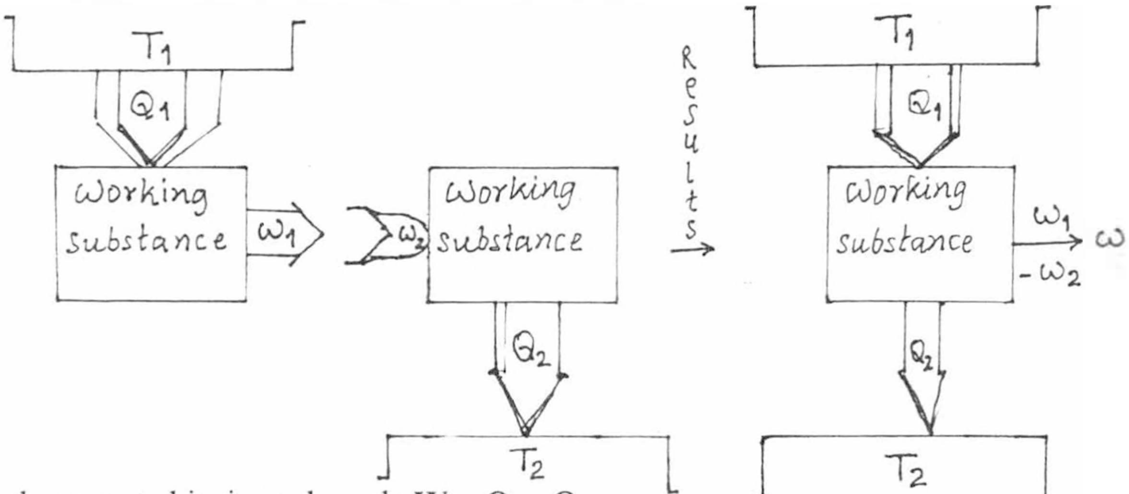
a. A high temperature reservoir called source with infinite thermal capacity (i.e., addition or extraction of heat would not alter its temperature).
b. A low temperature reservoir called sink of infinite thermal capacity (i.e., addition of heat will not alter its temperature) and

c. A working substance that absorbs heat and rejects whatever it has to in each cycle without itself undergoing a change.

Thus though it undergoes changes in temperature yet it regains its original state implying $\int_{\text{Closed cycle}} dU = 0$ or , $W = Q_2 - Q_1$.

Carnot Engine:- Is an idealized engine (free from friction and imperfections). It has perfectly non conducting stand where cylinder can be transferred. It works in cycles of perfectly reversible operations. During each cycle of operation the engine takes up heat from source converts a part of it into work and rejects the remainder to sink (usually a large capacity boiling water reservoir does the job of a source and a condenser immersed in water or exposed to atmosphere is a sink).

Figure shows how this process can be cyclic



Work generated is in each cycle $W = Q_1 - Q_2$.

The efficiency of engines is defined as the ratio of work generated to heat absorbed from source i.e.,

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

Since the second law of thermodynamics does not allow $Q_2 = 0$, under no condition efficiency is 100%. Maximum efficiency attainable for a reversible engine is given by above formula.

Carnot Engine is reversible engine consisting of an ideal gas contained in a cylinder with a piston. Gas delivers work when piston is pushed outwards and absorbs it when piston is pushed inside. The movement of piston is kept sufficiently slow as to make gas always in equilibrium configuration with the source or sink as the case may be (consider cases when piston movement is swift – heat transaction takes time – gas were not ideal – why we need to consider ideal conditions – non reversibility of engine, etc.,)

The Carnot engine operates in four steps.

1. Cylinder is kept in contact with the source. This allows gas to expand at constant temperature taking heat Q_1. This process is called isothermal expansion, gas pushing piston out.
2. Under new conditions of pressure P_2 and volume V_2, cylinder is isolated and allowed further expansion (without transaction of heat) in adiabatic mode. Work in further pushing out the piston is done by gas at the expense of its internal energy. So the gas attains a larger volume V_3, but reduced pressure P_3 and temperature T_2 respectively.
3. Once the gas attains temperature T_2 of sink, no work can be extracted further. So work is done on the gas by pushing the piston in, isothermally. The engine converts work into heat and rejects it to sink.
4. When the gas attains new state defined by P_4 , V_4 and T_2 such that $P_1>P_4>P_3$ and $V_1<V_4<V_3$, piston is removed from the sink and work is done adiabatically on the gas until the gas attains its initial state P_1 ,V_1 , T_1.

The shape of the Carnot cycle depends on the values of P,V and T at the different stages of operation with only restriction that

Stage II $V_2 > V_1$, $P_1 > P_2$, T_1 common

Stage III $V_3 > V_2$, $P_3 < P_2$, $T_2 < T_1$

Stage IV $V_4 < V_3$, $P_4 > P_3$, T_2 constant

Stage I $V_1 > V_4$, $P_1 > P_4$, $T_1 > T_2$

As long as the clockwise Carnot cycle encloses a definite area it is an engine that converts heat into work. But if one manipulates an anti-clock wise Carnot cycle work is converted into heat. Area enclosed by Carnot cycle denotes quantum of work done.

It is clear that heat exchange occurs only in step I (supply of heat from source and in step III (return of heat fraction to sink). Net heat consumed being $Q_1 - Q_2$.

Carnot could show that amounts of heats Q_1 and Q_2 exchanged at T_1 and T_2 are in direct proportionality to the respective temperatures i.e.,

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

$$\Rightarrow \frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1} = \eta$$

Indicating that efficiency of Carnot's Engine depends only on temperatures of the heat reservoirs.

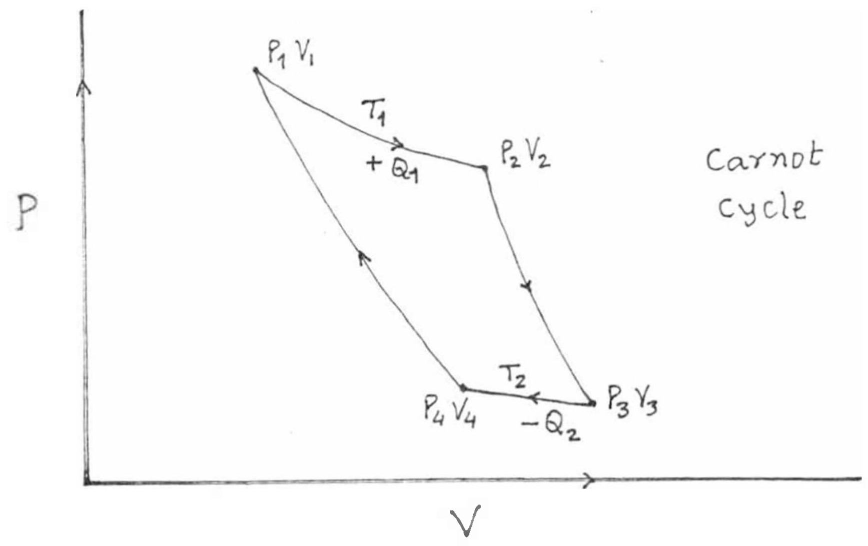
Questions --

If the Carnot cycle encloses zero of area discus consequences .

Can a Carnot operation be triangular on P – V graph? If so construct the cycle with proper explanation.

Pair of cyclic isothermal and adiabatic processes can only construct a heat engine, comment.

Slope of adiabatic and hence compression ratio determines the efficiency (and also work done) by the engine, substantiate.



SOME ASPECTS OF PRISM

Prism is a material medium bounded by two plane surfaces meeting at an angle at one end. The angle is conventionally called the angle of the prism or the refracting angle.

Prism essentially cause deviation to the path of the ray incident on it.

Commercially available prisms are triangular blocks. (Three tetragonal faces bound a transparent material medium).

Prism is usually represented by its principal cross-section (triangular) in two-dimensions as shown in Fig.1.

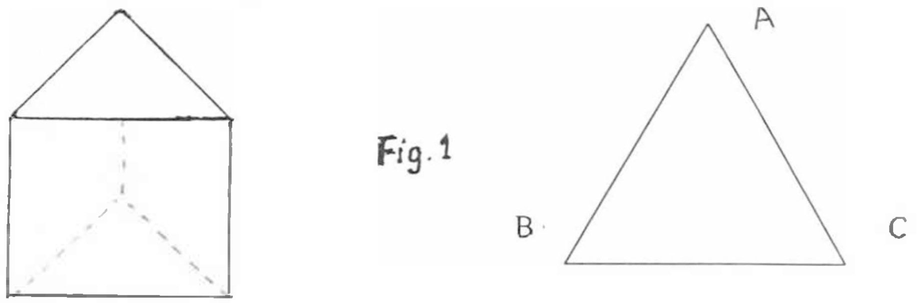


Fig.1

Though usually all the faces represented by AB, BC and CA are similar yet BA and AC are called refracting surfaces and ∠A is called the refracting angle. Sometimes face BC is grounded to differentiate it from the refracting surfaces.

A prism can cause deviation to a ray incident on one of its faces. If the incident ray after refracting into prism material from face BA falls on face CA at an angle greater than the critical angle, it does not emerge out from that face (See Fig.2). As suggested in Table 1, the critical angle depends on the

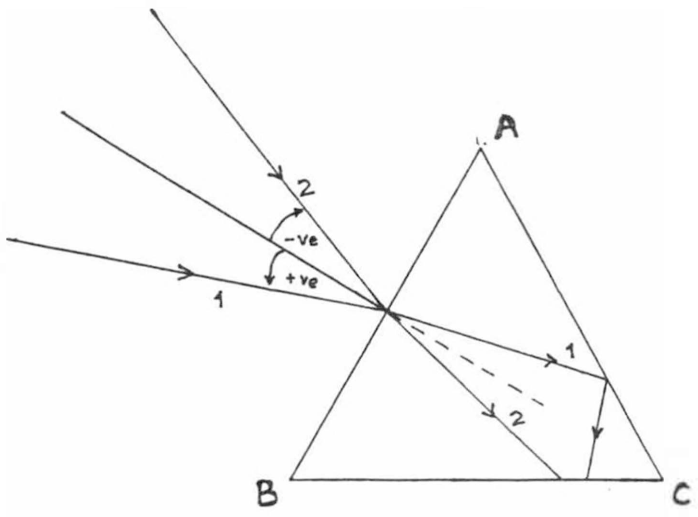


Fig.2

refractive index of the material of the prism. Table 2 gives values for angles of deviation caused to incident rays on passage through prism material, $\delta_{grounded}$ are corresponding values for the prism whose face BC is grounded.

Table 1 showing measure of critical angle for transparent materials (with respect to air) of different refractive indices.

μ	i_c (in degrees)
1.3	50.3
1.4	45.6
1.5	41.5
1.6	38.7
1.7	36.0
1.8	33.8
1.9	31.8
2.0	30.0
2.2	27.0
2.4	24.6

Table 2 showing different parameters related to angle of incidence on the face BA for a 60° prism of μ = 1.51. (angles are in degrees)

i_{BA}	r_{BA}	i_{AC}	δ	$\delta_{grounded}$
-20	-13.1	73.1	-20	Ray is lost
-17.5	-11.5	71.5	-25	Ray is lost
-10	-6.6	66.6	-40	Ray is lost
-5	-3.3	63.5	-50.1	Ray is lost
0	0	60	-60	Ray is lost
10	+6.6	53.4	-73.2	Ray is lost
20	+13.1	46.1	-82.2	Ray is lost
Critical			-97.1	Ray is lost
30	-19.3	40.7	-50°	-50
40	-25.2	34.8	-39.5	-39.5
50	-30.5	29.5	-38.0	-38.0
60	-35.0	25.0	-39.6	-39.6
70	-38.5	21.5	-43.6	-43.6
80	-40.7	19.3	-49.9	-49.9
85	-41.3	18.7	-54.0	-54.0
88	> | 41.4 |	18.6	-56.8	-56.8
89	< | 41.5 |	18.5	-57.6	-57.6
90	> | 41.5 |	18.5	-58.6	-58.6

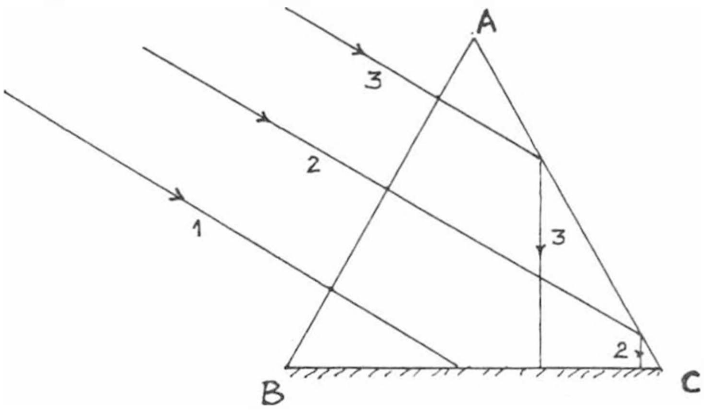
One face grounded 60° Prism

When the principal section of the prism is equilateral triangle and one of its refracting face (say BC) is grounded, we are left with only two refracting surfaces BA and CA. A ray incident on BA may emerge out from face CA following the laws of refraction.

Let us discuss a set of cases :

a) **Normal incidence**

When a ray is incident normally on the face BA it continues to proceed undeviated to fall on inner face CA making an angle of 60°.



This angle happens to be larger than the critical angle ($i_c = \sin^{-1}(1/\mu)$, $\mu = 1.51 \Rightarrow i_c = 41.47^\circ$, and so it is reflected back to strike face BC at 10° where it is lost. This will happen to all the rays which strike inner face CA at angles greater than 41.47°. This angle corresponds to 18.53° of angle of refraction at BA and 28.67° of angle of incidence at the face BA. In other words, to make a smaller angle than critical angle at inner face CA, the angle of incidence should be > 30°.

b) **Minimum Value of BN for incidence angle of 30°**

The ray incident at 30° on face BA can emerge out of face CA (See Fig.3) when distance CO $\geq$ 0.

