GYAN VIGYAN SARITA:शिक्षा

A non-remunerative, non-commercial and non-political initiative to Democratize Education as a Personal Social Responsibility (PSR)

1st Supplement dt 1st Feb'18 of 6th Quarterly e-Bulletin, Second Year of Publication

Special Issue: National Science to Commemorate Discovery of Raman Effect

CONTENTS:

$$\Delta E = \frac{\hbar}{2\pi I}(2J+3)$$

$$E_{elect} + \frac{\hbar^2}{2I}(J+2)(J+2+1)$$

$$E_{elect} + \frac{\hbar^2}{2I}J(J+1)$$

Incident photon

$$E_{photon} = h\upsilon$$

Raman scattered photon

$$\upsilon' = \upsilon - \frac{\hbar}{2\pi I}(2J+3)$$

Devika.M

Aim for the Best, but...

Online Mentoring From Texas

Equipments at Mentoring Center
1. Compatible Desk-/Lap-top
2. WebCam
3. Headset with Microphone
4. Wacom Tablet Pen
AND
Broadband-Internet Connection:
Minimum Bandwidth: 8 Mbps and Monthly Data Capacity: (1xN) GB ; Here, N= No of Hours of Monthly

Conceptual Representation of Interactive Online Mentoring Sessions (IOMS)
An Initiative To Bridge Gap between Passionate Teachers and Desperate Students
A Selfless Endeavour to Democratize Education with a sense of Personal Social Responsibility (PSR)

An Ideal Smart Training Center (If we can afford it for all)

Equipments at Learning Center
1. Compatible Desk-/Lap-top
2. WebCam
3. Speakers
4. USB Microphone
5. Overhead Projector.
6. Wacom Tablet Pen with Wireless Accessory
7. UPS (For Continuous Power Supply to computer, internet modem and L&F)
AND
Broadband-Internet Connection: **Min. 8 Mbps and (1xN) GB monthly data capacity; N= No of Hours of Monthly sessions**

Cloud WebEx (Internet Connected)

WebEx Whiteboard – a Fully Shared Space between Students and Mentor using Wacom Tablet **(Interactive Online Mentoring)**
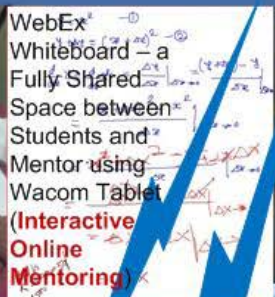
Primitive Mentoring-cum-Learning Centre (Demo)

Important Links
1. Good Internet Connectivity (Preferably-Wired Broadband Connection, or 4 G Mobile)- Exclusive
2. Subject-wise Coordinator for Each Session to Bridge Learning Gaps between Mentor & Students

Mentoring Centre

Learning Centre -1
Learning Centre - 2
Learning Centre - 3
Learning Centre-4
Learning Centre - 5

Special Features
1. Free and Open to all to adopt. Modify, Change, Use or Take-away
2. Welcomes participation, promotion and facilitation on Zero-Fund-Zero-Asset (ZFZA) basis
3. More details on Technological and Operational – please write on http://www.gyanvigyansarita.in/contact/

subhashjoshi2107@gmail.com

Learning Centre With LCD Screen Display at RKM School, Sitanagram, Guntur

We start with what is available in ground; Aim at best Grooming for Competence Building Unprivileged; Welcome better and more economical, but functionally suitable for IOMS, setup to reach Unprivileged Students : Spiritually Democratize Education.

Learning Centre With Projector Display (Widely Practiced)

... start, without loosing time, with whatever is available.

संपादकीय

समुद्र और आकाश का रंग नीला क्यों : चंद्रशेखर वेंकटरमन

महान व्यक्ति वह होता है जिसकी जानने की इच्छा कभी खत्म नहीं होती है। यह वही व्यक्ति होता है जिसके अंदर क्यों, कैसे, कहां, कब, अभी क्यों नहीं, ऐसा क्यों नहीं, ऐसा ही क्यों , अब इसके आगे क्या? जैसे प्रश्नों की झड़ी लगी रहती है। भौतिकी के सितारे चंद्रशेखर वेंकटरमन इसी प्रकार के व्यक्ति थे। उनका जीवन काल ऐसे ही प्रश्नों के उत्तर ढूंढने में बीता। उनका जन्म 7 नवंबर 1888 को तिरूचिरापल्ली (तमिलनाडु-भारत) में हुआ था। रमन के पिता का नाम चंद्रशेखर अय्यर और माता का नाम पार्वती अम्मल था।

वेंकटरमन एक सरल स्वभाव के व्यक्ति रहे। 28 फरवरी 1928 को उनका वह अनुसंधान पूरा हुआ, जिसके लिये उन्हें नोबेल पुरस्कार मिला था। उन्होंने उस अनुसंधान को 'रमन प्रभाव' का नाम दिया था। 1930 में रमन को नोबेल पुरस्कार के लिये चुना गया था। रूसी वैज्ञानिक चार्ल्सन, यूजीन लॉक, रदरफोर्ड, नील्स बोअर, चार्ल्स कैबी, और विल्सन आदि ने रमन का नाम नोबेल पुरस्कार के लिये प्रस्तावित किया था।

रमन एक देशभक्त थे। उन्हें भारत से बहुत प्रेम था। उनके दिमाग में एक प्रश्न सदा घूमता रहता था कि वैज्ञानिक प्रतिभाओं में यूरोप और अमेरिका ही श्रेष्ठ क्यों हैं? भारतीय प्रतिभायें श्रेष्ठ क्यों नहीं हैं? रमन ने देश के नौजवानों को श्रेष्ठ वैज्ञानिक बनाने के लिये प्रेरित किया और उन्हें जागरूक बनाने की दिशा में बहुत काम किया। उन्हीं का प्रभाव था कि विक्रम साराभाई, होमी जहांगीर भाभा, और केआर रामनाथन जैसे युवा वैज्ञानिकों ने पूरे विश्व में अपने नाम के साथ, भारत का नाम रौशन किया।

सन् 1952 में रमन को सभी राजनीतिक दलों ने निर्विरोध उपराष्ट्रपति बनाना चाहा, पर रमन को राजनीति पसंद नहीं थी, इसलिये उन्होंने यह प्रस्ताव नहीं माना। वे आजीवन शोध कार्यों में लगे रहे। रमन के खोज का ही नतीजा है कि मनुष्य अपनी रेटिना का चित्र स्वयं ही देख सकता है। वह यह भी देख सकता है कि उसकी आंखें कैसे काम करती हैं।

प्रकाश के प्रकीर्णन और रमन प्रभाव की खोज के लिये नोबेल पुरस्कार पाने वाले पहले एशियाई और अश्वेत भौतिक वैज्ञानिक सर सीवी रमन आधुनिक भारत के महान वैज्ञानिक माने जाते हैं।

पहली नौकरी रमन की कोलकाता में भारतसरकार के वित्त विभाग में सहायक महालेखाकार की थी। देश की जादी के बाद 1947 में भारत सरकार ने उन्हें *राष्ट्रीय प्रोफेसर* नियुक्त किया था।

1907 में उन्होंने एमएससी की डिग्री ली। वह 1934 में वेंगलूरू स्थित भारतीय विज्ञान संस्थान के निदेशक बने। 1948 में सेवानिवृत्त होने के बाद उन्होंने बेंगलूर में रमन रिसर्च इंस्टीटयूट की स्थापना की।

28 फरवरी का दिन भारतवर्ष में *राष्ट्रीय विज्ञान दिवस* के रूप में मनाया जाता है। रमन को 1924 में लंदन की रायल सोसायटी का सदस्य बनाया गया, 1929 में नाइटहुड की उपाधि से नवाजा गया, 1930 में नोबेलपुरस्कार मिला, 1954 में भारतरत्न मिला, और 1957 में लेनिन पुरस्कार से सम्मानित किया गया।

पूर्व राष्ट्रपति एपीजे कलाम जहां वीणा वादन कर अपने तनावों से मुक्ति पाते थे, प्रख्यात वैज्ञानिक अल्बर्ट आइंसटीन वायलिन बजा कर ध्यानमग्न होते थे, वहीं रमन भारतीय संगीत वाद्ययंत्रों के एकास्टिक पर कार्य किये। तबला और मृदंगम के संनादी यानि हार्मोनिक प्रकृति का पता किये।

रमन के *प्रकाश प्रकीर्णन* का सिद्धांत है कि *जब प्रकाश किसी पारदर्शी चीज से गुजरता है तब डिफलेक्टेड लाइट यानि सीधे रास्ते से हटे हुये प्रकाश की वेवलेंथ कुछ बदल जाती है।* यही रमन इफेक्ट कहा जाता है।