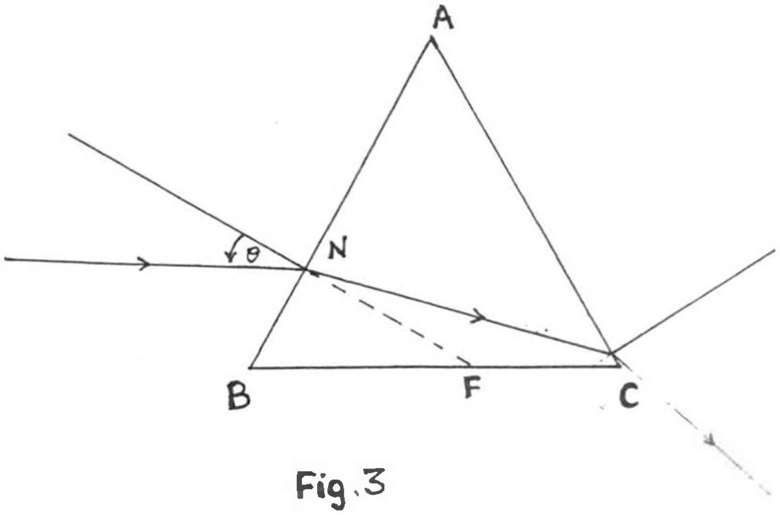


Fig.3

Consider the case when CO → 0, when ∠BCN = 10.7° indicating that

$$\frac{NB}{BC} = \frac{\sin\ 10.7}{\sin\ 109.3} = \frac{1857}{9438} = 0.197 = \frac{NB}{BA}$$

or, NB ≅ 20% of BA (the slide of the prism)

Clearly, if angle of incidence is decreased the distance BN should be increased correspondingly such that as i → 0, NB = 50% of side of the prism. Thus in order to produce deviation in conventional laboratory experiments, the location of incident ray is set such that BN ≥ 50% of the length of the side of the prism. For negative angles, BN increases further. Construct a table showing minimum values of BN for different angles of incidence from 90° to –90°. Can any inference be drawn from its careful observation ? Write instructions for experimenter.

c) **Negative Angles**

Angle of incidence is measured with respect to normal EN on the face BA of the prism. Positive angles are measured in anticlockwise direction while negative angles are measured in clockwise direction, as shown in Fig.2 One can use incident rays making negative angle at the prism face BA with proper selection of distance BN. For a 60°, 1.51 prism only those values of negative angle are acceptable which are larger than –48.2°. Even these rays are lost in grounded face (BC) prisms.

Prisms of other angles

As the angle of the prism is decreased successively from 60°, the critical value of angle of incidence decreases as indicated in Table 3.

Table 3 : Table showing angle of incidence leading to critical angle of incidence at face CA with angle of the prism (all values in degrees) of μ = 1.51.

Angle of Prism	Angle of incidence at face BA
60	28.7
50	12.9
41.5	0
40	-0.2
30	-17.5
20	-33.6
10	-52.1
1	-76.2
→ 0	→ 90

It is evident that 40° prism covers almost full range of positive angles for deviating the incident rays, while prism of 0.5 degree becomes universal (Should you prefer 30° prism over 60° prism? Why in the laboratory you need to take scan of incident rays for positive angle ≥ 30°)

Dispersion by Prism

Refractive index for violet is greater than for red. Hence for same angle of incidence violet ray is refracted at a smaller angle than the red ray, etc. This cause in dispersion of white light into its constituent colours.

Criterion for Dispersion

A prism causes dispersion of incident light only when the ray refraced into the prism material strikes the other face of the prism at angles less than critical angle.

This is the reason why dispersion occurs only when incident ray makes positive angles $\geq 30^{o}$.

For other angles the refracted ray strikes the second face of prism at angles larger than critical angle. (See Table 2) Hence it is totally internally reflected. In such cases whatever dispersion occurs at first interface is annulled in total by the internal reflection.

Suggested Activities

1. Determine disposition of 60^{o}, 1.51 prism for producing deviations of 30, 60 and 90^{o}.
2. From the scrutiny of the Table 2 try to find tentative relation for deviation caused by a prism as a function of angle of incidence and refractive index.
3. Verify the relation obtained in 2 for a prism of $\mu = 1.63$.
4. Value of BN depends upon the angle of incidence. Find the angle of incidence if BN = 0.75 BA.
5. Find value of BN for $i = 60^{o}$.
6. How would you produce deviations in anticlockwise direction?
7. What can be the reason for grounding one of the faces of a prism? Write an investigatory note.

SOME OBSERVATIONS ON THE PERFORMANCE OF PHASE DEPENDED BIASED TRANSISTOR

Transistor conducts when base emitter junction is forward biased. Usual common emitter configuration employs forward biasing of base-emitter junction to the tune of 0.2 to 1.5V (in exceptional cases upto 5V) while collector base junction is reverse biased beyond 2V (except in saturation region when both junctions are forward biased).

Unless specified collector is provided with a stable DC voltage and base is fed with some signal. Variation in input signal is reflected at the output.

Here we discuss a case where collector is given a pulsed DC (positive half of sine function) so that for half cycle of operation transistor remains idle. In such situations also base voltage determines output current of the transistor.

But if the phase of the base biasing mismatches the collector voltage, the results are entirely different. This stage is appropriate to introduce and reinforce the idea of phase.

The phase of the voltage at the base can easily be altered with RC combination. A circuit depicted in Fig.1 can easily achieve this objective.

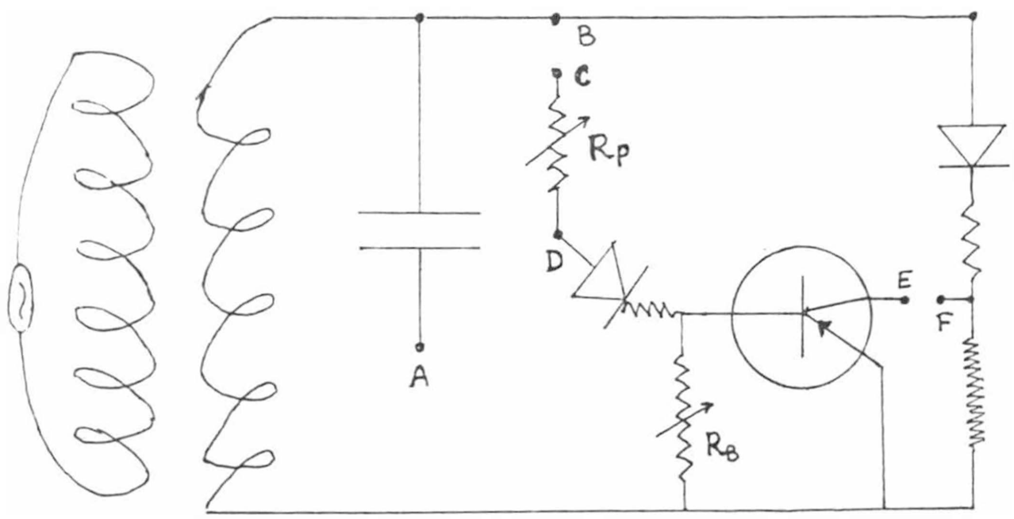


Fig.1

i) Join BC and AD for effective phase change from 0° to 90°.
ii) Join AC for effective phase change from 90° to 0°.
iii) Join milliampere meter between E and F (in both the cases)

Note : Variation in R_p causes change in phase of input ac while R_B sets the base bias.

Collector gets a positive voltage pulse every 1/50 second so does the base. Fig.2 shows the situations if phase of base voltage is changed successively. Vertical lines indicate that as the two voltages get out of phase, lesser duration of each half cycle collector sees proper biasing of the base for transistor to conduct.

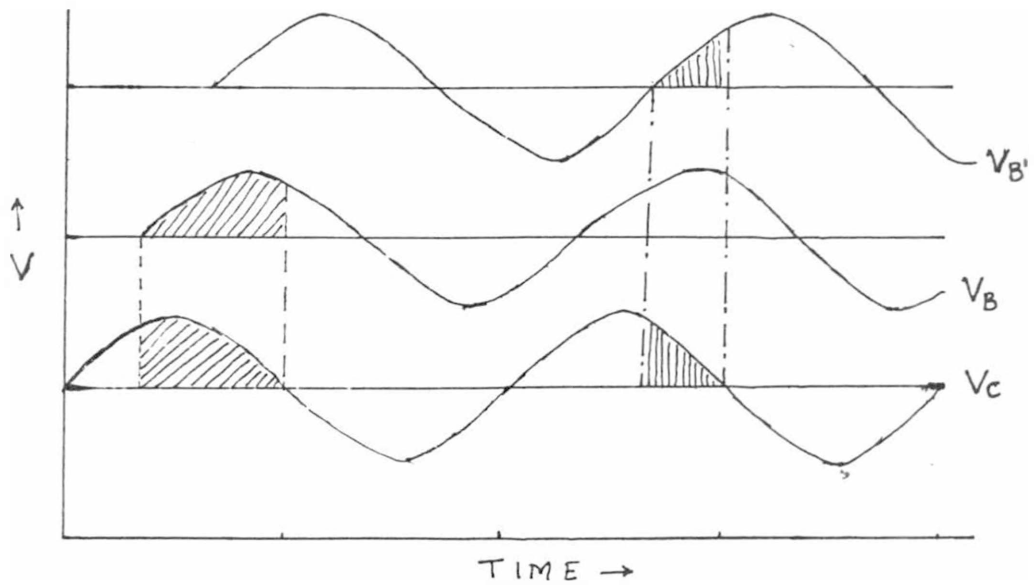


Fig.2

In other words, the average current measured as I_c changes though the base voltage and the collector voltages are not altered.

Suggested Activities

1. Change in phase angle is given by $\tan\phi = \frac{1}{\omega C R}$. Find out for which case of the circuit it holds good. What modification it must have for other mode ?
2. Average rectified current is given by I_o/π for half wave rectifier. On changing the phase at base, average current I_c changes where should it be accounted for ?
3. What do you expect to happen if a filter circuit is added before voltage is fed to collector ? Verify your claim.
4. Derive a relation (on the basis of variation of I_c) between I_c and ϕ and discuss.
5. Should you replace RC circuit by LC circuit, what would be tentative effect ?
6. Design a thought experiment where base is connected to two sources, the relative phases of which could be altered.

Contract Plan

(Teaching Science in Today's Secondary Schools by Thurber and Collette, Prentice Hall of India (Private) Ltd., New Delhi, 1964)

Signing a contract with pupils according to their abilities is one of the effective mode of teaching learning process. Here each pupil is given a list of set of tasks. Pupils can have contract to do a minimum number of these tasks upto desired satisfaction.

The tasks go as under –

Read through the following items and decide what grade you would like to contract for.

D starred items + one task from each group

C starred items + two tasks from each group

B starred items + three tasks from each group

A starred items + four tasks from each group

Now discuss with your teacher and sign a contract showing duration of execution.

Topic for transaction : Semiconductor diodes

The starred items are

- Prepare a title page for the topic semiconductor diodes.
- Introduce the topic semiconductor diode with description.
- Write an article on why semiconductor diodes are important to us.

As per performance level, choose one or more tasks from following groups.

Group one

Theme : Learn to use pn junction. Make necessary diagram. Use circuitry with ammeter, voltmeter and cell.

1. Discover forward bias characteristics
2. Find out resistance offered.

3. Find out VI relationship.
4. Set up circuitry for rectifier
5. Categorise different diodes
6. Write an article on diodes

Group two

Theme : Learn to handle the diode

1. Check whether given diode is OK.
2. Find limiting current through diode.
3. See changes in body temperature of the diode with passage of current.
4. Find knee voltage of the diode.
5. Use multimeter for checking diodes and list out limitations.

Group Three

Theme: Read about diodes and write your findings

1. How to make a diode ?
2. How to represent different diodes ?
3. What are different uses of diodes ?
4. Write the conditions under which a diode may get damaged.
5. Discuss pn junction from the contact potential/ chemical potential of the materials used.
6. Write an article on "if diodes were not discovered".

Certified that I will complete this job in ....days for the grade.............

Pupil's signature

Date : **Teacher's Signature**

LESSON PLAN 0

Centre	**Date:**
School	**Class:**
Name of the Teacher	**Subject: Physical Science**
Name of the Supervisor.....	**Topic : p-n junction**

1. Instructional Objectives:

a. To enable Pupils to know how p-n junction is formed.
b. To enable pupils to understand the process of electron and hole diffusion across the junction.

2.Teaching Points:

a. A wafer is a chip of n-type or p-type semiconductor.
b. p and n- type semiconductors when brought into intimate contact form a p-n Junction.
c. Diffusion is movement of majority charge carriers across the junction due to electrostatic forces between them.
d. Diffusion of electrons and holes across a p-n junction builds up a potential barrier for further diffusion of majority charge carriers.

3. Previous Knowledge:

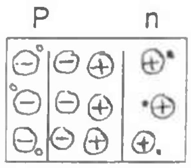
p-type and n-type semiconductors, majority and minority carriers in p-type and n-type semiconductors.

4. Materials/Resources.

Chart showing P-N Junction, majority charges and potential barrier.
Common p-n junction diodes.

Expected Behavioral Outcome	Sequential Learning Experiences	Evaluation
	T. In the last class we studied about extrinsic (impurity) semiconductors	
Recalls p-type and n-type	Which are the two types of semiconductor we studied?	
Recalls holes	Which are the majority charge carriers in p-type semiconductor?	
Recalls electrons	Are there any other kind of charges in a p-type semiconductor?	
Recalls electrons and holes respectively	Which are the majority and minority charge carriers in n-type semiconductor?	
Plan an activity	Let us divert a little take a glass rod rub it With silk and another rod of ebonite rub it with resin. What kind of charges do these rods acquire? If we bring those rod together in contact what kind of phenomenon we expect at the contact? Today let us see what happens (what properties are shown when a p-type and n-type semiconductors are brought in intimate contact with each other. Teacher shows two chips of a p-type and an n-type semiconductor and introduces the term 'water' for such chips. He explain formation of junction between the two. Teacher introduce the term p-n junction for such a device. He demonstrates a p-n junction (diode) and draws the attention of students towards its size, weight, structure and markings on it.	How many kinds of charges we can have? Why is this device called a p-n junction? Why is a tape recorder so light and small compared to a Gramophone?
Interprets – the charges are disturbed	Should the charges remain unaffected once the junction is formed?	
Sees relationship electrons tend to attracted be by the p-type semiconductor.	Consider the electrons on the n-side close to p-type. How are they affected due to the proximity of p-type semiconductor ?	
Recalls – move towards p-region crossing the junction	In what direction do they move?	

Sees relation they are attracted by the electrons of them side.	How are the holes near the junction affected by the n-site of the junction?	
Recalls – they leave the inside and enter the n-side recalls electrons from n top and holes from p to n	What is the direction of movement of the holes and electrons across the Junction? Teacher introduces the term 'diffusion' for such movement of charges across the junction due to their attraction. Teacher show me chart of p-n junction and asks students to mark the direction of i) Diffusion of electrons ii) Diffusion of holes	What is the sign and magnitude of charge on a i) hole and ii) an electron.
Reasons- They get neutralized	Suppose an electron at the junction meets a hole from the opposite side what may be the result?	
Recognizes that electrons are negatively charged while holes are positively charge.	If I bring n-type and p-type waters in close contact. I should expect some rearrangement in the charge distribution. Should I?	
Infers? Explains the process of Electrons entering into p-region and holes into n-region.	What electrons of n-region which is close to p-side semiconductor would tend to do? Should we expect a similar situation for holes of p-region which is close to n-side of semiconductor?	
Introduces process of diffusion	T. electrons from n-region entering into nearby p-type region due to natural attraction is called diffusion, Similarly holes from p-region entering into nearby n-region is diffusion of holes.	What kind of charged species take part in the process of diffusion.
Recognizes that opposite kind of charges annihilate.	When electron diffuses into p-region and meets a hole what kind of	
	Teacher introduces the term 'recombination' for such neutralization of charges. Therefore. Draws the attention of the students to the region where the charges are neutralized, near the junction.	How many electrons can 'recombine' with a hole?

	Teacher introduces the term 'charge depletion region' for such a space surrounding the junction which is tree of bath kinds of free charges.	As more and more charges 'recombine', how does it affect the size of the charge depletion region?
Recognizes charge depletion region.	Teachers makes use of the p-n junction chart to locate the charge depletion region near the junction.	What is the net charge on a n-type semiconductor?
Sees relation – The n-type gets positively charged	As consider the diffusion of charges on either side. How is the number of charges related to the net charge on the n-type semiconductors ?	
Recalls- They are the loosely bound Electrons of the donor impurities	Where from the diffusing electrons come [illegible] in the n-type?	Why are the electrons of the donor free to move?
Recalls- they are positively charged	If electrons are removed from donor impurities what will be the charge on them?	What is a charged atom called?
Recalls- they are fixed. Reasons-they are bonded in the Solid.	Are the donor ions movable? Why are they fixed ? 	
	Teacher explains with the help of the chart that a layer of fixed +ve donor ions are formed near the n side of the junction.	
	Teacher makes students recognizes that a layer of – ve charged ions are formed on the p side of the junction.	What type of fixed ions we can expect on the p side of the junction?
Recognizer – the + ve and – ve ion layers.	Teachers draws the attention of the students to these layers on the chart.	
Recalls- the p.d.between the p side and n side of the junction.	Suppose we connect a voltmeter across the junction what does its reading indicate?	Why do you say that there is a p.d. across the junction?
	Teacher introduces the terms 'barrier potential difference' for this p.d. between either side of the junction.	

LESSON PLAN 1

Topic : **A course on silicon semiconductor.**

Previous Knowledge :
Semiconductor is a class of material whose conductivity lies between that of a metal and an insulator.

Objective :
To teach that silicon possesses all the characteristic properties that a semiconductor should exhibit.

Introduction Phase :
1. Teacher asks question on last lesson.
2. Teacher finds from pupils what are the two major characteristics of a semiconductor.

Development Phase:
Teacher poses a problem – whether silicon is an insulator ?

Activity : Teacher writes on the blackboard.
1. Take a silicon chip.
2. Connect ohm meter probes across its faces.
3. Record the value of resistance.
4. Heat the chip.
5. Record the value of new resistance.

Students perform activities as per instructions.

Group discussion : When silicon becomes warm, it does not lose its resistance. Students discuss match results and infer that when silicon is heated, its resistance decreases.

Teacher tells – This is so with all semiconductors. All semiconductors also show decrease in resistance when impurities (specially tri- and pentavalent) are added to it.

Conclusion : Pupils make short note of the result and with teachers help formulate a further problem.
What is the cause for increase in conductivity ? Where from the additional charge carriers come ?

Participation or Teachers Part
Introduction to new work. Sources of silicon and general discussion aout its procurement.

Demonstrates how to measure resistance.
Instructions for heating silicon chip.
Supervision of pupils' work.
Formulation of result.

Pupils' part :
Contribution to introduction
Conduct of experiment
Discussion for inference
Notes for result

Blackboard work :
Instructions
Formulation of statement of result.

Materials :
Silicon chip, tong, burner, multimeter, notebook.

LESSON PLAN 2

Title of the Lesson : n-type semiconductors

Goals : To acquire knowledge of n-type semiconductor, its preparation and properties.

Classroom Management
Method : Introducing topic by recalling – What is semiconductor? What are the different kinds of semiconductors? What is valency of Ge/ Si? Find out the role of impurity in Ge/Si semiconductors.

Showing chart for structure of Ge/Si and configuration of pentavalent impurity say P.

Group Role : Discover the conduction in Si/Ge crystal, Role of valence electrons, formation of bonds.

Materials : Chart showing Ge/Si structure.

Mindjog : What would happen if a few bonds in Ge./Si break ?
What would happen if an atom of Ge/Si is replaced by P ?

Personal Connection

Information exchange – atom as a whole is neutral. Pure Ge/Si crystal has all bonds saturated. Breaking a bond causes release of mobile charge carriers. Ge/Si cannot accommodate extra electron of pentavalent impurity.

Unbound electron of pentavalent impurity becomes free with extremely small energies ~0.01 eV. Thus pentavalent impurity can donate electron for conduction.

Information Application

Pentavalent impurity when substituted for a Ge/Si atom makes available a free electron. Free electron is available for conduction. Higher concentration of impurity atoms give large concentration of electron. This is known as n-type semiconductor.

Real World Connection

Ge/Si crystals are doped with pentavalent impurity to produce n-type semiconductors. Many devices use n-type semiconductors such as transistors, FET, Hall probe.

Reflection

Can we expect large concentration of electrons with hexavalent impurity? What should happen if Ge/Si atom is replaced by a Tetravalent/Trivalent impurity?

Assessment

List uses of n-type semiconductor. What is the effect of temperature on n-type semiconductor? How do you represent impurity atom in Ge/Si lattice?

LESSON PLAN 3

Statement : Study of p-type semiconductors.

Behavioural Objectives:

1. Understanding : Explains what is p-type semiconductor.
2. Value pattern: Recognises role of impurity. Discriminates it from n-type semiconductor.
3. Skill and abilities : Predicts kind of charges responsible for conduction.

Initiating the Unit

A. Teacher preparation for room environment.
1. Pictures : Show pictorial representation of p-type semiconductor.
2. Artifacts : Nil

Development of the Unit

Generalisation	Content Outline	Activities
Impurity atom can be substituted for an atom of Ge/Si in the lattice.	Trivalent impurity substituted for a Ge/Si atom produce p-type impurity.	Al is put on, a silicon block and heated. What we should expect?
Trivalent impurity leads to unsaturated bond.	Fourth bond of Ge/Si remains unsaturated for each Al atom substituted.	What would unsaturated bond tend to do?
Unsaturated bond can attract a nearby electron.	Missing electron site is called a hole.	What should be the nature of charge of the hole ? (Shows chart of p type semiconductor highlighting impurity).

Lesson Plan 4

Title : Diode and its operation.
Grade : X
Students : Familiar with p-n junction.
Time : 40 min.

Unit Objectives

1. Diode is an electronic device that allows unidirectional flow of current.
2. Diode works as a rectifier.

Specific Objectives	Teacher Procedure	Pupils' Activities	Evidence of Mastering
Pupils recognize diode.	Teacher provides a variety of diodes available and asks students to observe, its 1. Size 2. Markings 3. Color 4. Terminals	Students handle diodes and note down specifications of diodes.	What is the difference between diode and a carbon resistance? Capacitor also has two terminals. How will you differentiate it?

Pupils identify n-side in a diode.	Teacher tells the terminal closer to ring mark, dot or indicated by arrow is n-side of diode.	Pupils identify n-sides of different diodes.	Which is p-side of diode ?
Diode conducts in forward bias.	Teacher suggests that when +ve terminal of the battery is connected to p-side and –ve terminal to n-side of diode current can pass through it.	Students take a dry cell and try to connect diode to it.	How will you ensure that current is passing?
	Teacher makes them aware of the fact that current is detected by a galvanometer connected in series.	Students use galvanometer in the circuit.	What is the direction of the current shown by galvanometer?
Diode offers large resistance in reverse bias.	Teacher seeks to know what happens if +ve terminal of the battery is connected to n-side and –ve terminal to p-side of the diode.	Students try opposite polarity and discuss their observations.	What is the difference between two cases?
	Teacher introduces terms forward and reverse bias.	Students write the results of current flow in two bias.	Do you find same amount of currents?
Diode allows unidirectional flow of current.	Teacher suggests to verify the results and arrive at conclusion.	Students draw the conclusion that current flows only in forward bias.	
	Teacher asks if we apply alter-nating voltages across diode, what should they expect?	Students infer that current can flow only when voltage is forward biasing.	What do you call the device that allows unidirectional passage?

Diode is a rectifier.	Teacher informs that electronic device that allows unidirectional flow is rectifier.	Students task. Find out whether all diode behave similarly.	Why do we need several versions for a diode?

Lesson Plan 5

Subject : Physical Science
Class : X
Date
Time :
Lesson : Semiconductors
Period :

Lesson Objectives

1. To gain knowledge about semiconductors.
2. To learn properties of semiconductors and factors affecting them.
3. To recognize importance of semiconductor in daily life situations.

Previous Knowledge

1. Matter exhibits itself in three state.
2. Solid state has two forms.
3. Crystalline form of matter.
4. Free charges contribute to conduction.

Teaching Aids :

1. Three kinds of solids – conductor; insulator and semiconductor.
2. Chart depicting Si/Ge structure.
3. Databook – Clark Table

Specific Objectives	Teacher's Activities	Pupils' Activities
Recall electrical conduction.	What materials conduct electricity? Teacher provides a few materials.	Students classify materials according to conductivity.
	Teacher introduces the term semiconductor.	
Conductivity of semiconductors lie between metals and insulators.	Teacher gives information about conductivity of semiconductor, provides databook for analysis.	Find from conductivity table what materials can be semiconductors.
Conductivity of semiconductors increase with temperature and presence of impurity.	Teacher suggests that semiconductor having extraordinary property of change in resistance, finds several domestic applications.	How to affect conductivity – heat it, how to incorporate impurity – see processes.

Recapitulation.	Define semiconductor. List out parameters affecting conductivity of a semiconductor.	

Assignment : Note the devices that make use of semiconductors. Collect information about Ge and Si.

Lesson Plan 6

I. **Aim :** Acquire knowledge about Ge Semiconductor.
II. **Assignment:** Made at preceding class
   a) Devices that make use of semiconductors
   b) Information about Ge and Si

III. **Presentation of new material**

Facts/Principles to be taught	Method used to teach each fact or principle
Ge is a tetravalent material.	Teacher discusses the structure of Ge atom.
Crystalline Ge forms saturated tetrahedral bonds with neighbouring atoms.	Teacher shows chart displaying two-dimensional Ge lattice and discusses it.
Covalent bonds are susceptible to breaking on imparting small energy.	Teacher gives information about fragile nature of bonding in Ge lattice.
	The bonds break to produce free charges.
Free charges are responsible for conduction.	Temperature can cause breaking of bonds. Hence, he infers that increase in temperature causes increase in conductivity.
Impurities can also cause rupture of bonds.	Teacher suggests that increase in conductivity of Ge crystal may result on incorporation of impurity on it. Trivalent and pentavalent atoms are good candidates for impurity.

IV. **Summary**

Ge is a semiconductor with all four valency saturated. Rise in temperature or presence of impurities rupture the bonds and cause increase in conductivity.

V. **Assignment**

1. Represent Ge lattice pictorially show a ruptured bond also.
2. Obtain information about Ge.

(Source- Strategies on Programmed Instructions : S.P.Mullick, Sunday Press, New Delhi 1985; A synthesis of Teaching methods : C.Morton Shipley et.al . McGraw Hill Co. of Canada Ltd, NY 1964)

PROGRAMME INSTRUCTIONS

It is a strategy of instructions based on the principles of efficient learning under controlled laboratory conditions. It can be viewed as a *standardised interactive instructional system* in which the learner interacts with each step in the programme.

Its principles emphasise the need to specify the terminal behaviour to be developed in the learner and accordingly design the instructional process in order to maximise the acquisition of the terminal behaviour, which is achieved through active responses and reinforcements moving gradually towards the goal with empirical validation.

Characteristics of PI

- Active responses for a limited amount of learning material.
- Questions posed on information provided.
- Learning material and questions form such a set that learner tends to give correct responses.
- Correct responses are followed by rewarding events.
- Reinforcements are maximized.
- Each step is designed to evoke and reinforce towards terminal behaviour. Each subsequent step also is in the direction of terminal behaviour. Steps are from lower to higher levels of complexity.
- Graduation in step is achieved by the use of prompting, fading or vanishing techniques.
  (Prompting => getting learner emit low strength responses with minimum error. Fading => gradual removal of prompts so that by the time the learner has completed all steps, he is able to respond well to stimulus material which will be available to him when he exhibits terminal behaviour).
- Every learning step assumes an appropriate shape solely to suit the needs and ability of intended learner. Hence its efficacy on a sample of intended learner is tested. The step is finalized only when it demonstrates what it is purported to teach.

Why PI?

Because

- Extreme dearth of well informed teachers existing.
- Existing teachers are overloaded.
- Explosion of new knowledge (especially in science) challenges capability of teacher to keep pace with it.

Methods of PI

a) *Linear model of PI* postulates that inducing and then reinforcing the desired behaviour can bring about a desired change in entry behavior. This is achieved by small learning steps (called frames).

The subject matter is presented as **incomplete** statements from text (i.e., with intermittent blanks). Correct answers for each blank are given at some convenient place (but away from the frame). The learner is required to read the frame and construct the response (think and recall). Finally he compares it with correct answer.

The premises of this method are

- Educational control is not aversive
- There are a number of reinforcement contingencies
- Complex behaviour is best learnt by a series of progressive stages leading to final desired behaviour.
- Frames are learner friendly and enable him to select correct response.

b) *The branching model of PI* consists of development of a series of learning excercises. Each exercise contains a short discussion of the material followed by a multiple-choice questions (behaviour involved is recognition). Each answer choice has directions for the learner about where to go next. If his answer is correct he goes to exercise that contains material of next unit. If chosen answer is incorrect, he is directed to the exercise that tells why the answer is incorrect along with alternative discussion. The learner is then again directed to go to the same exercise and tryout the answer. He can proceed to next unit only after getting successfully through the frame at hand. Thus this method has inbuilt remedial material.

The premises of this method are

-The learner chooses responses.