सर सीवी रमन के कुछ नामी छात्र हुये हैं-

जीएन रामचंद्रनः यह पेप्टाइड संरचना को समझने के लिये रामचंद्रन प्लांट के लिये विख्यात हैं।

विक्रम साराभाईः यह भारत के अंतरिक्ष कार्यक्रम के जनक माने जाते हैं।

शिवरामकृष्णन पंचरत्नमः यह क्रिस्टल से गुजरने वाले धुवीकृत बीमों के लिये पंचरत्नम फेज की खोज के लिये प्रसिद्ध हैं।

रमन को जब नोबेल पुरस्कार देने की घोषणा हुयी तो उस समय उन्हें अपने देश के बारे में कैसी अनुभूति हुयी, यह उनकी निम्न पंक्तियों से समझा जा सकता है-

"जिस पुरस्कार को प्राप्त करने के लिये मैंने सात साल तक मेहनत करते हुये इंतजार किया, जब नोबेल पुरस्कार की घोषणा हुयी तो मैंने इसे अपना और अपने सहयोगी की उपलब्धि माना, लेकिन जब मैंने उस खचाखच हाल में इर्दगिर्द पश्चिमी चेहरों का समुद्र देखा जहां मैं अकेला एक भारतीय अपनी पगड़ी और बंद गले के कोट में था, तब मुझे लगा कि मैं वास्तव में अपने लोगों और अपने देश का प्रतिनिधित्व कर रहा हूं। जब किंग गुस्ताव ने मुझे पुरस्कार दिया तो मैंने अपने आपको वास्तव में विनम्र महसूस किया। यह मेरे लिये भाव प्रवण पल था लेकिन मैं अपने ऊपर नियंत्रण रखने में सफल रहा। जब मैं पीछे घूमा और ऊपर ब्रिटिश यूनियन जैक देखा जिसके नीचे मैं बैठा हुआ था तब मैंने महसूस किया कि मेरे गरीब देश, भारत का अपना ध्वज भी नहीं है"

रमन का दिमाग हमेशा नयी नयी खोज में ही लगा रहता था। 1921 में आक्सफोर्ड, इंगलैंड में होने वाली यूनिवर्सिटीज कांग्रेस के लिये रमन को निमंत्रण मिला। वह समुद्र के रास्ते जा रहे थे। समुद्री यात्रा में दो ही चीजें दीखती हैं - एक नीचे समुद्र और दूसरा ऊपर दीखने वाला नीला आकाश। रमन ने देखा कि भूमध्य सागर का जल नीला है। इस नीलेपन ने रमन को बहुत आकर्षित किया। वह सोचने लगे कि आकाश और समुद्र का रंग एक जैसा कैसे हो सकता है, और वह भी नीला? रमन को मालूम था कि लार्ड रेले ने आकाश के नीलेपन का कारण हवा में पाये जाने वाले नाइट्रोजन और आक्सीजन के अणुओं द्वारा सूर्य के प्रकाश की किरणों को छितराना माना है। लार्ड रेले ने यह कहा था कि सागर का नीलापन मात्र आकाश का प्रतिबिंब है, लेकिन भूमध्यसागर के नीलेपन को देखकर लार्ड रेले के स्पष्टीकरण से रमन को संतोष नहीं हुआ। वह इसकी खोज में तत्काल जुट गये और आगे चलकर पता किया कि समुद्र का नीलापन उसके भीतर से है।

कलकत्ता लौटने पर उन्होंने शोध कार्य जारी रखा और इस नतीजे पर पहुंचे कि समुद्र के नीलेपन का कारण सूर्य की रोशनी पड़ने पर समुद्री पानी के अणुओं द्वारा नीले प्रकाश का छितराना है।

समुद्र के जल में जब सूर्य के प्रकाश की सफेद किरण प्रवेश करती है तो उसमें सभी इंद्रधनुषीय रंग रहते हैं - (VIBGYOR- Violet, Indigo, Blue, Green, Yellow, Orange, Red) यानि बैंगनी, जामुनी, नीला, हरा, पीला, नारंगी, लाल। इनमें से समुद्र लाल, पीला, और हरा रंग को अवशोषित कर लेता है क्योंकि इनकी वेवलेंथ लंबी होती है और नीला रंग को परावर्तित कर देता है क्योंकि इसकी वेवलेंथ छोटी होती है। कुछ नीला प्रकाश समुद्र में मौजूद पानी के अणुओं में मिल जाता है, और यह बिखरा नीला प्रकाश समुद्र से बाहर आता है, और हमें लगता है कि समुद्र का रंग नीला है। यह घटना तब घटती है जब माध्यम के अणु प्रकाश ऊर्जा के कणों को छितरा या फैला देते हैं। यह उसी तरह होता है जैसे कैरम बोर्ड पर स्ट्राइकर गोटियों को छितरा देता है।

आकाश के नीला होने की वजह भी यही है कि जब सूर्य का प्रकाश पृथ्वी के वातावरण में प्रवेश करता है तो वातावरण के कणों से टकराकर प्रत्येक दिशा में बिखर जाता है। प्रकाश के रंगों में नीले रंग के छितरने की क्षमता सबसे अधिक होती है इसलिये आकाश में आने वाले रंगों में नीले रंग की ही मात्रा अधिक होती है। रमन प्रभाव के अनुसार प्रकाश की प्रकृति और स्वभाव में परिवर्तन तब होता है जब वह किसी पारदर्शी माध्यम से गुजरता है। यह माध्यम ठोस, द्रव अथवा गैस कुछ भी हो सकता है।

वेंकटरमन के पुत्र वेंकटरमन राधाकृष्णन अपने पिता की भांति प्रतिभा संपन्न थे। उन्होंने खगोल विज्ञान और खगोल भौतिकी के क्षेत्र में बहुत योगदान दिया। वह रायल स्वीडिस एकेडमी आफ साइंसेज के सदस्य रहे।

भारतीय भौतिकी के चमकते सितारे सर चंद्रशेखर वेंकटरमन को ज्ञानविज्ञानसरिता परिवार शत शत नमन करता है और ईश्वर से प्रार्थना करता है कि हम सबके अंदर, हमारे विद्यार्थियों के अंदर और वैज्ञानिक शोध करने वाले हर व्यक्ति के अंदर यह जज्बा जगे कि वह भी कुछ ऐसा करे जिससे भारत।

—00—

An Appeal: Gyan Vigyan Sarita

A non-organizational initiative of a small set of Co-passionate Persons

Philosophy: Personal Social Responsibility (PSR)

Objective: Groom competence to Compete among unprivileged children from 9th-12th in Maths and Physics, leading to IIT-JEE.

Financial Model: *Zero-&-Fund-Zero-Asset (ZFZA).* It calls for promoters and facilitators to provide infrastructure for use to the extent they feel it is neither abused nor there is a breach of trust. And, reimbursement of operational expenses to the participators

Operation:

a. **Mode:** Online since July'16, using Google Hangouts, a free we-conferencing S/w, with connectivity upto 15 nodes.
b. **Participation:** Voluntary and Non-remunerative, Non-Commercial and Non-Political

Involvement:

a. **As Promoter** –
   i. Initiate a Learning Center,
   ii. Sponsor a Mentor who is willing to join on certain terms,
   iii. sponsor cost of operation and up-gradation of infrastructure to voluntary mentors,
   iv. Sponsor Website.
b. **As Facilitator** –
   i. Provide space and infrastructure for **Online Mentoring Sessions (OMS)**, which is generally available, with a marginal add-on,
   ii. Garner support of elite persons to act as coordinators at a Learning Centre.
c. **As Participator** –
   i. As a Mentor,
   ii. As Coordinator,
   iii. As Editor and or contributor of thought provoking articles for e-Bulletin, which are relevant to the initiative, and make it more purposeful and reachable to the target audience.
   iv. As author of Chapters for Mentors' Manual, being uploaded as a Free Web Resource,
   v. Anything else that you feel can add value to the mission and make it more purposeful.

vi. *Anything else that you consider to make this initiative to become more effective.*

Background: *The initiative had its offing in May'12, when its coordinator, a power engineer by profession, soonafter submission of Ph.D. Thesis in April'12, at IIT Roorkee, at the age of 61 years, decided to mentor unprivileged students.*

SARTHAK PRAYASH, a Ghaziabad based NGO, warmly accepted the proposition and created a facility to mentor students from 8+ to prepare in mathematics and physics and prepare them for engineering entrance tests. They warmly reciprocated and created a class room.