-The responses serve as diagnostic tools.

c) *The methetics model of PI* follows steps of linear model with provision of analysing the behaviour in terms of operants. The unit of learning is an exercise that follows.

demonstration phase – prompting phase – rehearse phase

Advantages of PI

These are individually paced programme. Hence these allow the learner to read, re-read at his own pace.

Teacher's job

According to the lot of pupils allotted to him teacher can select an appropriate method of instructions. The presentation device can be printed material, multimedia etc. Teacher can act as consultant, supervisor, diagnoser or provider of remedial instructions to the pupils. He is expected to advise the students to record time spent on each of teaching point.

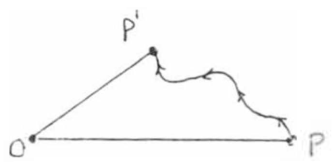
Illustrative examples for PI

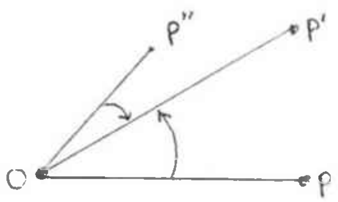
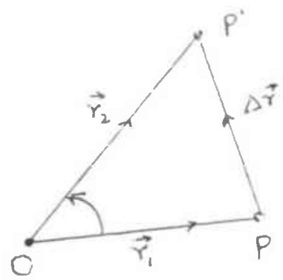
a) Linear Programme

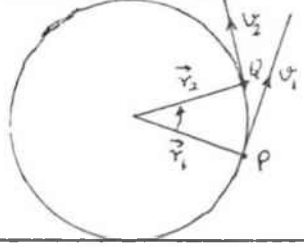
(Instruction – Concept to be developed is written on LHS. Frames are numbered serially. Read each frame, think, respond and then check for answer. If answer is correct then only proceed to next frame otherwise read * material and re read the same frame. Intermittently see if the underlying concept is taken care of. Hide column III while undertaking PI)

Topic - Rotational Motion

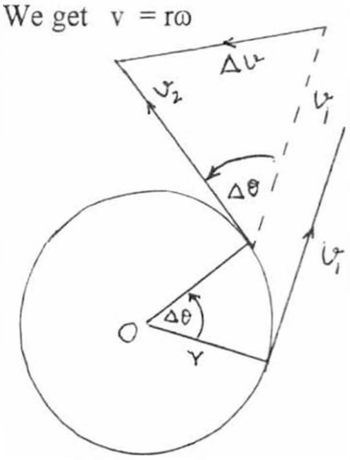
Concept I	Frame II	Answer/Remediation III
Rotational motion is a motion of objects with change in direction.	1. When a body changes its position with the passage of time, it is said to be in motion. In general a body can move without change in direction (motion along a straight line) or it may change the direction as it moves (motion along a curved path). Rotational motion is motion along a curved path.	1 a) Rotational motion. * If body deviates away from X axis as it moves, the motion cannot be called a rectilinear motion. * If a body makes constant angle with X-axis as it moves, it is not changing the direction. Hence such motion is rectilinear motion. * A body can make constant angle with X, Y, and Z axis

	a) A body moving initially along X-axis continuously deviates from it along its path. The motion of the body can be described as …… motion. b) To trace a curve we need a paper. Hence motion along a curve must at least be ----- dimensional.	as it moves still its motion is along a straight line. * For rotational motion the body has to change its direction as it moves. b) two * Try to draw a curve along a straight line. * Deviation from one axis needs another dimensions.
Essentials in rotatory motion i) Fixed point, origin, center or a fixed line ii) Position vector or radius vector. iii) Angular displacement	2. Rotational motion is characterized by a fixed point or a fixed line depending on the specific kind of motion it is called origin, center, pivot, focus, axis of rotation, etc. The line joining this fixed point (or line) to the body in motion at any instant enables to know instantaneous position of body. Such line segment is called position vector or radius vector. The radius vector at t=0 is called initial line, reference line or initial position vector. The angle subtended by radius vector at any instant of time with reference line is called angular  displacement or angular position θ a) Origin is a ----- point in rotational motion. b) A point P moves about O then OP is called………… c) The angle θ , between OP and OP' in fig. is……	2a) fixed * There is always a fixed point within or outside the body about which the body rotates, * Earth rotates about the sun * A wheel rotates about an axis * A convenient point with reference to which motion and position of a body can be defined is called origin. b) position or radius vector. * OP is not only a length but indicates the direction also. * Position of a body is described with respect to a fixed point O. c) Angle of displacement or angular position. * Two distinct points on a curve make an angle with a fixed point. * Any point with respect to initial point on the curve is said to be displaced by a definite angle.

		* Rotational motion is motion along a curve.
Sign convention in rotational motion 1. +ve angle 2. Radius Vector	3. Angles measured anticlockwise with respect to reference line are positive. These are measured in radian or degree and denoted by θ. Distances from fixed point (radius vector) are positive and denoted by **r**. a) Angle POP' is...  While P'' OP' is .... b) PO distance is .... But OP' is	3a) positive, negative * As P Moves towards P' the angle increases in anticlockwise direction. * If P" moves towards P' radius vector moves in clockwise direction. * Anticlockwise rotation of radius vector about a fixed point subtends positive angle with initial line. b) negative, positive * OP is positive PO is negative. * OP> OP" since P" is closer to O .
Rotational motion causes change in θ and **r**	4. Rate of change of angular displacement is called angular velocity $\frac{\Delta\theta}{\Delta t}$ = ω and it is measured in radian per second. Direction of angular velocity is given by right hand thumb if rotation is along folded fingers. Change in position vector Δ**r** in small interval Δt is called velocity vector **v**. the direction of **v** is tangential to path of the body. a) Direction of Δ**r** is....... to **r**. b) Direction of ω is along the ...... of rotation.	4 a) normal * suppose $\mathbf{r}_1$ and $\mathbf{r}_2$ are two position vectors of point P at two instances t_1 and t_2 then $\Delta\mathbf{r} = \mathbf{r}_2 - \mathbf{r}_1$  As Δ**r** → 0, PP' is normal to $\mathbf{r}_1$ b) axis * Path of rotating particle lies in a plane perpendicular to axis of rotation. * Direction of ω is normal

		to the path of particle **v** = ω x **r** $= \frac{d\theta}{dt} \; x \; \vec{r}$ i.e., $\perp \; \vec{r}$ *and* $\Delta\theta$
Special Cases of rotational motion. 1. Circular 2. Elliptical 3. Oscillatory 4. Spin	5. When magnitude of position vector is constant, the motion of body is circular. If body moves with constant speed along the circular path the motion is uniform circular motion. Elliptical motion is another kind of rotational motion where magnitude of radius vector changes between r_{min} to r_{max} to r_{min} etc. during its rotational motion Motion of pendulum is a rotational motion where direction of rotation changes periodically. a) Constant circular motion is that in which angular velocity is .... b) Earth moves around the sun in .... path c) Motion of see-saw is ...... d) When a body moves about an axis that passes through it, the rotational motion of this kind is called spin. Hence motion of bicycle wheel is	5 a) constant * If r and v are constant |rxv| has to be constant. * For uniform circular motion change in θ with time should be same. b) elliptical * Distance between earth and sun changes continuously between two values. c) rotational * Fulcrum is a fixed point and each point on see-saw beam (lever) rotates about it. d) spin * The bicycle wheel rotates about axle which is within the wheel * Spinning of top is another example of spin motion.
Acceleration vector in circular motion	6. The rate of change of angular velocity of a body about a given axis is called angular acceleration. $\alpha = (\Delta\omega / \Delta t)$ $= \text{Limit}_{\Delta t \to 0} \, d^2\theta/dt^2$ 	6 a) **a** = **r**α * $\alpha = (d\omega/dt)$ $= d(v/r)/dt$ $= \frac{1}{r} \frac{dv}{dt}$ $= \frac{a}{r}$ b) towards

since $|r_1| = |r_2| = r$ and
$|v_1| = |v_2| = v$
From PQ = v dt and
PQ = rdθ
We get $v = r\omega$



$\therefore \Delta\mathbf{v} = \Delta\omega\,(r) + \omega\Delta r$
for constant ω , $\Delta\omega = 0$.
Again in the limit
$\Delta t \to 0,\ a = \dfrac{dv}{dt} = \omega\dfrac{dv}{dt}$
or $\mathbf{a} = \omega.\mathbf{v} = \mathbf{r}\omega\omega = v^2/r$

From the figure, $\Delta\mathbf{v}$ is perpendicular to $\mathbf{v}_1$ which is also perpendicular to **r**.
Since $\vec{a}$ and $\Delta\mathbf{v}$ are parallel
$\vec{a}$ is also along - $\vec{r}$

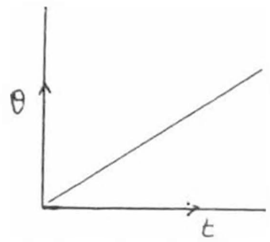
a) α and **a** are related through ……….
b) **a** is called centripetal acceleration because its direction is ……….center
c) The graph between θ and time is ……
d) Area under ω, t curve represents……

* Since $\vec{a} = \dfrac{d\vec{v}}{dt}$ its direction should be same as direction of d**v**.

*Direction of $d\vec{v}$ is always perpendicular to $\vec{v}$.

c) a straight line

* for uniform circular motion θ increases linearly with time.

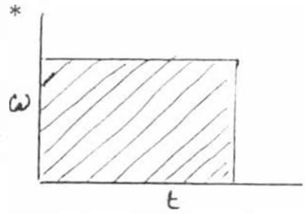


* If slope is zero, body is not rotating, slope cannot be 90^0 also.

d) angular displacement

* $\theta = \omega.t$

*



Area = ω x t

Quantities characteristic of uniform circular motion. 1. Time period 2. Frequency.	7. In circular motion body repeats its path after one revolution. One complete rotation is equivalent to a path of $2\pi r$ In uniform circular motion $\lvert v\rvert$ and ω are constant. If T is time taken by a body to complete one revolution then $vT = 2\pi r$ $\therefore T = 2\pi r/v = 2\pi/\omega$ If a body makes f revolutions in unit time. $v.1 = 2\pi rf$ or $f = v/2\pi r = \omega/2\pi$ Unit of T is second and of f is radian per second (not per second) a) The time period of second's hand of a clock is ..... b) The relation between f and T is ..... c) Unit of ω is .... d) Rotation of Moon about the Earth is an example of .... motion	7 a) 60 s * Seconds hand completes one revolution in 60 s. b) $f = \frac{1}{T}$ * Since $vT = 2\pi r$ and $v = 2\pi rf$ $\therefore 2\pi rfT = 2\pi r$ or $fT = 1$ *T seconds are needed for 1 revolution $\therefore$ in one second number of revolutions would be $\frac{1}{T}$ which nothing but frequency. $\therefore \frac{1}{T} = f$. c) radian per second * $\omega = \frac{\theta}{t}$ * Though $\omega = \frac{v}{r}$ v is not linear velocity hence its unit cannot be per second. d) uniform circular * Moon takes similar times in one rotation about the earth

Note: Each frame has several sub divisions, which are the real frames. For the sake of brevity they have been put together. Words of encouragement are also missing. After the answer one should include them.

b) *Branched Programme*

(Instructions - Read the learning material and choose correct answer for multiple-choice question that follows. Its only recall type programme. Hide the key while recalling the answer. If answer is incorrect re-read the learning material.)

Concept	Development of Frame	Answer
Centripetal acceleration	Take a pendulum bob and tie it to the end of a string of $\cong$ 1m. Make the bob move by hand in circle providing a nearly constant angular velocity. Release the string from your hand. 1. New motion of pendulum bob is a) circular b) elongated circle c) along a straight line away from hand d) towards hand	1. (c)
	Rotational motion imparted tangential velocity to the pendulum as is evident from observations in Frame 1. this force acting radially away can be perceived by tension in the string. 2. An athlete before throwing discus whirls about himself. This is done in order to give what kind of velocity to disc at the release a) circular b) tangential c) upward d) downward	2. (b)
	Tie a mass of 10 g to one end of an elastic thread (or to a spring balance). Hold its other end in hand give rotation to mass in horizontal plane. Observe carefully what happens to the length of the thread as the speed of rotation is increased successively. 3. As the mass attached to an elastic thread acquire more and more of circular velocity, the elastic thread a) contracts b) elongates c) length is not affected d) the event is unpredictable.	3. (b)
	From Frame 3 we learn that due to circular motion a psudo force (since no physical agency is seen that gives push hence the name psudo) Acts outward on the mass which causes elongation of the elastic thread. In equilibrium some real force must balance it whose magnitude is equal to the outward psudo force. This real force is made available by hand which is at center of circular motion. The inward force acting towards center is real and is known as centripetal force.	

	4. Centripetal force is supplied to a rotating body through some agency like thread. What can be the agency for centripetal force provided to Moon when it rotates about Earth? a) may be some invisible string b) light rays c) gravity d) some unknown effect	4. (c)
	Though in uniform circular motion a body moves with a constant velocity, its direction changes at every instant. e.g., after T/4 period change in velocity is v-0 = v, after T/2 period change in velocity is v-(-v) = 2v etc, suppose after T/n period change in velocity is dv then acceleration caused is $a = \frac{dv}{T/n}$ Which yields $a = v^2 / r$ Acceleration cannot be produced without application of a force, for producing circular motion, torque or moment of a force is needed. Torque is equal to force acting tangential to the path multiplied by radius of the circle i.e $\tau = \mathbf{r} \times \mathbf{F}$ 5. A force of 0.1 N is applied tangentially on the rim of bicycle of radius 20 cm. The quantum of torque is a) 2 Nm b) 0.2 Nm c) 20 Nm d) 0.02Nm	5. (d)
	Couple is another agency that gives rise to rotational motion. The pair of equal and opposite forces whose line of action is separated by d form a couple. The moment of couple is given by one of the forces multiplied by the distance between the two forces. If moment of force or moment of couple is more, imparting circular motion to a body becomes easier. 6. Bicycle wheel is rotated by applying a couple on free wheel. What should be the effort qualitatively if size of the freewheel is increased. a) effort needed is less b) effort needed is more c) no change in effort d) cannot say.	6. (a)

"EINSTEIN'S PHOTO-ELECTRIC EQUATION"

Whenever light of sufficiently high frequency(ν should be greater than ν_0, ν_0 is the threshold frequency), falls on a photosensitive surface electrons are ejected from the surface. The phenomena is called photo electric effect. Photo Cell is a device, which makes use of the phenomena of photo electric effect. It is an evacuated tube containing two electrodes, one in the form of semi cylinder coated with photosensitive material and the other is rod, which is held at the axial location of the cylinder. It is connected to the external circuit as shown.