*Experience in this selfless social work were used to navigate across without losing focus. He was associated with SUBODH FOUNDATION from Sept'15 to Sept'16 during which he published a monthly e-Bulletin **SUBODH-पत्रिका** to create visibility across persons who could make a difference.*

*In Sept'16, post transition, the mission has been continued as a non-organizational entity **Gyan Vigyan Sarita**, with a set of Four persons, including retired **Prof. SB Dhar**, Alumnus-IIT Kanpur, a middle aged **Shri Shailendra Parolkar**, Alumnus-IIT Kharagpur, settled at Texas, US and **Smt. Kumud Bala**, Retired Principal, Govt. School Haryana. Earlier, they were complementing the OMS. While, the initiative survived transition, a website:* http://gyanvigyansarita.in *has been launched. It contains under its **Menu: Publication>e-Bulletins,** and>**Mentors' Manual.** You may like to read them.*

Actions Requested: May please like to ponder upon this initiative. **Queries**, *if any, are heartily welcome*. We would welcome your collective complementing in any of the areas listed at **Involvement**, above, to make the mission more purposeful and reachable to target children.

Coordinator's Views

IOMS: Opportunities and Challenges

Online education is a way to connect students with the teachers, who are otherwise inaccessible to each other. Inaccessibility can be due to multiple constraints viz, inconvenient time slots, geographical positioning, health, economic, cultural, sociological or any other. Online education using ICT is a big opportunity. Increase in accessibility and affordability of ICT has created a rapid influx of multiple players. At this juncture it is essential to introspect challenges associated with the opportunity. Education is not a commodity, where one always has liberty to choose an alternative; this liberty is definitely not available to marginalized students. In this context every player needs to deeply consider the responsibility associated with the opportunity. Any anguish among students arising out of improper education might surface as negativity among them. This article stretches out to challenges and opportunities to analyze prevalent models of Online Education and evaluate relevance of Interactive Online Mentoring Sessions (IOMS) to reach to masses, in a scenario where masses cannot reach to education.

Our President Shri Ram Nath Kovind in his address on the eve of Republic Day'18 advised nation - "***Our schooling system has to encourage our children to think and tinker, not just to memorize and reproduce***". This advice after 70 years of independence in a country celebrating its 69th Republic Day and aspiring to become the largest economy in the world needs deep meditation by every Indian especially elite.

Swami Vivekananda has said - "***if we have to rise again, which we have to…. , education must be spread to masses***". There are numerous reports and critiques on education in India that highlight a wide gap in actual and expected learning, paucity teachers, and more so, with passion, global competition and masses affected by commercialization in education. This is where society and nation as a whole has to act upon to alleviate imbalance of competence, if it has to achieve a coordinated growth. Increase in longevity together with better financial and physical health among elite cross-section of society is a great opportunity to bridge the gaps in education. Further, growing concept of work-from-home and open-working-hours reinforces the opportunities for youngsters to be able to contribute in educational initiatives. These youngsters have an advantage of growth in an era of ICT. Further, indulgence of youngsters in the initiative would be extremely helpful to the passionate senior citizen to adapt the ICT. In addition, it will create a harmony in the society and place of pride for elders for their contribution to the society and positivity in their life through an invaluable service in education.

Dr Sarvapalli Radhakrishnan, former President had said- "***Technology won't replace the teachers…, but teachers who use technology will probably replace teachers who don't***". The needs of passionate teachers and demographic diversity have brought us at a brink where obsolescence of teachers who are averse to ICT is not remote and *it is a big* **Opportunity** *to stand up to carve a forward path*.

Nearly for Six years hectic efforts were made to offers free services at every level and every segment of socio-economic matrix. It is only in August'17 this initiative, Interactive Online Mentoring Sessions (IOMS) of Gyan Vigyan Sarita, was connected to Vivekananda Vidya Vihar, Ramkrishna Mission High School, Sithanagram, District Guntur, on the banks of Krishna River across Vijayawada. Until then, it remained unheard and unattended proposition. It is only at this school it was realized that there prevails a spirit that "***if poor can't reach to education let education reach the poor***", as was advocated by Swami Vivekananda. This initiative was welcomed but supported by Monks of Ramakrishna Order in letter and spirit. Teachers did not see the remote mentor as their competitor but, participated in IOMS to complement the initiative by bridging the learning gaps. Students perpetuated the mentoring efforts with a discipline and punctuality to consolidate their day-to-day learning. It did not stop at that, rather they reached out to their remote mentor for guidance and value addition using e-mail. Students minimized flux of mails to mentor by organizing themselves in group. Each of the group is identified with name of a great scientist, thus setting a high ideal. Intra- and inter-group interaction has evolved a group dynamics of collective growth, an essential attribute of a progressive society and prospective responsible citizens.

It does not stop at that; their dedicated volunteer, reached out to other learning centres within and outside the Ramakrishna Order. They selflessly open their model for others to know and witness their experience of IOMS and consider to take-away or associate in it with PSR to the extent they can. It was two pronged benefits, firstly share their experience with IOMS for enrichment with better ideas, and stretch out share know-how for technological upgradation for enhancing its effectiveness.

This IOMS model has received a wide acceptance other school of Ramakrishna order viz. Vishakhapattanam, Gwalior, Coimbatore, Ramakrishna Sewa Samiti, Kakinada, and central schools at ordinance factories at Dehuroad-Pune, Ishapore-Kolkata and Bhusawal. In addition enthusiasm among senior citizens notably Shri Appa Rao sir, from Guntur to mentor Physics, Madam Saraswathi and Dr Hemavathi from Rajahmindri to mentor English, Prof. S.B. Dhar to mentor Mathematics from Noida, a middle aged NRI Shri Shailendra Parolkar, in Physics has compounded strength. Among youngsters Dr. Madhuri Arya to teach Mathematics from Saharanpur, and Shri Sidharth Sehgal to mentor from Noida are adding in to the premise of IOMS. This involvement of individuals is setting a forward path for more co-passionate persons to funnel in enhance the synergy.

Openness in Interactive Online Teaching initiative at VivekDisha, Vivekananda University, Belur Math, Ramkrishna Ashram, to share their expertise of more than a decade and opening up to this initiative for a proactive involvement in broadening the scope and reach to unprivileged children has strengthened belief that- **a)** there are many working in the direction but unaware of each other, **b)** each of such initiative is selflessly aimed at social reform through education, but has its own nuances based on context, expertise and experience during growth, **c)** each model can function by maintaining its sovereignty, yet collectively complement each other, **d)** there is a need for each model to coexist to cater to diversity of demography and evolve a strong federal structure for a coordinated growth.

There are many institutions imparting on-line education spanning over a wide spectrum, right from academic level in schools, to universities, corporate programs and commercialized education. Each has its own thrust area and financial model. Operationally, the process of imparting education has been classified into Four categories:

a) Online Education: It involves use of ICT with pre-prepared slides*, videos* and their illustrations using pointers and whiteboard writing wherever considered to be must. In this, interaction with students is encouraged through oral questioning. It has advantage of keeping up speed of teaching and matching the expectations or time constraints of the learners. Generally, it fits well where teaching is constrained within limited hours of school curriculum. Quality of slides and videos is growing phenomenally to make them impressive and comprehensible to any students. Yet, there are students whose linguistic competence is far below colloquial language of mentors. This requires moderation of illustrations and language more than often. This model is more apt for students of profile moderate or above, both academically and having a good learning support systems, either at school or at home.

b) IOMS: In this model also uses ICT to create a virtual classroom where mentor builds the subject matter right from scratch using Whiteboard. It also involves students in evolving solution using a surface writing device. Use of One such device in wireless mode gives manoeuvrability for students to collaborate the whiteboard space, right from their seat. This makes the learning process fully interactive. Group dynamics practiced by students has elevated their level of confidence and synergy. This model operates outside school hours with a clear message during motivational session that school syllabus is not a boundary. Students are motivated to think out-of-box and grasp to the limits of their imagination with conceptual reasoning.

c) Digital Classrooms: In this concept video containing slides, animations or real experiments are used in a regulated mode. Teaching material covering pre-schooling to higher classes are being marketed for standalone use by student at leisure or supported with teacher. Such apps are available both in intranet and internet environment. It helps to make teaching less dependent on teacher is suitable in dire paucity of teachers. Side-effect of this model is robotization of education. Only remedy to safeguard of this side-effect is to maintain a close interaction between students and teachers, and limits its use to supplement constraints of local teaching capacity. Porting of videos on intranet makes it independent of internet, the weakest link in (a and b) above.

d) Conventional Education: It is purely in Chalk-N-Talk mode and is best as long as passionate teachers are available both number to span over geographical diversity. This premise in prevalent socio-economic scenario is good imagination, but far from reality. All the above models are remedies to

conventional education, in absence of passionate teachers both in number and quality.

Challenges in IOMS: Biggest challenge is availability of **broadband internet connectivity**. IOMS becomes frustrating in absence stable and at broadband internet connection. Ramakrishna Mission School at Narayanpur, Chhattisgarh is striving hard to impart quality education to children coming from deep tribal villages. It is constrained to embrace IOMS. Democratization of education in Digital India requires internet access. Next challenge in IOMS is **involvement of administration and motivation of teachers** rather than students. Failure of IOMS at Jhabua, a tribal district in MP, despite a brilliant start, is a glaring example. Mentor being at remote point, is open to fiddle with the system, in multiple ways, right from equipment to discipline. This requires motivated teachers to act as coordinators not only for creating a successful operation of learning centre but, to create a potential mentor to perpetuate IOMS to connect students down the line. Competence of students is not a pre-requisite in IOMS. It believes in opening an opportunity for all, through motivational sessions for an out-of-the-box learning, outside the school curriculum. Drop out of students who are not prepared to align with IOMS methodology should not be considered as a parameter of success of the IOMS. Relative change in competence of students who carry through it is important. **Yardstick of numbers and absolute competence of the students** targeted in IOMS is a cruelty towards the philosophy behind the initiative. Target students of IOMS are victim of **socio-economic-cultural adversities**. Therefore, need of motivating parents should not be ruled out without much of expectations. It is experienced that NGOs and Corporate world are in close collaboration to extract statutory provisions and creating attractive statistics. But, approaches to them for collectively complementing this non-organizational, non-remunerative, non-commercial and non-political initiative meted closed doors. Such a non-transparent reciprocation is intriguing in respect of **intent and purpose**. Experience with governmental setup is yet to become encouraging. No initiative can run without funds and IOMS is no exception to it. In view of this a new financial model has been evolved and named Zero-Fund-&-Zero-Asset (ZFZA). It retains ownership of the financer, promoter or facilitator of the infrastructural support extended for operation and maintenance of IOMS.

Any organization which has its philanthropic operations can sponsor IOMS. In turn it can derive backup support from donations and offerings with transparent accountability. At IOMS we owe to return respectfully the infrastructural support in the event of breach of trust or ability to perform on either side. If it is viewed philosophically it might be found close to निष्काम कर्म योग. **Making IOMS, an acceptable proposition and just not mentoring is a big challenge in this commercial scenario.**

Operationally challenges arise due to **many diversities among students.** Some of the diversities are related to background, language of education, language of family of target students. **Indispensability of local coordinator** was responsible for failure of IOMS at Jhabua, vis-a-vis success if the model at RKM School, Sithanagram is attributed to proactive involvement of coordinator, teachers and administration. **Efforts to frame IOMS within school curriculum** is another big retardant. Success requires a proactive and positive mindset of school administration. **Pseudo competition and parallel schooling** has created a rat-ace for shortcuts through distant-learning, and escape from need of self-carving for excellence. Growing accessibility of ICT is infusing an attitude of learning at convenience. This proposition is good for a person constrained to earn-and-learn, wherein joining regular and formal schooling is unfeasible. This scenario of alternative means of learning in **open-schooling is being made lucratively marketed** to students who candidly deserving formal education.

Conclusion: IOMS is a big opportunity for senior citizens and persons in corporate world. All that it needs is awakening of conscience to pro-act with PSR; it would automatically create a way forward. This requires clarity of thoughts, sincerity of purpose, and a vision of social reform through education. It is bound to create a legacy of growth with coexistence, peace and harmony. Our beloved descendents are bound to feel pride in carrying such a legacy. All players of IOMS, in whatever name or frame when take steps forward to collectively complement, it would exponentially enhance synergy and create an enhanced opportunity for all. It is pertinent to emphasise that quality education is a non-perishable demand, it will keeps growing as a society progresses.

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Blending Spirituality-Culture-Technology Through Education
At
Ramkrishna Mission High School, Sithanagram, Guntur, AP

1ˢᵗ Mass Learning Centre of Interactive Online Mentoring Centre (IOMS)

LIFE SKILLS THROUGH EDUCATION

T.Saraswathi & Dr.T.Hemavathi

Swami Vivekananda pointed out that the defect of the present-day education is that it has no definite goal to pursue. A sculptor has a clear idea about what he wants to shape out of the marble block; similarly, a painter knows what he is going to paint, but a student does not know what he wants to do . All that he can say is , that he wants a good job or a Government job. Even here he is not sure as to how to go about to get that job.

There is no point in blaming the colonial system of education.We, the products of that system have been able to realise the potential and benefits of education. It is hence essential to understand Mahatma Gandhi, who once said that education not only moulds the new generation, but reflects a society's fundamental assumptions about itself and the individuals which compose it.

Creating a few more schools or allowing hundreds of colleges and private universities to mushroom is not going to solve the crisis of education in India. We are at the crossroad in a country where people are spending their parent's life savings and borrowed money on education – and even then not getting standard education, and struggling to find employment of their choice .Millions of students are victim of an unrealistic, pointless, mindless rat race.

How can this situation be rectified? : Catch them young. Change the methodology of teaching. Children are like tender saplings. Expose them to Nature and give them practical, creative, innovative real life learning. Leave them free to learn at their own pace. Ensure that the environment is friendly and encourage the principle of CARING and SHARING.

At the secondary level, guide them in art and craft, theatre, reading, athletics, gardening, experimenting and exploring on their own. Encouragement not marks and grades should be the order of the day. This is the crucial stage that brings out the inherent talent of the child.The mind numbing competition and rote learning not only crush the creativity and originality of the students every year, it also drives brilliant students to commit suicide

Education doesn't only refer to formal education, but all ways of increasing personal knowledge. It's important to broaden one's horizon and learn in different, non-conventional ways. In this system, the teacher invokes the spirit of inquiry in the pupil who is supposed to find out things for himself under the bias-free guidance of the teacher.

.Our national poet, great philosopher and follower of naturalistic approach of education wrote that, the highest education is that which does not merely give us information but makes our life in harmony with all existence."

The goal of our new education system should be to create entrepreneurs, innovators, artists, scientists, thinkers and writers who can establish the foundation of a knowledgebased economy rather than the low-quality service provider nation that we are turning into. This requires the involvement of one and all from the highest to the lowest level. It is high time to encourage a breed of superstar teachers, not those who wear a mantle and work for a salary. We need leaders, innovators and entrepreneurs from all fields in teaching positions.

In the field of higher education, there must be meritocracy. Our education system today encourages mediocracy – in students, in teachers,in every sphere throughout the system. It is easy to survive as a mediocre student. Reservations and caste based scholarships in higher education is the bane of our society. Many parents are sacrificing their entire fortune to enable an ill-equipped child to go in for unattainable higher education.

A change can be done through technology. The main obstacle is not technology or implementation. The problem is one of mind set. We have reservation in education today because education is not available universally. Education has to be rationed. If we want to emerge as a country built on a knowledge economy, driven by highly educated people – we need to make good education so universally available that reservation will lose its meaning.

There is no reservation in online education – because it scales. Today top universities worldwide are taking various courses online. Anyone can easily attend a live class taught by top professors of any University online no matter to which country theybelong . This makes it easy for the genuine learner . The growth of the country is dependent on

all kinds of jobs, technical, nontechnical, scientific or humanitarian. This is the future, this is the easy way to make the country strong and disciplined.

Authors are experienced teachers of English with more than four decades of experience in teaching. They have stepped up their teaching with Chalk-N-Talk to Online Classes for Soft Skills and Communicative English.

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The Opportunities & Challenges of Online Interactions

Siddharth Sehgal

The advent of technology has radically changed the way we interact, the plethora of options like email, WhatsApp, video conferencing has given new dimensions to way we interact but though nothing compares to a one to one interaction the technology still bridge that gap that can be thousands of miles apart.

Let's examine some of the day to day medium of interactions that are used in offices and workplace. Emails are indispensable to the way we do business, you can do business over it, hire and fire staff, share pictures of an office outing to last minute details that needs to be conveyed someone sitting in United States. Though email is a very strong communication mode it's as good as what you write in there. People often say things they would otherwise avoid in a face to face interaction which can jeopardize a personal or professional rapport. For those who are not good with grammar, things can get much trickier if one cannot understand what you intend to say. Emails can get lost just like regular mails in a pile or can simply be ignored. While it serves the purpose it still cannot replace a personal touch.

Video conferencing or chat through software's like skype, WebEx are much better in bringing people closer if separated by a distance. Education is one such field that has been positively impacted by this application. Teachers cannot go everywhere but technology can. Digitalization has made possible world class education to reach rural parts of India. In business, team leads can design a prototype of a shoe with a counterpart in New York. Strategies can be built by not only coming together in a virtual room but data can be shared in real time to supplement your argument. PowerPoint, spreadsheets, diagrams can be readily shared to enhance the interaction.