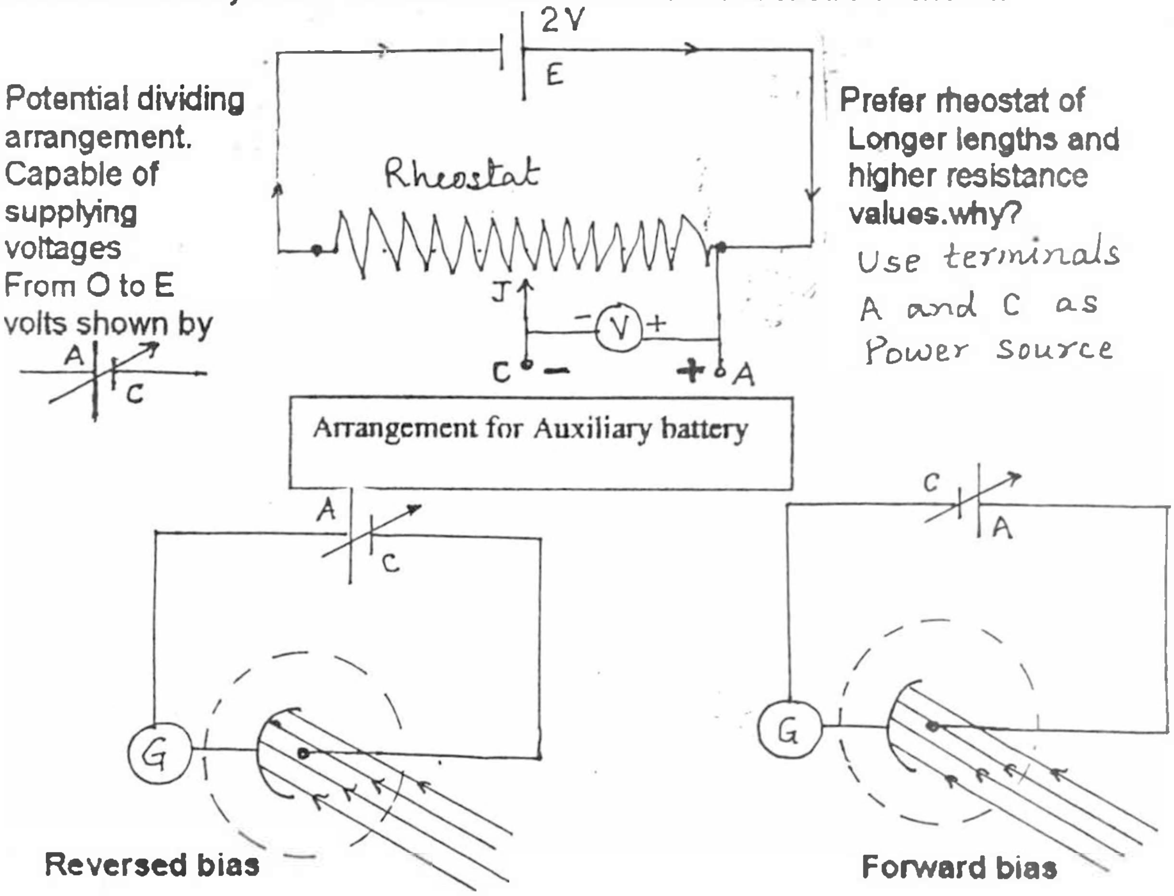


Fig:1 change only terminals of auxiliary battery when desired. When sliding contact J is moved we get different voltage for the battery $C^- A^+$.

When the photosensitive surface is irradiated, some photo electrons are ejected from it (their number is proportional to the intensity of incident light). The electrons those have sufficient energy reach the other electrode (Maximum kinetic energy that an electron have is determined by ($h\upsilon$ - $h\upsilon_0$).

If the anode A, is at positive potential most of the ejected electrons are collected by it. But if it is kept at negative potential then those electrons which have smaller energy than eV do not reach A. Hence photo current is lower in reverse biased photo cell. When $(KE)_{max}$ equals eV_0 no electron reach A. Hence photo current becomes zero. V_0 is then called the stopping potential.

Generally photocell is connected in reverse bias that is the photosensitive surface is kept at positive potential as compared to collecting electrode. Thus A is connected to cathode (see figure). In such situation only a few photoelectrons reach cathode despite its negative polarity and constitute a small current. The current is measured by a galvanometer in the circuit.

As the numerical value of negative potential (retarding potential) is increased. Fewer and fewer electrons reach A, the cathode and hence current drops. Ultimately when V equals or exceeds V_0 (which is only a few volts) no electrons reaches cathode and hence current ceases. The nature of the curve is shown below.

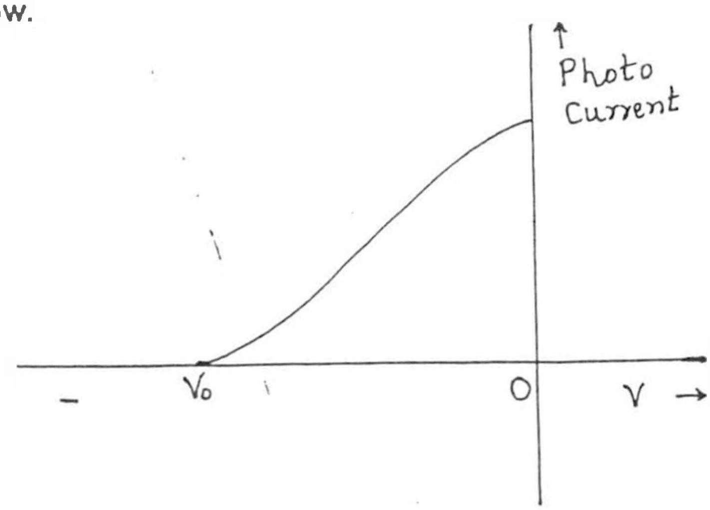
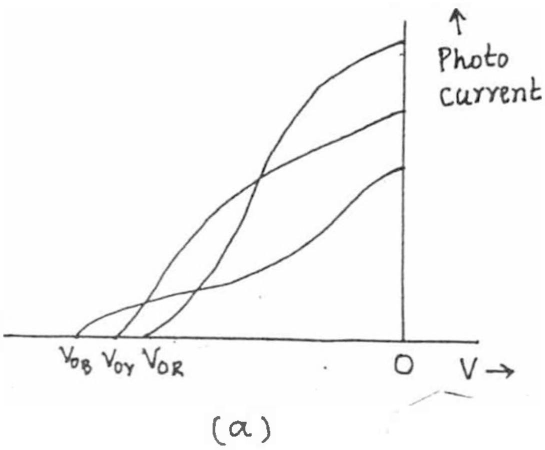


Fig 2

However if the frequency of the light is increased we get a different value for stopping potential as dictated by $h\upsilon = h\upsilon_0 + eV_0$. Thus we can plot a curve between photo current and retarding potential for different set of frequencies. (see Fig 3a).

We know that if the intensity of the light falling on the surface increases. More number of photo electrons become available and hence the current for the same colour of light increases. The stopping potential however remains the same. The curves obtained in such a case are as shown in the figure 3b.



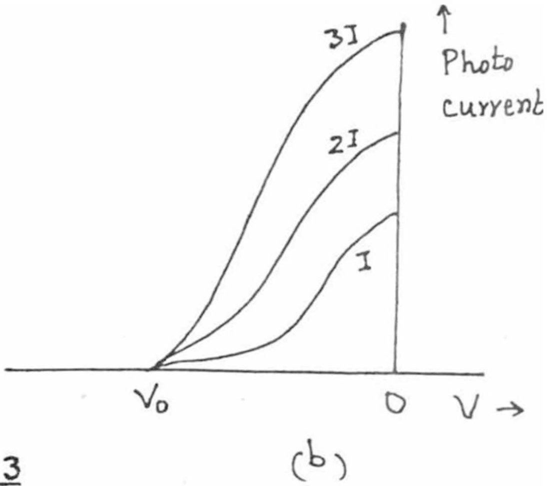
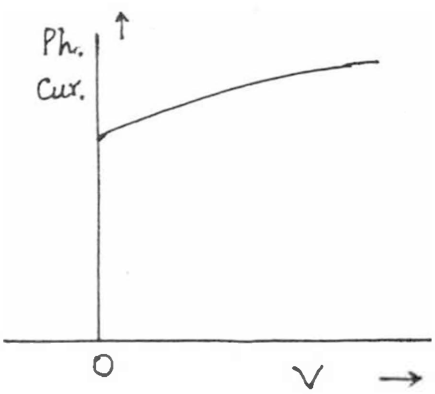


Fig 3

Hence we take observation by increasing the intensity of light falling on the photo sensitive surface i.e. by decreasing the distance between the light source and the photo cell. The third set of curves may be obtained by keeping the photocell in forward biased condition (As far as possible this part should be avoided to save the life of the photo cell). Where we will find response of photo current with increase in potential. The nature of the curve is given below.



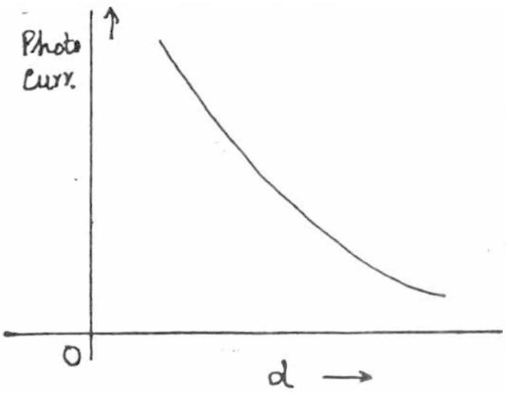


Fig 4

Finally for a fixed applied potential we take photo current versus distance of the light source. To suggest that photo current is inversely proportional to the square of the distance of the light source.

The sets of observation to be taken:

Set I

Keep photo cell reverse biased, light source at certain fixed distance, change retarding potential and note the corresponding current till stopping potential is reached i.e. current ceases to flow (like Fig.2)

Set II: Repeat set I for different colours of light (Fig 3a).

Set III: Keep the photo cell reverse biased repeat set I with variation in intensity of light (like Fig 3)

Set IV: Keep the photo cell forward biased light intensity constant and note observation for V and I. (like fig 4)

Set V: If observations are not taken in the dark room, (-V) I readings may be taken for stray light and corresponding corrections should be made in observation of set I, Set II & Set III.

Calculate:

1. Stopping potential for different colours.
2. Value of h
3. Work function.
4. Account for increase in photo current with +V voltage across the cell.
5. Should you expect conventional current from photosensitive surface to axial electrode ? How & why?

Write sources of error.

Note:-

- Reverse bias potential may be varied in steps of 0.1 V
- •• Distance between photo cell and light source may be kept minimum and varied by not more than 3 cm.
- ••• For changing bias change only terminals of the circuit $^{-}$C and $^{+}$A .
- •••• Always note photo current with respect to change in only one parameter at a time for one set.

Solar Cells

Crystalline silicon with deliberately added impurities is an essential ingredient of a silicon PV Cell.

In a p-n junction the free electrons in N side see free holes on the P side and hence rush to fill them in but only near the junction in the process the charge neutrality is disrupted. This forms a barrier to other electrons on the N side to cross to the P side. In equilibrium we have an electric field separating the two sides (Fig.1 a). Thus a PV Cell has p and n type silicon in contact, between which an electric field is set.

The electric field makes the junction to act as a diode, in which electrons can move only in one direction.

When light 'HITS' the solar cell, each photon with sufficient energy frees one electron (and results in a free hole as well). If the freed electron or the hole happens to wander into the range of electric field of the diode, the field will send the electron to N side and the hole to P side. This causes a disruption of electrical neutrality. If we provide an external current path electrons would flow through this path to P side to unite with hole there which the electric field had created (Fig.1 b).

The flow of electrons provide current and the junction electric field causes a voltage. With both current and voltage we get power.

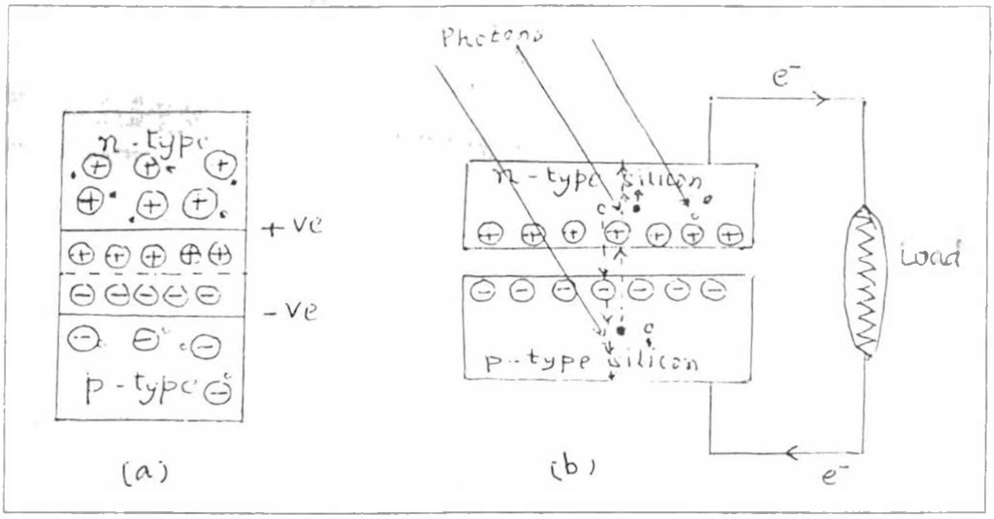


Fig.1. Operation of a P V Cell, ∘ hole, • electron, ⊕ ⊖ bound ions

It may be useful to note that only about 15% of sunlight's energy is useful for Solar Cell. This is because light photons have a wide range of energy, some of them do not have enough energy to form an electron hole pair. Still other photons may have too much energy than that required, then also the extra energy is lost (unless photon has twice the required energy to create one more electron hole pair). This speaks of the quantisation of energy in nature, eg. if the energy of photon is 1.5 times that is needed for the formation of electron-hole pair, 0.5 part of the energy goes waste as heat. These two effects alone cause loss of about 70% of radiation energy incident on the cell.