Challenges with these online resources is that they are not one to one interactions, as simple as that, I have personal experience that the amount of work one that can get done through emails is twice or thrice longer as compared to a personal interaction.

We are reaching a point that a handshake would be a thing of the past, the way things are developing, 3D communication will not be a thing of a distant future.

Author is editor of an Indian Periodical, an online weekly, and works in the technology sector. He often writes on social, political and cultural issues. He is passionate about mentoring unprivileged children Online taking out time from his profession.

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Poem: GYAN VIGYAN SARITA

Chicha Viswesvara Rao

It takes courage to venture
Where none dares to enter
Besides caring the family
To burden the downtrodden with responsibility!

Starting the Gyan Vigyan Sarita
A small group created this mantra!
Catalysing learning with digital delight
Targeting remote schools is his might.

Exhibiting personal social responsibility
They spares no effort to enhance children's ability.
Money is not his criteria for education
It's his endeavour to free the future generations from subjugation.

To help children learn the concepts
With masterly approach- gain academic receipts.
Mathematics and Science are the subjects taught
As most children- into this "black hole" are caught!

Exhibiting his true patriotism
They expand their altruism
With sincere effort and clean mind
Only in Bharat such people we find!

Mera Bharat Mahan - **Jai Bharat!**

This poem has been written in appreciation of a small group of compassionate persons whose brave effort to launch a digital learning platform for unprivileged children across the country. Such an effort requires a large heart and courage to fight against the draconian clutches of western imports of education models to our country. The Indian mind is very different from that of the Western people. We are deep rooted in culture, tradition and ethos. Our GOD- fearing nature keeps us grounded and gives us the strength of unity in diversity. This composition is an imprint of interaction on 3oth Jan'18 at RKM School, soonafter the Lunar eclipse that exhibited the celestial "Holi" of the MOON from turning blue to red and then retaining its milky colour.

Author is a trained graduate in Science from Ranchi University. Born and bought up in Jamshedpur. He worked in major cities of the country and is currently settled in Visakhapatnam with his family. He has over forty years of teaching experience in Mathematics and Physics upto +2 level, including coaching for Engineering and Medical entrance examinations. He has a vast exposure to computer software, business, industry, research and teaching in his entire working career. Currently, he is tutoring students in Mathematics and Science from his residence and sparing his time for teaching at the Ramkrishna Mission High School, Visakhapatnam. Writing poems in English and Hindi is his favourite hobby. **His motto in life is: LOVE ALL SERVE ALL.**   E-mail: cvrao21@gmail.com

SOLAR APPLIANCES : Way To Sustainable Living

Aarti Sharma

With an average of 250–300 clear sunny days and 2300–3200 hours of sun shine per year, India is blessed with abundance of solar power .Given an annual radiation range 1200–2300kWh per square meter , it is estimated that the solar radiation incident over India is adequately high varying from to 4–7 kWh per square meter per day. India's electricity needs can be met on a total land area of 3000 km2 which is equal to 0.1% of total land in the country .

Its not that the awareness about potential of solar energy has arisen only recently . In fact , it dates back to the vedic era . Ancient Indians were scientifically very well advanced and were aware about benefits of solar energy . The Rig veda which enlighten not only on spirituality but also on science mention in verse 3.2.3 about the multiple technologies developed from solar energy for long term benefits.

 Solar energy prospects at a glance: It is estimated that the total solar energy absorbed by earth's atmosphere oceans and land masses is approximately 38,50,000 (EJ) Exajoules per year. Interestingly , the amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all the earth's non-renewable resources such as coal, oil, natural gas and uranium.

Soon, India is all set to become the world's third-biggest solar market after China and the US, and the nation's mission is to produce 40 per cent of its power from non-fossil fuels by 2030

Significance of Solar energy powered technology appliances: Solar energy appliances have the potential to meet many of the energy challenges confronting the contemporary world. Due to this ,there is a great need to promote the usage of such appliances which are based on a vital source of renewable energy- Sun . Some of important appliances that must be   used by an energy conscious environmental friendly home are stated below .

Solar Cooker: Solar cooking is a method of preparing food that uses the free energy from the sun as the fuel source . Solar cooking is becoming more and more popular around the globe. A solar cooker needs an outdoor spot that is sunny for several hours   with minimal inflow of winds . A transparent heat trap fitted in the   solar cooker lets   in the solar energy and retains it in the box . The heat trapping potential is further increased if the   surface is shiny as it reflects extra sunlight into the cooking pot. Food cooks best in dark, shallow, thin metal pots with dark tight fitting lids .

Solar Water Heater: Water heating accounts for a major portion of a typical home's energy use. Most of the Indian homes heat water using thermal energy generated from burning coal   thereby releasing many tons of carbon going into the atmosphere. In addition, particulates and other byproducts of burning coal cause air pollution and adverse impact on health . Switching to solar hot water is a great way to reduce carbon and other greenhouse emissions   apart from reducing air pollution and protect our environment.
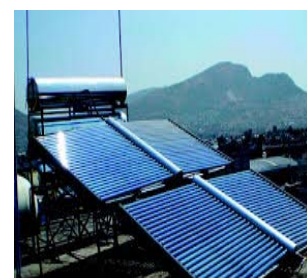
Solar Water Pump: This form of water pumping is a breakthrough pioneering technology for irrigation needs of the farming sector that is gaining importance all over the world. A solar water pump is a system that collects energy from the sun with the help of inbuilt solar panels .The solar energy thus stored is used to power the solar water pump motor, which then powers a surface or bore pump. Usually, the water is pumped from a nearby stream or from beneath the ground where, ultimately, it is stored in a storage tank.

Solar Charger: Solar charger is a versatile device that assists in gathering energy out of sunlight and storing this energy for later use for different

purposes such as powering electronic devices, lighting up rooms or just keep it as backup energy for emergencies. Energy is optimally tapped when there is clear sky with bright sunlight, but solar panels are also capable of charging under cloudy weather or when there is lots of shade .

Raw Uses of Solar Energy: Urban living styles all around the world have become heavily dependent on electronic appliances so mush so that we have forgotten the presence of natural energy from sun which can reduce our dependence on these gadgets without a single penny . Urban homes' reliance on electronic washing machines is a case in point . Having washed the clothes in the machines , many users can avoid the use of drier as there is abundance of sun heat to dry the clothes . Besides , solar energy is a natural way to kill the germs present in the clothes. Drying the clothes in sun is most simple and cost effective way to reduce thermal electricity consumption and in turn reduce carbon foot prints .

Conclusion: The above mentioned solar powered appliances are just an illustrative list of consumer goods that are an effective replacement for the conventional fuel based appliances . Many breakthrough technological innovations based on solar power are already underway which would be a key milestone in sustainable living which is the key for survival of the humanity as Solar power is the safest alternative to coal and gas based fossil fuels and can help to minimize land , water , air and sound pollution besides combating climate change . Its just that with a little awareness , inclination and initiative that we can contribute towards saving planet earth by adopting clean and green solar powered technologies .

IसौरIIऊर्जा - अक्षय ऊर्जाII

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हमारापंचवर्षीयप्रवास

| Start: June-2012 | April-2015 | June-2016…….. |

पारम्परिक शैक्षणिक मार्दर्शन से प्रारम्भ कर आज हम तकनीकी-विकास के सहारे मूलभूत प्रासंगिकता को आगे बढ़ने में संलग्न हैं…

यह प्रयास अपने सामाजिक कर्त्तव्य के प्रति सहजविनीत आग्रह है; कृपया इस पर विचार करें.

OUR MENTORING PHILOSOPHY: Mentoring is not teaching, neither tuition nor coaching. It is an activity driven by passion, and commerce has no place in it. In this effort is to caution students that -

- This place is not where they will be taught how to score marks and get higher ranks, but to conceptualize and visualize subject matter in their real life so that it becomes intuitive.

- This place is not to aim at solutions but inculcate competence to analyze a problem and evolve solution.

- This place does not extend selective and personalized attention, rather an opportunity to become a part of which is focused on learning and problem solving ability collectively.

- This place provides an opportunity to find students above and below one's own level of learning. Thus students develop not in isolation but learn from better ones and associate in problem solving to those who need help. This group dynamics while create a team spirit, an essential attribute of personality, while one learns more by teaching others.

- This place has strategically chosen Online Mentoring, so that those who are unprivileged can gather at one point and those who can facilitate learning of such students by creating, necessary IT setup. Aseperate **Mentor's Manual**is being developed to support the cause.

We are implementing this philosophy through **Online Mentoring**

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GROWING WITH CONCEPTS

Concepts of an expert are not like a static foundation of a huge structure; rather it is like blood flowing in a vibrant mind.

*During growing into an expert, each one must have used best of the books available on subject and received guidance of best of the teachers. Authors might have had limitations to take every concept thread bare from first principle and so also must be the constraint of teacher while mentoring a class with a diversity of inquisitiveness and focus. As a result, there are instances when on a certain concept a discomfort remains. The only remedy is to live with the conceptual problem and continue to visualize it thread bare till it goes to bottom of heart and that is an **ingenious illustration**.*

In this column an effort is being made to take one topic on Mathematics, Physics and Chemistry in each e-Bulletin and provide its illustration from First Principle. We invite all experts in these subjects to please mail us their ingenious illustrations and it would be our pleasure to include it in the column.

We hope this repository of ingenious illustrations, built over a period of time, would be helpful to ignite minds of children, particularly to aspiring unprivileged students, that we target in this initiative, and in general to all, as a free educational web resource.

This e-Bulletin covers – a) Mathematics,   b) Physics , and c) Chemistry. This is just a beginning in this direction. These articles are not replacement of text books and reference books. These books provide a large number of solved examples, problems and objective questions, necessary to make the concepts intuitive, a journey of educational enlightenment.

Looking forward, these articles are being integrated into Mentors' Manual. After completion of series of such articles on Physics it is contemplated to come up representative problems from contemporary text books and Question papers from various competitive examinationsand a guide to theirsolutions in a structured manner, as a dynamic exercise to catalyse the conceptual thought process.

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Students' Section

C. V. Raman

T.Vijaya

Sir ChandrasekharaVenkata Raman (7 November 1888 – 21 November 1970) was an Indian physicist born in the former Madras Province in India presently the state of Tamil Nadu, who carried out ground-breaking work in the field of light scattering, which earned him the 1930 Nobel Prize for Physics. He discovered that when light traverses a transparent material, some of the deflected light changes wavelength. This phenomenon, subsequently known as Raman scattering, results from the Raman effect. In 1954, India honoured him with its highest civilian award, the Bharat Ratna. He was married on 6 May 1907 to LokasundariAmmal (1892–1980). They had two sons, Chandrasekhar and radio-astronomer Radhakrishnan.

Raman was the paternal uncle of Subrahmanyan Chandrasekhar, who later won the Nobel Prize in Physics (1983) for his discovery of the Chandrasekhar limit in 1931 and for his subsequent work on the nuclear reactions necessary for stellar evolution.

Honours and awards: Sir Raman was honoured with a large number of honorary doctorates and memberships of scientific societies.

- He was elected a Fellow of the Royal Society early in his career (1924) and knighted in 1929. He resigned from the Fellowship of the Royal Society in 1968 for unrecorded reasons, the only Indian FRS ever to do so.

- In 1930 he won the Nobel Prize in Physics.

- In 1941 he was awarded the Franklin Medal.

- In 1954 he was awarded the Bharat Ratna.

- He was awarded the Lenin Peace Prize in 1957. In 1998, the American Chemical Society and Indian Association for the Cultivation of Science recognised Raman's discovery as an International Historic Chemical Landmark.

India celebrates National Science Day on 28 February of every year to commemorate the discovery of the Raman effect in 1928.

RAMAN EFFECT: When photons are scattered from an atom or molecule vibrates by an inelastic scattering process. In inelastic scattering, an absorbed photon is re-emmited with lower energy; the difference in energy between the incident photons and scattered photons corresponds to the energy required to excite a higher vibrational mode.

In Raman spectroscopy high intensity laser radiation with wavelengths in either the visible or near-infrared regions of the spectrum is passed through a sample. Photons from laser beam produce an oscillating polarization in the molecules, exciting them a virtual energy state. The oscillating polarization of the molecule can couple with other possible polarizations of the molecule, including vibrational & electronic excitations. If the polarizations in the molecule does not couple to these other possible polarizations, then it will not change the vibrational state that the molecule started & the scattered photon will have the same energy as the original photon will have the same energy as the original photon

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Students' Section (Contd..)

CREATIVITY - At Learning Centre, RKM School, Sithanagram, Guntur

Ramakrishna Mission High School, Sithanagram, Guntur, AP

Students' Section (Contd..)

Students' Gestures To Online Mentor
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Sithanagram, Guntur, AP
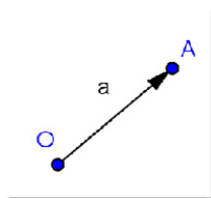
GROWING WITH CONCEPTS - Mathematics

VECTOR ALGEBRA

Prof. SB DHAR

There are two types of Quantities:

(a) *Scalar*: The quantity that has only magnitude.

(b) *Vector*: The quantity that has magnitude as well as direction.

We shall discuss here in this article, about vector quantities and say them simply vectors.

Vector has two end points: (1) The Originating, and   (2) The Terminating

The Originating point is written (in general) as *O* and the terminating point as *A*, or *B* etc.

The vector is represented by $\vec{OA}$.

It is also represented as $\overrightarrow{AB}$ where A is the originating point and B is the terminating point.
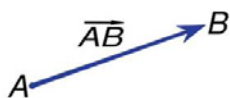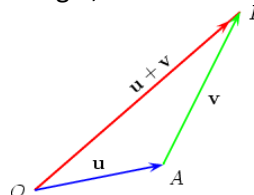

In a vector, the length of the vector is called its *magnitude* and the heading towards the terminating point from the originating point is called its *direction*.
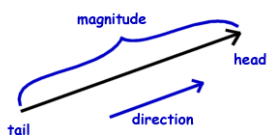
Sum of the vectors is given by $\overrightarrow{OA} + \overrightarrow{AB} + \overrightarrow{BC} = \overrightarrow{OC}$.
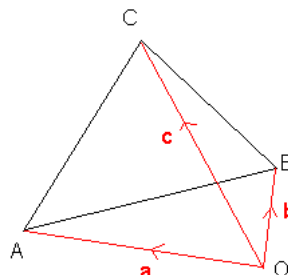
Or in a triangle,

$$\overline{OP} = \overline{OA} + \overline{AP}$$

The Position vector: If the point A is represented by $\vec{OA}$ and the point B by $\vec{OB}$ then $\vec{AB}$ is represented by $\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA}$

= (Position vector of B) – (Position vector of A)

= (Position vector of terminating point) – (Position vector of originating point).

Types of vectors

(a) *Equal vectors*:   The vectors that have same magnitude and same direction.
(b) *Negative vectors*:   The vectors that have same magnitude but opposite direction.
(c) *Like vectors*: The vectors that have same direction.
(d) *Unlike vectors*: The vectors that have different directions.
(e) *Null vectors*: The vector that have zero magnitude like OO, AA, BB etc.
(f) *Unit vectors*: The vectors that have unit magnitude.

They are represented by $\hat{a} = \dfrac{\vec{a}}{|\vec{a}|}$.

(g) *Collinear vectors*:   The vectors that are either parallel or coincident.
(h) *Non-collinear vectors*: The vectors that are neither parallel nor coincident.

(i) *Coplanar vectors*: The three or more vectors are called coplanar if they are parallel to the same plane or lie in the same plane.
(j) *Co-initial vectors*: The vectors that have the same point of origination.
(k) *Free vectors*: The vectors that are free to move anywhere on the plane parallel to them.
(l) *Localised vectors*: The vectors that are unable to move on the plane.
(m) *Proper vector*: The vector whose magnitude is not zero.
(n) *Reciprocal vectors*: Two vectors are said to be reciprocal if they have the same direction but whose modulii are reciprocal to each other.

Note:

(a) The word *"vector"* is derived from Latin word *"Vehere"* meaning *"to carry"*. It was developed in the later part of the 19th Century by the American physicist and mathematician *Josiah Willard Gibbs* (1839-1903 AD) and the English engineer *Oliver Heaviside* (1850-1925 AD) independently. The main idea came from Irish mathematician *William Rowen Hamilton* (1805-1865 AD), Scottish physicist *James Clerk Maxwell* (1831-1879 AD) and *H.G. Grassman* (1809-1877 AD).
(b) *Hamilton* introduced scalar and vector terms in 1844.
(c) *Maxwell* used some of Hamilton's ideas in his study of electro-magnetic theory.

Some Important Results

(a) Vectors *a,b,c* are said to be *linearly dependent* iff there exists real scalars x,y,z not all zero such that $x\bar{a} + y\bar{b} + z\bar{c} = 0$.
(b) Vectors *a,b,c* are said to be *linearly independent* iff there exists real scalars *x,y,z* all zero such that $x\bar{a} + y\bar{b} + z\bar{c} = 0$.
(c) Three points with possible vectors *a,b,c* are said to be collinear iff there exists scalars x,y,z not all zero such that $x\bar{a} + y\bar{b} + z\bar{c} = 0$ where x+y+z=0.
(d) Three vectors *a,b,c* are said to be coplanar iff any one of them can be represented as the linear combination of the other two vectors.