Optimal band gap for Solar Cell

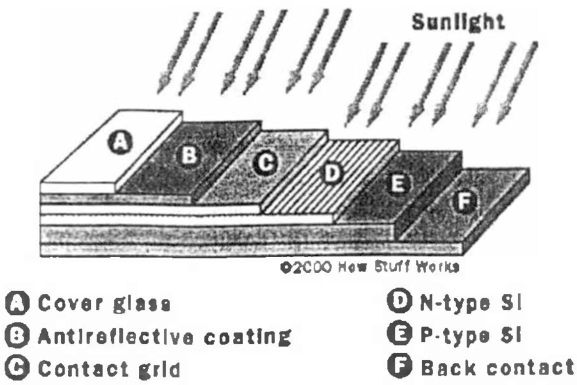
If we choose a material with a low band gap we can make use of more incident photons. But what we get in the form of extra current, we loose by having a small Voltage. Balancing these two effects a band gap of 1.4 eV has been found suitable for a cell made from a single material.

Other requirements:

1. The incident photons have to reach the junction hence one side of the junction should be left open as window. The other side is covered with a metal (acting as anode) for good conduction. Sometimes a transparent window of conducting material is provided over the upper n type silicon which acts as the cathode of the cell.

2. Silicon being very shiny material the photons that are reflected away by it cannot be used by the cell. Hence an anti-reflective coating is applied to the window of the cell.

Finally, the cell is protected by a glass cover plate. In one unit 36 such Cells are connected in series and parallel combinations and mounted over sturdy frame to achieve satisfactory levels of voltage and current.



Source
file://A:\Howstuffworks%20How%20solar%20Cells%20Work.htm

Fig.2. Basic structure of Silicon PV Cell

These days other materials such as GaAs, $CuInSe_2$, CdTe and amorphous Silicon are being used in PV Cells. Now even two different kinds of materials (high band gap on the window side and low band gap on the base side) are being tried. Such cells are more efficient and have been identified as multijunction Cells.

The Solar Cells that you see on Calculators and Satellites are photovoltaic (PV) cells also known as modules.

On a bright sunny day we receive about 1000 W of energy per square meter. We venture into collecting most of it to power our homes. If it could be done we will have "Solar revolution". However, it is limited today to power electrical systems on satellites and frequently for emergency road signs, remote tracks, on buoys and in calculators etc.

BUOYANCY FROM A DIFFERENT ANGLE

According to scientific dictionary, buoyancy is upward thrust on a body by a static fluid in which it is immersed or floating[1]. It is a single force acting vertically upward through the centre of gravity of the displaced fluid[2]. The upward thrust is equal to the weight of the fluid displaced. This fact is connected to the discoveries of Archimedes' wherein he suggested apparent loss in the weight of the body on being immersed. Let us discuss the phenomenon quantitatively.

The universal law of gravitation suggests that the force of attraction between two bodies depends on the mass of the individual bodies (in the case of attraction by earth, it depends on the mass of the second body itself). But now consider that there is another fluid intervening the two bodies also present. Then the picture of the force between two bodies is modified and if the second body is partially or completely immersed in the intervening fluid, the picture gets further modified. The idea of the three cases namely (i)bodies screened by intervening media, (ii) bodies partially immersed in the intervening media and (iii) bodies completely immersed in intervening media can be got as :
(i) Two bodies screened by a glass, (ii) vessel floating on water and (iii) attraction of bodies above the earth's surface when intervening media is air (or a body inside sea, where the intervening media is water) respectively (See Fig 1).

If the mass of one of the bodies is too large, as compared to the second body (as in the case of earth taken as one body), we may for brevity assume that the net effective force acts on the second body and so it moves towards the larger body. The motion here, of course, is governed by the effective force acting on it.

[One physical example may be given for it. Consider a few persons wanting to move through a heavy crowd. Then the one who exerts more force only gets through quickly.]

Thus if we release a stone just immersed in water, the stone makes way through water to reach the bottom. It may happen due to one or more of the following reasons.

(a) Because its attraction towards earth is more.
(b) Because it is more massive, i.e., its relative density is more.
(c) Because it can make way through water easily.
(d) Because Viscous force acting on it is small.
(e) Because water lifts it up with lesser effort, etc.

But let us examine this fact critically. Let the stone occupies location A just before its release as shown in Fig.2. Further, the stone has definite Volume dV, and lastly the fluid was still before the stone occupied the location A and remains still after it has occupied location A. This would just suggest that if the submerged stone were withdrawn and the resulting cavity is allowed to fill with the fluid, then the latter would be in equilibrium under joint action of its own attraction (weight in the case of earth), and the external force exerted by the surrounding fluid.

In other words a force acts on an equivalent volume of fluid at A, which is equal in to magnitude force of attraction between the two bodies (weight in the case of earth) but having an opposite direction. Then if we place the stone at A the force of attraction between more massive stone and body B is more than the force exerted by rest of the fluid in opposite direction. The force exerted by rest of the fluid depends only on the volume occupied. Hence, the relative pull on A by body B becomes less. Thus two quantities that should creep in the discussion are (i) massiveness of the body A and (ii) volume of the body A, which displaces the intervening fluid. The physical quantity that incorporates the two aspects of the body A, is relative density. Thus, we say that a relatively denser body is attracted by a stronger force.

Let us gather the idea separately Volume of the body A is dV then the mass of the Volume dV and of the fluid of density ρ, that would have occupied location A is ρ dV. So force of attraction between B and fluid of Volume dV at location A

$$= G \frac{M \rho \, dV}{r^2}$$

But there is no motion in the liquid. Hence, the fluid at A should be experiencing same net force in opposite direction.

Now place the body at A whose density is ρ', then the force of attraction on it is $\frac{G M \rho' dV}{r^2}$ whereas force of repulsion to Volume dV at A is unaltered (as it is due to rest of the fluid). Hence, net force on the body is

$$\frac{GM}{r^2} dV \, (\rho' - \rho)$$

This, in the case of earth, represent loss of weight of the body due to the presence of intervening medium, whenever $\rho > 0$.

If $\rho' > \rho$, the net force is a positive quantity.

If $\rho' = \rho$, the net force is zero. Hence the body can stay in the intervening fluid without movement. An unbalanced force would act on the body if the centre of gravity and centre of buoyancy do not lie in the same line as the force of attraction.

If $\rho' < \rho$, the net thrust will be against the force of attraction and so the body will tend to move away from the massive attracting body.

The equation of motion then becomes $\frac{GM}{r^2} dV \, (\rho' - \rho) = dV \rho' a$

where 'a' is the acceleration produced.

Case I : When $\rho = 0$ the equation reduces to $\frac{GM}{r^2} = a$ i.e. acceleration is independent of the properties of the body eg. size shape, mass, etc. as verified by Galileo.

Case II : When $\rho \neq 0$, the body experiences different quantum of accelerations depending on volume and density of the body. A few further factors enter in such cases e.g. Stoke's force opposing the motion due to viscosity, fluid resistance depending on the effective area of the body etc.

References :

1. a) McGraw Hill Dictionary of Physics 1986.
   b) A dictionary of Physics, A.M.Goldstein, CBS Publishers and Distributors, 1986.
   c) Dictionary of Physics, H.J. Grey, Longman, 1970.
2. Van Nostrands Scientific Encyclopedia, New Jersey, 1958.

Submitted by
Dr M N Bapat
Regional Institute of Education
Mysore 570 006

Some aspects of satellite moving around the earth without falling

Archana Dubey* & M N Bapat
Regional Institute of Education
Mysore 570 006

For a body orbiting with velocity v at certain height h, from the surface of the earth, we have following possibilities :

1. If $v < v_o$, the body fails to revolve around the earth in circular orbit.
2. $v = v_o$ the body revolves around the earth in a circular orbit.
3. If $v \geq v_e$ the body escapes from the gravitational field of the earth following a hyperbolic path.
4. $v_o < v < v_e$ the body revolves around the earth in an elliptical orbit.
5. The velocity of a body moving in interstellar space is given by

   $v^1 = \sqrt{v^2 - v_e^2}$

In the above discussion v_o is the velocity when body is in a stable orbit and v_e is escape velocity. For stable orbits, gravitational pull is just balanced. Hence, in the frame of the satellite, there is no gravity.

Few points about Satellite

1. Total energy of satellite = P.E. + K.E.

If a satellite of mass m is orbiting with velocity v_o in an orbit of radius r around the earth of mass M, then kinetic energy of the satellite

$$E_k = \frac{1}{2} m v_0^2 = \frac{GMm}{2r} \qquad \left[\because \frac{mv_o^2}{r} = \frac{GMm}{r^2}\right]$$

And P.E. i.e $E_p = -GMm/r$

So total energy $E_k + E_p = -E_k = \frac{1}{2} E_p$, which is negative. The negative sign shows that the satellite is bound to the earth.

* *Navodaya Vidyalaya, Chandrapur, (MS)*

2. Binding energy of a satellite = + $\frac{GMm}{2r}$ (from 1). When a satellite is orbiting in its stable orbit, no additional energy is required to keep it in its orbit.

3. When velocity of the satellite is increased, its total energy will increase and hence it will orbit in a circular path of larger radius.

4. If the velocity of a satellite orbiting near the earth. is increased by 41.4% or if its K.E. is doubled, then it will escape away from the gravitational field of the earth. The formula $\sqrt{2gR}$ for escape velocity assumes that the body is kept on the surface of the earth, where g = $\frac{GM}{R^2}$. Hence if the satellite is to be given escape velocity, the formula would be $\sqrt{2gR} - \sqrt{gR/(R+b)}$. Otherwise, the distance of satellite from the earth's surface h should be negligible as compared to radius of the earth R.

5. When a body falls freely on the earth from infinity, it will reach the surface of earth with a velocity of 11.2 km/s (assuming that atmospheric friction plays no roles, which actually is not the case. Generally bodies settle to a velocity of a fraction of km per second). From
Escape velocity = $\sqrt{2}$ × orbital velocity, we can find orbital velocity at a given height.

Note: When a body is projected vertically upward from the surface of the earth, with a certain velocity, its motion is opposed by gravitational pull (and to some extent by the resistance of earth's atmosphere), due to which body rises upto a certain height and then falls back to the earth. As velocity of projection is increased, the body attains a greater height before falling. Finally, a stage may reach when the velocity is so large that it just escapes from the gravitational field and does not return to the earth on its own. Then the body is said to have escaped.

A body is acted upon by the gravitational force of attraction.

$$F = \frac{GMm}{r^2}$$

Where M = mass of earth and r = distance of the body from the earth, m = mass of the body.

Work done against gravitational force in moving it through a small distance δr is given by $\delta w = F.\delta r$. Hence work done in moving m to a distance r is

$$W = \int_R^r \frac{GMm}{r^2}\, dr$$

$$= \frac{-GMm}{r} + \frac{GMm}{R} = GMm\left(\frac{1}{R} - \frac{1}{r}\right) \text{ where } r = (R + h).$$

This work is done at the cost of the kinetic energy given to the body at the surface of the earth i.e.

$$W = K.E. = \tfrac{1}{2} mv^2$$

or $$= GMm\left(\frac{1}{R} - \frac{1}{r}\right)$$

or $$v^2 = \frac{2GM}{Rr}(r - R) \Rightarrow v = \sqrt{\frac{2GM}{Rr}(r - R)}$$

Substituting $g = \frac{GM}{R^2}$, we get $v = \sqrt{2gR(r - R)/r} = \sqrt{2gRh/r}$.

This velocity would take the body to a distance r.

Let us suppose that the satellite is orbiting at a distance r with some velocity "v_o". Due to gravitational pull of the earth, the satellite falls. Let us assume that in a very short interval of time (Δt), it covers a distance 'δs' = v_o . Δt and also falls through a distance δh. Then from the laws of motion for freely falling body

$$\delta h = \frac{1}{2} g'(\Delta t)^2$$

e.g. if the time during which satellite falls is one second, then the distance of fall can be obtained by the relation

$$\delta h = \frac{1}{2} g' (1)^2$$

or $$\delta h = \frac{g'}{2}$$

and velocity = $\frac{distance}{time} = \frac{g'/2}{1} = \frac{g'}{2} \approx 4.9$ m/s.

(g' is the value of g at a distance r from the earth).

Velocity of the satellite

Let us also find out the velocity of the satellite in an alternative manner.

Consider that at some instant of time, the satellite is at S (Fig.1), r distance away from the center of the earth. Its velocity is v_0 along the direction perpendicular to r and its momentum vector is p_0. Due to force of gravitation, the satellite has a tendency to fall on the earth. The result is its change in momentum vector to p such that $p - p_o = dp$.

From Newton's law, the gravitational pull can be expressed as

$$F = \frac{dp}{dt} \quad \text{so that} \quad dp = F\,dt$$

At the new position of the satellite after time dt, the force of gravity is still perpendicular to its direction of velocity. (The satellite in the present case is deflected by an angle $\delta\theta$ during each time interval Δt due to gravitational pull directed towards earth. As a result, the satellite moves in a circular orbit). We know that a force everywhere perpendicular to velocity leads to a circular path. Further, since force is acting perpendicular to the direction of velocity, there is no change in the magnitude of the velocity. Clearly the direction of p differs from p_0 by an angle $\delta\theta$. Continual exertion of the gravitational force on the satellite can be seen as if satellite is acted upon by a train of impulses F. dt directed towards earth.

Thus the motion of the satellite at S is not only along SA but simultaneously along SO also. Hence during the lapse of time Δt, it does not travel as SA = $v_0\Delta t$ but also continuously moves towards O so that it remains at a distance r from earth (essentially its instantaneous "fall path" is curved along AS'). . Thus SS' = $v_0\Delta t$ is the result of vo and simultaneous motion towards earth. This can be identified as along a curve AS' such that AS' = SA . $\delta\theta$.

From simple geometry

$$\frac{SS'}{r} = \frac{AS'}{SA}$$

or $$\frac{\frac{1}{2} g' (\Delta t)^2}{v_o \Delta t} = \frac{\delta\theta}{2} \quad [\because \angle SS'P = \frac{\delta\theta}{2} \text{ See Fig. 2}]$$

$$\Rightarrow \quad \delta\theta = \frac{g' \Delta t}{v_o} \approx \frac{v_o \Delta t}{r} \quad [\because \frac{SS'}{r} = \delta\theta]$$

or, $$\frac{g'}{v_o} = \frac{v_o}{r}$$

or $$v_0^2 = g'r.$$

Special Cases :

i) If $AS' < \frac{1}{2} g'(\Delta t)^2$, the orbit of satellite will be expanding spiral.

ii) If $AS' > \frac{1}{2} g'(\Delta t)^2$ the orbit of the satellite will be a contracting spiral.

Note: AS′ is the distance through which satellite moves away from earth in time Δt, due to its linear velocity.

Acknowledgement

The authors are thankful to Dr Somnath Datta, Retired Professor of Physics, Regional Institute of Education, Mysore for his critical comments.