(e) Four points with position vectors *a,b,c,d* are said to be coplanar iff there exists scalars x,y,z, u such that $x\bar{a} + y\bar{b} + z\bar{c} + u\bar{d} = 0$ where x+y+z+u=0.
(f) Two vectors are called collinear if one can be expressed in terms of the other. i.e. a and b are collinear if $\bar{a} = \lambda \bar{b}$ where λ is an arbitrary constant.
(g) Two vectors *a* and *b* are said to be non-collinear if $\lambda \bar{a} + \mu \bar{b} = \bar{0}$ such that λ=μ=0 .
(h) *a,b,c* are called non-coplanar or linearly independent if they form a relation mathematically such that $x\bar{a} + y\bar{b} + z\bar{c} = 0$ where x=y=z=0.
(i) The Position vector of a point R dividing a line segment joining P and Q whose position vectors are *a* and *b* respectively in the ratio m and n by

$$\overrightarrow{OR} = \frac{n\bar{a} + m\bar{b}}{m + n}$$ if divided internally and

$$\overrightarrow{OR} = \frac{n\bar{a} - m\bar{b}}{n - m}$$ if divided externally.

(j) $\left| \bar{a} + \bar{b} \right| \le \left| \bar{a} \right| + \left| \bar{b} \right|$
(k) $\left| \bar{a} - \bar{b} \right| \ge \left| \bar{a} \right| - \left| \bar{b} \right|$
(l) $\left| \bar{a} + \bar{b} \right| = \left| \bar{a} \right| + \left| \bar{b} \right|$ iff *a* and *b* have the same direction.
(m) Product of a vector and a scalar is a vector of same direction but of scalar times magnitude.
(n) If the Product of two vectors is scalar then this is called a **Scalar Product** or **dot (.)** product and is written as $\bar{a}.\bar{b}$.
(o) If the product of two vectors is a vector, then the product is called vector product or cross (x) product and is written as $\bar{a} \times \bar{b}$.
(p) Scalar Product

Product of two vectors *a* and *b* is defined as $\bar{a}.\bar{b} = ab\cos\theta$ where θ is the angle between vectors $\bar{a}$ and $\bar{b}$.
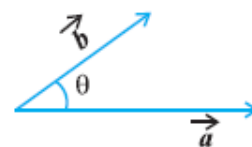
(q) This can also be written as

$\overline{a}.\overline{b} = ab\cos\theta$ = a (b cosθ)

= (length of **a**)(length of projection of **b** on **a**)

(r) $\overline{a}.\overline{a} = \overline{a}^2 = a^2$

(s) $\overline{a}.\overline{b} = \overline{b}.\overline{a}$

(t) $\hat{i}.\hat{i} = \hat{j}.\hat{j} = \hat{k}.\hat{k} = 1$

(u) $\hat{i}.\hat{j} = \hat{j}.\hat{k} = \hat{k}.\hat{i} = 0$

(v) Work= $\overline{F}.\overline{d}$

(w) Projection of $\overline{a}$ in the direction of $\overline{b}$

$= \dfrac{\overline{a}.\overline{b}}{\left|\overline{b}\right|}$

(x) If $\overline{a}$ and $\overline{b}$ are perpendicular to each other and $\overline{a} \neq 0$ and $\overline{b} \neq 0$, then $\overline{a}.\overline{b} = 0$.

(y) $\left|\overline{a}+\overline{b}\right| = \left|\overline{a}-\overline{b}\right|$ if $\overline{a}$ and $\overline{b}$ are perpendicular to each other.

(z) $\left|\overline{a}.\overline{b}\right| \leq \left|\overline{a}\right|\left|\overline{b}\right|$

(aa) Component of vector $\overline{r}$ in the direction of $\overline{a}$ = $\dfrac{(\overline{r}.\overline{a})\overline{a}}{\left|\overline{a}\right|^2}$

(bb) Component of vector $\overline{r}$ in the direction perpendicular to $\overline{a}$ = $\overline{r} - \dfrac{(\overline{r}.\overline{a})\overline{a}}{\left|\overline{a}\right|^2}$

Vector or Cross Product

(a) Vector product of $\overline{a}$ and $\overline{b}$ is defined as $\overline{a} \times \overline{b} = (ab\sin\theta)\hat{n}$ where $\hat{n}$ is a unit vector perpendicular to both $\overline{a}$ and $\overline{b}$.
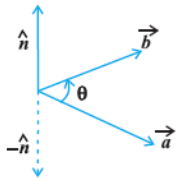
(b) $\overline{a} \times \overline{b} = -\overline{b} \times \overline{a}$

(c) $\overline{a} \times (\overline{b} + \overline{c}) = \overline{a} \times \overline{b} + \overline{a} \times \overline{c}$

(d) If $\overline{a} = a_1\hat{i} + a_2\hat{j} + a_3\hat{k}$, $\overline{b} = b_1\hat{i} + b_2\hat{j} + b_3\hat{k}$, then $\overline{a}$ and $\overline{b}$ are said to be parallel iff $\dfrac{a_1}{b_1} = \dfrac{a_2}{b_2} = \dfrac{a_3}{b_3}$ or $\overline{a} \times \overline{b} = 0$.

(e) Unit vector perpendicular to both $\overline{a}$ and $\overline{b}$ = $\dfrac{\overline{a}\times\overline{b}}{\left|\overline{a}\times\overline{b}\right|}$

(f) $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$

(g) $\hat{i} \times \hat{j} = \hat{k}, \hat{j} \times \hat{k} = \hat{i}, \hat{k} \times \hat{i} = \hat{j}$

(h) $\overline{a} \times \overline{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$

(i) $\left|\overline{a}\times\overline{b}\right|$ represents area of a parallelogram whose adjacent sides are $\overline{a}$ and $\overline{b}$.

(j) $\dfrac{1}{2}\left|\overline{a}\times\overline{b}\right|$ represents area of a triangle whose sides are $\overline{a}$ and $\overline{b}$.

(k) $\dfrac{1}{2}\left|\overline{a}\times\overline{b}\right|$ represents area of a parallelogram if the diagonal are $\overline{a}$ and $\overline{b}$.

(l) $\dfrac{1}{2}\left|\overline{a}\times\overline{b} + \overline{b}\times\overline{c} + \overline{c}\times\overline{a}\right|$ represents area of a triangle if the vertices are $\overline{a}$, $\overline{b}$ and $\overline{c}$.

(m) Moment of force : r x F

(n) $(\overline{a}.\overline{b})^2 = (\overline{a}\times\overline{b})^2 = a^2b^2$.

(o) $(\overline{a}.\overline{b})^2 \leq a^2b^2$

(p) Formula for scalar triple product where $\overline{a} = a_1\hat{i} + a_2\hat{j} + a_3\hat{k}$, $\overline{b} = b_1\hat{i} + b_2\hat{j} + b_3\hat{k}$, $\overline{c} = c_1\hat{i} + c_2\hat{j} + c_3\hat{k}$,

$[\overline{a}\ \overline{b}\ \overline{c}]= \overline{a}.(\overline{b}\times\overline{c}) = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix}$

(q) For any three vectors $\overline{a}$, $\overline{b}$ and $\overline{c}$

(1) $[\overline{a}+\overline{b}\ \ \overline{b}+\overline{c}\ \ \overline{c}+\overline{a}]= 2\,[\overline{a}\ \overline{b}\ \overline{c}\ ]$

(2) $[\overline{a}-\overline{b}\ \ \overline{b}-\overline{c}\ \ \overline{c}-\overline{a}]=0$

(3) $[\overline{a}\times\overline{b}\ \ \overline{b}\times\overline{c}\ \ \overline{c}\times\overline{a}]= [\overline{a}\ \overline{b}\ \overline{c}\ ]^2$

(4) $[\overline{a}\ \overline{b}\ \overline{c}\ ] = [\overline{b}\ \overline{c}\ \overline{a}\ ] =[\overline{c}\ \overline{a}\ \overline{b}\ ]$

(5) $[\overline{a}\ \overline{a}\ \overline{b}\ ] =0$

(6) $[\bar{a}\ \bar{b}\ \bar{c}\ ] = 0$ if $\bar{a}$, $\bar{b}$, $\bar{c}$ are coplanar.