Reference

Enrichment Material in Physics for Senior Secondary Teachers, Regional Institute of Education, Mysore, 1997, p.17.

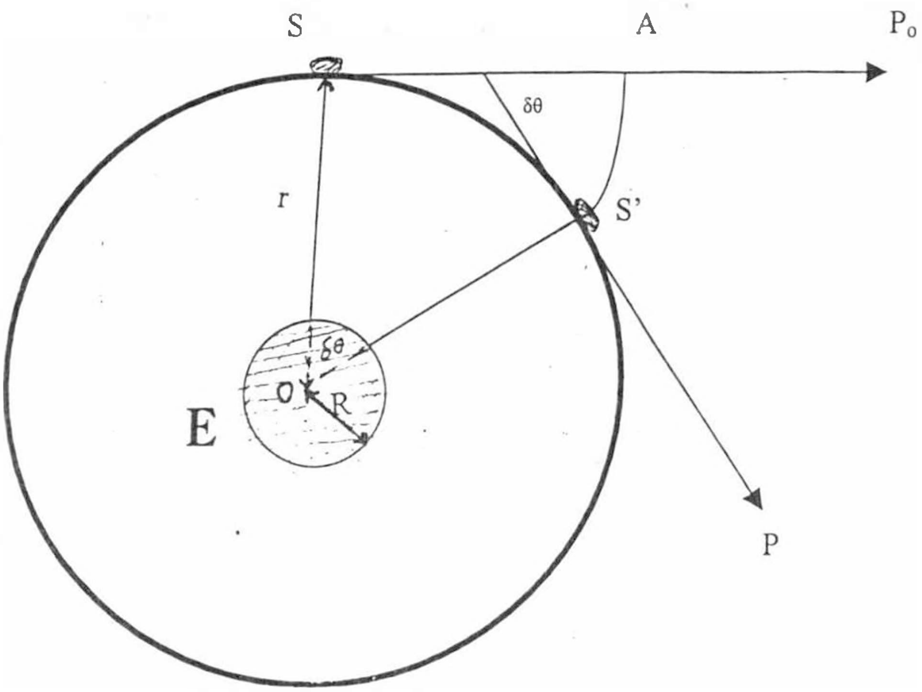


Fig. 1

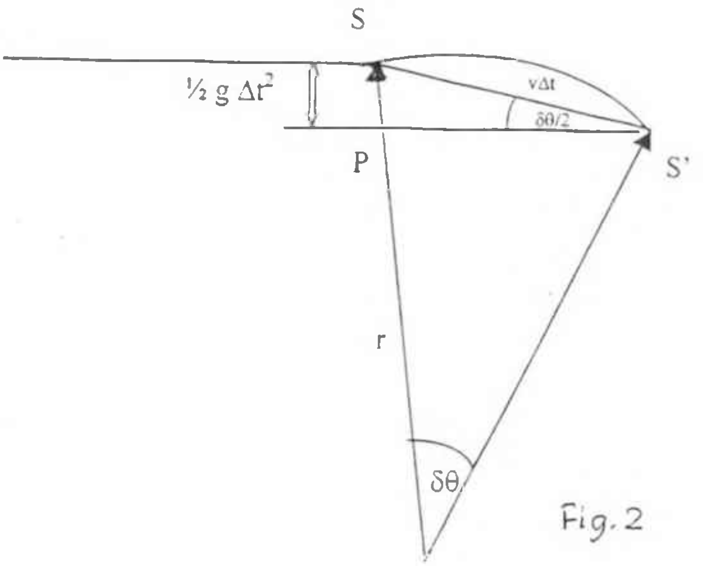


Fig. 2

Understanding a Capacitor through Mechanical Analogue

(To know how far we can be justified in giving analogies)

Capacitor is one of the important components of the electronic technology. Its numerous applications have made it indispensable to scientific sophistication.

In simple terms, capacitor is an electronic device that has definite capacity for storing/handling charges. The electronic circuits, however use it as an element which blocks DC, offers certain impedance to AC and has something to do with the phase of the signals. Strictly speaking, it does not allow passage of charged carrier (neither in DC nor in AC) through it.

Simple capacitors have two conducting plates separated by a dielectric. The two wires from these two plates form terminals for connecting it in the circuit. When it is connected in a circuit one terminal (with respect to other) sends out information of its status (in terms of electrical potential) through displacement current to the circuitry that follows.

Thus to understand the action of the capacitor is really very difficult. It is also difficult to devise mechanical analogue for a capacitor (it will become clear from the discussion part of this article), yet we may show some characteristics of the capacitors by the following model.*

*Note that *not much significance should be given to analogues. Analogues never represent a physical phenomenon truly.* These are used only to understand a complex concept by something, which is easier to visualize.

The Model:

Mechanical capacitor version (analogue) is shown in Fig.1. It consists of capacitor plates A and B. The dielectric is in the form of a plate D attached to plates A and B by springs. Plate D is fixed such that it can be forced to move towards A or B.

Water or some fluid may serve here as charge that can be poured in the capacitor portion AD or BD through tubes. Special water battery R may be devised for such capacitors as shown in Fig.2.

When terminal 1 is connected to A, water fills in the portion AD thus displacing the dielectric plate towards B causing a strain in the springs. In this way, mechanical energy is stores in this mechanical capacitor (just as electrical energy is stored in a capacitor). Charging depends on the potential and the capacity, as in the ordinary capacitors. Height of R relative to capacitor provides potential, portion 1 in Fig. acts as positive terminal and 2 as the negative terminal. The displacement of the dielectric plate is proportional to potential R. Hence energy stored in the capacitor.

= ½ capacity.(potential)^2
becomes = ½ k x^2 [try to relate k with capacity]
where k is the force constant of the spring.

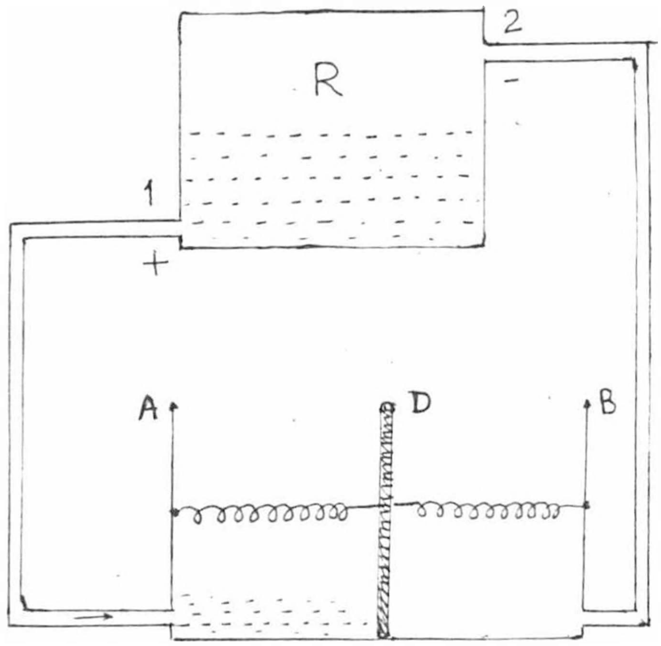
To understand the behaviour with AC source, we can use AC reservoir (source) shown in Fig.2 and connect it to the capacitor directly or through constriction (resistance). In mechanical analogue constriction plays the role of a resistance to the flow of fluid.

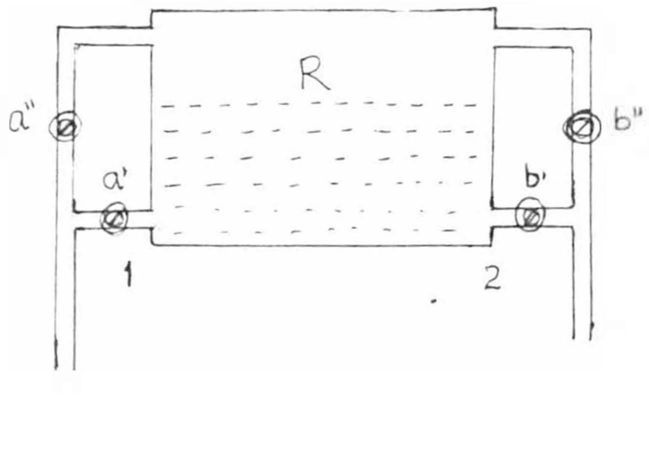
We can go further to show how this mechanical analogue would react under different situations/applications. However, we shall see what is lacking in such a mechanical analogue.

1. Charge has no material aspect as of water/fluid, so no perfect analogy can be expected. Further positive charge on one plate and negative on the other would not be equivalent to presence of fluid in one portion and absence of fluid in the other portion.
2. It is known that more charge can be accommodated on a plate if its surroundings is oppositely charged. No such fluid with anti properties can at present be visualized for the mechanical capacitor.
3. Under alternating source conditions, there is no abrupt change in the behaviour of the capacitor with the frequence. But the mechanical capacitor will respond and allow resonance when the alternating source has a frequency $\sqrt{k/m}$.

Acknowledgement:

Sincere thanks are due to Mrs S Imavathi, RIE, Mysore for careful scripting of the article.





1 is positive ⇒ a' open b'' open, a'' and b' closed.

2 is positive ⇒ b' open a'' open, a' and b'' closed.

Demonstration of Lissajous' figures mechanically

Superposition of two progressive waves moving perpendicular to each other produce interesting pattern for resultant motion. A few constraints are imposed on their nature to get a stable pattern. These being the constancy of amplitude, frequency and the phases of the constituent waves.

The possibility of mechanical display (unless we have ideal Blackburns pendulum) narrows down due to difficulty in obtaining constant amplitude waves. However, Lissajous' figures can be demonstrated on Osciloscope with input from two fixed frequency Oscillators. It can be shown that the amplitude of vibration of a unaided tuning fork or a spring diminishes rapidly. Hence, if mechanical demonstration of the pattern is to be successful, atleast the rate of decrease of amplitude must be the same for both the sources of waves, and has a large frequency.

Let us analyse superposition of two simple harmonic motions

$x = a \sin(nwt + \alpha)$ and

$y = b \sin wt$

So that $\frac{x}{a} = \sin nwt \cos\alpha + \cos nwt . \sin\alpha$

$$= n \sin wt \cos\alpha - \frac{n(n^2-1)}{3!} \sin^3 wt \cos\alpha + \ldots$$

$$+ \cos wt \sin\alpha - \frac{(n^2-1)}{2!} \cos wt \sin^2 wt \sin\alpha + \ldots$$

and $\frac{y}{b} = \sin wt$ with $\sqrt{1-\frac{y^2}{b^2}} = \cos wt$

We obtain

$$\frac{x}{a} = \frac{ny\cos\alpha}{b} - \frac{n(n^2-1)}{3!} \frac{y^3\cos\alpha}{b^3} + \ldots$$

$$+ \sin \alpha \sqrt{1-\frac{y^2}{b^2}} - \frac{(n^2-1)}{2!} \frac{y^2}{b^2} \sin \alpha \sqrt{1-\frac{y^2}{b^2}} + \ldots\ldots\ldots\ldots$$

which represents a very complicated curve for large values of n.

The equation is easily solvable for n=1 and n=2 (or for a simple fraction) with $\alpha = 0, \frac{\pi}{2}, \pi,$ etc. The set of the familiar curves thus obtained are Lissajous' curves. Here a and b denote amplitudes of the individual wave trains that determine extension of curve along x and y axis respectively. Hece if a and b diminish with the passage of time the size of the pattern will go on diminishing ultimately to converge in a point.

Now let us investigate into spring equation. If a spring is stretched by a force say mg it attains equilibrium length (L + l). Where L is the length of unstretched spring and l is length through which it has been stretched. Now if the spring is further stretched by a distance x and released it executes simple harmonic oscillations of frequency $\sqrt{\frac{k}{m^*}}$ but of successively diminishing amplitudes. Where $m^* = m + \frac{1}{3} m_s$ for forces applied by hanging mass m on a vertically suspended spring of mass m_s The value of k can be obtained from the slope of force - extension curve. m^* can be taken equal to m if spring is not directly acted upon by the gravity.

Experimental Set up

Take a Wooden plank collared at two adjacent sides. Fix hooks at the mid points of the Collars and attach one spring each to it. Join the other ends of the springs by threads knotting at cross points. One pen may also be attached at the knot. Allow the threads to pass over pulleys and hang known weights at their free ends as shown in the figure.

Procedure

1. Find value of k for each spring.

2. Fix springs at the hook and find w for each by suspending known weight m. Thus try to have same frequency for each of the spring.

3. Now make complete arrangement e.g. attach sketch pen at the knot, place a paper below it. See that pen makes mark on the paper if it is moved.

4. Stretch the springs further by pushing each weight down. Next release them simultaneously or allowing a time delay as desired.

5. Observe and record the shape of the curve drawn by the pen. Does it conform to Lissajous' pattern?

6. Change the mass to appropriate value to adjust different frequency. Record the change in pattern.

7. What additional information do you get from the sketches?

8. What are the different errors that may show up?

9. Can the effect of length of the spring be studied here?

10. Compare the pattern with that obtained by double pendulum of Blackburn.

Information: The length of the spring is usually small in comparison to the wavelength of longitudinal waves produced. Verify it.

Reference:

F.W. Sears, Mechanics, Wavemotion and Heat, Addision Wesley Publication Co. Inc. USA 1965

*Lissajous' figures are the pattern traced out by a particle which is made to oscillate simu.taneously in two mutually perpendicular directions.

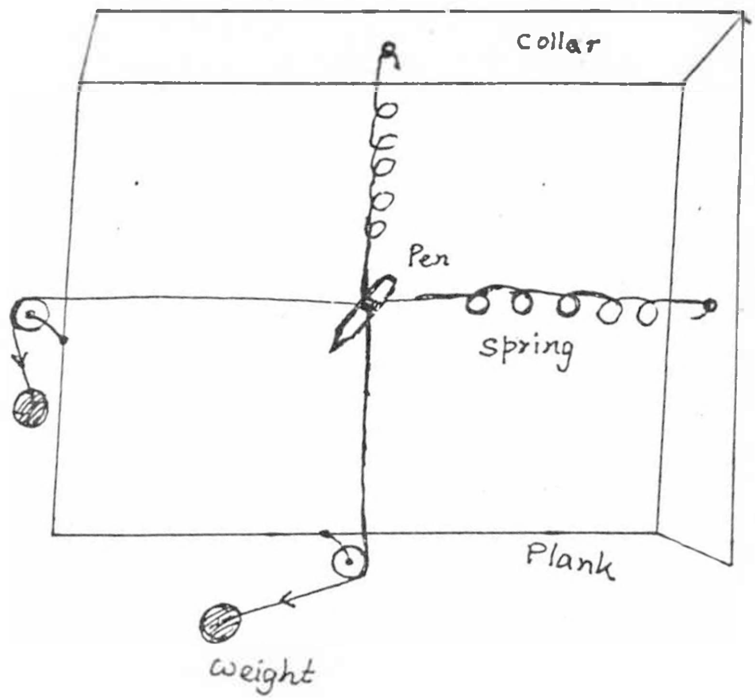


Fig. Mechanical version for Lissajous' figure
Note Periodic pull of weights will also trace the curves.

Supplementary Material for Gurukul (AP) Resource Persons

6 – 11 September 2004

1. To estimate heat of vaporisation

When heat is supplied to a liquid at a constant temperature and pressure so that change of state (from liquid to vapor) takes place, then heat required per unit mass of liquid for such change of state is called heat of vaporization.

How to determine the quantity of heat supplied ?

i) Put on a heater and allow it to warm up for 5 minutes (Why? How to determine the wait period?). Should we expect that it will give out heat at constant rate? (What are the other factors affecting constant supply? List out. For what factors we should have more concern? How to minimize their effects?).

ii) Take identical set of beakers and fill them with 100g, 200g,....of water and note its initial temperature. Put these one by one on the heater and note the rise in temperature in 5 minutes. [You can do this with a single pot maintaining initial conditions of temperature. The quantity of water and time of heating may be determined as per convenience].

iii) Quantity of heat taken by beaker and water in first case.

$(ms + w_1)\ \Delta T_1 = \delta Q.$

Quantity of heat taken by beaker and heater in second case

$(ms + w_2)\ .\ \Delta T_2 = \delta Q$

where δQ is quantity of heat given by heater in 5 minutes, ms is water equivalent of beaker, w_1 and w_2 are quantities of water and ΔT_1 and ΔT_2 are rise in temperatures in two cases respectively. Then according to conservation of energy

$$\frac{\delta Q}{\Delta T_2} - \frac{\delta Q}{\Delta T_1} = w_2 - w_1$$

or $$\delta Q = (w_2 - w_1) \ / \left[\frac{1}{\Delta T_2} - \frac{1}{\Delta T_1} \right]$$

The relation suggests that if we take different sets of observation for a given quantities of water and note their rise in temperatures, then the slope of w vs $\frac{1}{\Delta T}$ curve will give the quantity of heat in given interval of time. [Investigate how estimation of δQ changes with number of sets taken. What are the causes for such a change?].

(iv) Find the time taken by 5g of water in the same beaker to evaporate completely. Estimate quantity of heat required in the vaporization. Hence find latent heat of vaporization.

Verify the constancy by taking different quantities of water. What can be the parameters affecting the measurement? What precautions would you suggest? Can you find latent heat of vaporization for other liquids also?

Discuss.

Make list of materials needed.

2. To estimate latent heat of fusion

When we heat ice *slowly* at 0°C and at atmospheric pressure, it melts into liquid (water). The temperature remains 0°C until all the ice is melted. The heat required per unit mass for change in phase from solid to liquid is called heat of fusion.

[Why should we add heat slowly to the ice? Comment about advantages and disadvantages if we add heat to a given quantity of ice kept in 'some' water at 0°C. What should be the properties of container used here?].

1. Use small flame device, like candle and arrange a fixing of container over it so that no part of flame goes waste. [Should you keep the distance between flame and container constant? How will you protect flame from wind]. Put mesh (wire gauge) or sand bath if needed over the flame.
2. Take copper vessel (calorimeter) add some water to it and find quantity of heat received by it in unit time by method described in experiment 1. [Can the quantity of heat received be manipulated as per requirements? List out different modes identified. It is possible to design a constant temperature bath of desired temperature? Suggest designs to make baths for different temperatures].
3. Take some water at 0°C and add a measured quantity of ice. Put the system on heat bath and note the time required for its complete melting.
4. Estimate latent heat of fusion from series of observations. Do they match with reported values?
5. What are the necessary precautions to be taken in order to improve the result?
6. List out materials needed to conduct this experiment. What can possible improvisations be?

3. Quantity of heat determines extent of cooking of food

For cooking food, we have to supply heat maintaining the temperature of the system above a certain temperature. What is the easily maintainable temperature? (Hint : 100° C) How is its value increased ?

1. Find the rate of heat delivered to a container per unit time for a heater. (It depends from container to container. Why?)
2. Take a measured quantity of water in the container and add appropriate quantity of rice in it. Weigh the system. Put it on heater. As soon as water starts boiling, start stop watch. (Why not from beginning?). Take a few grains of rice and place them on a glass plate. Now after each 5 minute

take out a few grains and arrange them on glass plate in sequence of cooking time spent.

3. Note properties of cooked grains in relation to time spent i.e. heat given.
4. Weigh the container with cooked food. Find the difference between initial weight and final weight. What is this quantity ? (Hint : Quantity of water evaporated). Calculate what quantity of heat is lost in water – vapour transformation. Find total quantity of heat supplied in the duration of experiment.
5. Subtract quantity of heat wasted (in making water vapour. How to reduce such a waste?) from total quantity of heat supplied. What does it represent? Find heat supplied in cooking food and so per unit time. Thus calculate how much of heat was supplied to each of your sample.
6. What are significant results on heat supplied in relation to cooking achieved? Find the places in procedure where we might go wrong in justified estimations.
7. Take up the investigation to find
   i) Optimum temperature to be maintained in proper cooking of a given food item.
   ii) Time required (quantity of heat required by unit mass of certain food item at optimum temperature) for cooking a given food item.
   iii) Role of quantity of water in deciding quantum of heat imparted to food item of unit mass.
8. List out materials needed for different investigations.

4. To estimate calorific value of food items

On burning, food gives out certain quantity of heat per unit mass. This is called calorific value.

For finding calorific value of food items, it is advisable to have it in the form of dry powder. [What are disadvantages if food material is watery e.g. fruits? What is the advantage if material is in powder form?]

1. Take 5g camphor on asbestos sheet and arrange copper calorimeter containing water just above it so that when camphor burns flame will be confined to the base of calorimeter. See that minimum of smoke is produced in the process (Why? What other fuel can be taken?). Note rise in temperature of water. Calculate heat imparted to the calorimeter assembly. Since heat produced is small, should you use other liquids? Comment.
2. Mix 2g of rice powder to 5g camphor. Burn under similar calorimeter and calculate heat imparted by this mixture. Is it same as the previous value? This can even be less. When ? Ensure that full mixture has burnt. If needed, increase quantity of camphor.
3. Find contribution to heat by rice powder and hence calorific value of rice. Compare it with the reported values. In what respect your method is inferior to bomb calorimeter? How will you improve your results? Enlist precautions and improvisations.
4. Suggest methods for different kind of food items. Enlist materials needed for carrying out the experiment. When food material gives out heat, why do you need supplementary material for its complete burning?

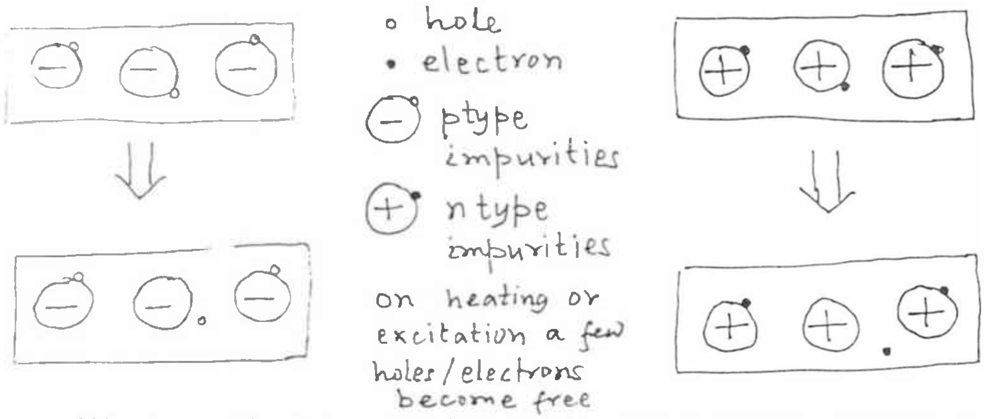
How a semiconductor diode works ?

Semiconductor is a material whose conductivity lies between the conductivity of a good conductor and a bad conductor. The popular semiconductors are Si and Ge. The other promising materials being binary phosphide compounds of Ga, As, In, etc.

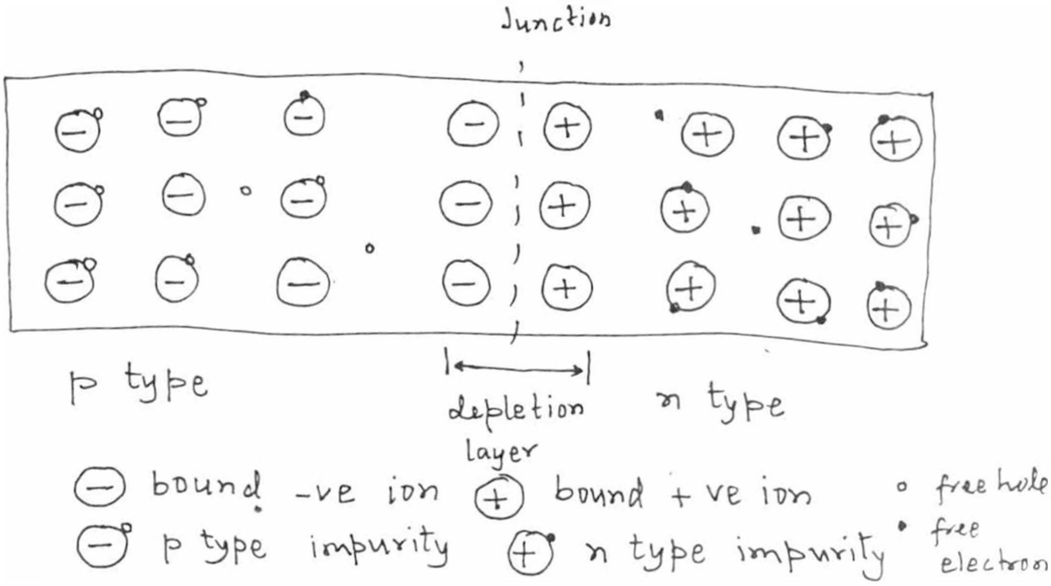
The semiconducting materials exhibit two prominent characteristics which have made them indispensable for modern electronic industry. These are : strong dependence of their conductivity on (i) the temperature and (ii) presence of impurities.

Whenever acceptor type of impurities (having less number of electrons in outermost orbit than that needed for the formation of covalent bonds) are added, the semiconductor is endowed with 'holes' which can move freely within the material as they can be easily detached from their parent atom leaving it as a bound negatively charged species. Such semiconductor is called p-type semiconductor. Another class of semiconductor is n-type which is formed when a donor type of impurity (having excess number of electrons in the outermost orbit than that needed for formation of covalent bond with host material) is added, the semiconductor is endowed with plenty of 'electrons' which can move freely within the semiconductor material as they can be easily detached from their parent atom leaving it as a bound positively charged species.

The p and n type of semiconductors are represented as shown below.



When p and n type materials are brought in intimate contact, the mobile holes move towards negatively charged species while electrons move towards positively charged species making them neutral ions. Movement and ultimately loss of electron leaves n type material positively charged. Similarly, movement of holes leading to their loss leaves p type material negatively charged as shown below.



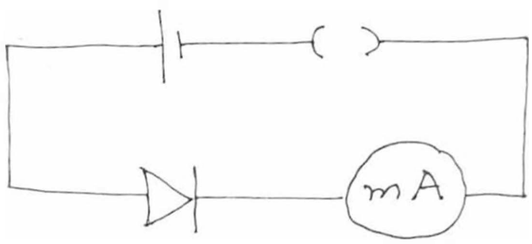
The region so formed is depletion (containing no free charge) region and the junction is called p-n junction.

This region forbids flow of further charge unless external potential is applied which would overcome the potential developed between p and n type of semiconductors due to diffusion of free electrons and holes.

If, however, reverse potential is applied, the mobile carriers diffuse into their respective counterpart regions more vigorously making depletion region thicker and hence forbidding conduction.

Activity A

1. Take a semiconductor diode and connect it to Lechlanche cell.
   Note the current.

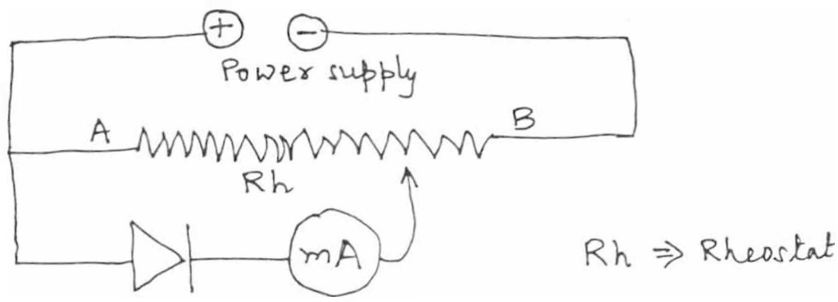


2. Reverse the diode terminals and note the current.
3. Repeat the procedure with other diodes.
4. Repeat the procedure 1-3 with Daniel Cell.
5. Tabulate the result and discuss.

What inferences you will draw ?

Activity B

1. Take a power supply and make connections as shown.



Specifications of Rh for one group will be 10 Ω , for second group 50Ω, for third group ~250Ω, etc.

2. Move the jockey from end A successively by 5 cm and note corresponding current till you reach end B.
3. Tabulate result as under :

Power Supply Specifications...............................

Sl. No.	Distance of jockey from end A	Current passing through circuit
1.	5 cm	
2.	10 cm	
3.	.....	

4. Compare the results with other groups.

Try to answer the questions :

1. What are the reasons the reading of various groups do not match ?
2. What is the role of rheostat ?
3. What happens when diode terminals are interchanged ?
4. In what respects this activity is different from Activity A.
5. What can you infer about power of the cell ?
6. How will you relate current with cells having more resistance ?

Further Investigations

1. For activity A, tabulate response of different diodes and hence try to infer about their resistance to the flow of current.
2. Heat a given diode while in circuit in activity A. Find what happens to current. Try to find relationship between temperature and current.
3. See effect of rheostat/RB in series and in parallel to power supply for Activity B for their values 1000 Ω and above.

(RB ⇒ Resistance box)