(7) For any vector $\bar{a}$, $\bar{b}$, $\bar{c}$, $\bar{d}$;

(8) $[\bar{a} + \bar{b}\ \bar{c}\ \bar{d}\ ] = [\bar{a}\ \bar{c}\ \bar{d}\ ] + [\bar{b}\ \bar{c}\ \bar{d}\ ]$

(9) Volume of a parallelepiped=$[\bar{a}\ \bar{b}\ \bar{c}\ ]$

(10) Volume of a tetrahedron OABC where O is the origin and $\bar{a}$, $\bar{b}$, $\bar{c}$ are the position vectors of A, B, C is given by $\dfrac{1}{6}[\ \bar{a}\ \bar{b}\ \bar{c}\ ]$

(11) If $\bar{a}\ \bar{b}\ \bar{c}\ \bar{d}$ are the position vectors of A, B, C, D then the volume of tetrahedron ABCD is given by

$(1/6)[\ \bar{b} - \bar{a}\ \ \bar{c} - \bar{a}\ \ \bar{d} - \bar{a}\ ]$

(1) For any three vectors $\bar{a}\ \bar{b}\ \bar{c}$; the vector triple product is given by

$\bar{a} \times (\bar{b} \times \bar{c}) = (\bar{a}.\bar{c})\bar{b} - (\bar{a}.\bar{b})\bar{c}$

(r) If $\bar{a}$ and $\bar{b}$ are two vectors, then their internal bisector is given by $\bar{a} + \bar{b}$ and external bisector by $\bar{a} - \bar{b}$.

(s) Bisectors of the angle between the lines

$\bar{r} = t\ \bar{a}$ and $\bar{r} = s\bar{b}$ are given by

$\bar{r} = u\ (\bar{a} + \bar{b}\ )$ where u is a scalar.

(t) Equation of a plane passing through a point $\bar{a}$ and parallel to the plane containing $\bar{b}$ and $\bar{c}$ is given by

$\bar{r} = \bar{a} + t\ \bar{b} + s\bar{c}$, or

$[\bar{r} - \bar{a}\ ,\ \bar{b}\ ,\ \bar{c}\ ]=0$

(u) The equation of a plane through three points $\bar{a}$, $\bar{b}$, $\bar{c}$ is given by

$\bar{r} = \bar{a} + t\ (\bar{b} - \bar{a}\ ) + s(\bar{c} - \bar{a}\ )$ or

$\bar{r}.[\bar{b} \times \bar{c} + \bar{c} \times \bar{a} + \bar{a} \times \bar{b}\ ]=[\bar{a}\ \bar{b}\ \bar{c}\ ]$

(v) Equation of a plane at distance p from the origin

$\bar{r}.\hat{n} = p$.

(w) Product of four vectors:

$(\bar{a} \times \bar{b}\ ).(\bar{c} \times \bar{d}\ )= \begin{vmatrix} \bar{a}.\bar{c} & \bar{a}.\bar{d} \\ \bar{b}.\bar{c} & \bar{b}.\bar{d} \end{vmatrix}$

Some Solved Problems

1. *Represent graphically a displacement of 40km, 30^0 west of south.*

Solution:
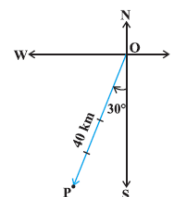
Important thing to keep in mind is 30 degrees west of south.

2. *Find a vector in the direction of the vector $\bar{a} = \hat{i} - 2\hat{j}$ that has magnitude 5 units.*

Solution:

$\hat{a} = \dfrac{\bar{a}}{|\bar{a}|} = \dfrac{\hat{i} - 2\hat{j}}{\sqrt{1^2 + (-2)^2}} = \dfrac{\hat{i} - 2\hat{j}}{\sqrt{5}}$

So, the vector whose magnitude is 5 units will be given by $5\dfrac{\hat{i} - 2\hat{j}}{\sqrt{5}} = \sqrt{5}(\hat{i} - 2\hat{j})$

3. *Write the direction ratios of the vector $\bar{a} = \hat{i} + \hat{j} - 2\hat{k}$ and hence calculate its direction cosines.*

Solution:

Direction ratios of a vector are given by the coefficients of $\hat{i}, \hat{j}, \hat{k}$ in order. In this question, the coefficients are < 1, 1, -2>

The direction cosines are the direction ratios whose squares sum to 1, i.e.,

$\left\langle \dfrac{1}{\sqrt{1^2 + 1^2 + (-2)^2}}, \dfrac{1}{\sqrt{1^2 + 1^2 + (-2)^2}}, \dfrac{-2}{\sqrt{1^2 + 1^2 + (-2)^2}} \right\rangle$ or

$\left\langle \dfrac{1}{\sqrt{6}}, \dfrac{1}{\sqrt{6}}, \dfrac{-2}{\sqrt{6}} \right\rangle$

4. *Find the vector joining the points A(2,3,0) and B(-1,-2,-3) directed from A to B.*

Solution:

It is given that $\overrightarrow{OA} = 2\hat{i} + 3\hat{j} + 0\hat{k}$ and $\overrightarrow{OB} = -\hat{i} - 2\hat{j} - 3\hat{k}$

$\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA} = (-\hat{i} - 2\hat{j} - 3\hat{k}) - (2\hat{i} + 3\hat{j} + 0\hat{k})$

$$= -3\hat{i} - 5\hat{j} - 3\hat{k}$$

5. Show that the points $\vec{A} = 2\hat{i} - \hat{j} + \hat{k}$, $\vec{B} = \hat{i} - 3\hat{j} - 5\hat{k}$, $\vec{C} = 3\hat{i} - 4\hat{j} - 4\hat{k}$ re the vertices of a right angled triangle.

Solution:
Position vectors of points A, B, C are given. We shall find out the vectors of the sides AB, BC, CA and then find out their lengths. By applying Pythagorean theorem $AB^2 = BC^2 + CA^2$ or sum of the squares of any two sides is equal to the square of the other third side.

$$\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA} = -\hat{i} - 2\hat{j} - 6\hat{k}$$
$$\overrightarrow{BC} = \overrightarrow{OC} - \overrightarrow{OB} = 2\hat{i} - \hat{j} + \hat{k}$$
$$\overrightarrow{CA} = \overrightarrow{OA} - \overrightarrow{OC} = -\hat{i} + 3\hat{j} + 5\hat{k}$$
$$\left|\overrightarrow{AB}\right| = \sqrt{41}, \left|\overrightarrow{BC}\right| = \sqrt{6}, \left|\overrightarrow{CA}\right| = \sqrt{35}$$

Obiously, $AB^2 = BC^2 + CA^2$

Hence the triangle ABC is a right angled triangle.

6. Show that the vector $\hat{i} + \hat{j} + \hat{k}$ is equally inclined to the axes OX, OY, and OZ.

Solution:
Equally inclined to the axes means the vector's direction cosines are equal, i.e., $\cos\alpha = \cos\beta = \cos\gamma$.

So, the direction cosines are $\left\langle \dfrac{1}{\sqrt{1^2 + 1^2 + 1^2}}, \dfrac{1}{\sqrt{1^2 + 1^2 + 1^2}}, \dfrac{1}{\sqrt{1^2 + 1^2 + 1^2}} \right\rangle$ or $\left\langle \dfrac{1}{\sqrt{3}}, \dfrac{1}{\sqrt{3}}, \dfrac{1}{\sqrt{3}} \right\rangle$.

All are equal, hence the vector is equally inclined to the axes.

7. Find the angle between two vectors $\bar{a}$ and $\bar{b}$ with magnitudes 1 and 2 respectively and when $\bar{a}.\bar{b} = 1$.

Solution:

We know that $\bar{a}.\bar{b} = 1 \Rightarrow \left|\bar{a}\right|\left|\bar{b}\right|\cos\theta = 1 \Rightarrow \cos\theta = \dfrac{1}{2}$

i.e. θ=60⁰

8. Find the projection of vector $\bar{a} = 2\hat{i} + 3\hat{j} + 2\hat{k}$ on the vector $\bar{b} = \hat{i} + 2\hat{j} + \hat{k}$.

Solution:

Projection of $\bar{a}$ on $\bar{b}$ is given by $\dfrac{\bar{a}.\bar{b}}{\left|\bar{b}\right|}$

Hence $\dfrac{\bar{a}.\bar{b}}{\left|\bar{b}\right|} = \dfrac{2+6+2}{\sqrt{1^2 + 2^2 + 1^2}} = \dfrac{10}{\sqrt{6}}$

9. Find $\left|\bar{x}\right|$ if for a unit vector $\hat{a}$, $(\bar{x} - \hat{a}).(\bar{x} + \hat{a}) = 12$

Solution:

$(\bar{x} - \hat{a}).(\bar{x} + \hat{a}) = 12 \Rightarrow \left|\bar{x}\right|^2 - 1 = 12 \Rightarrow \left|\bar{x}\right| = \sqrt{13}$

10. Find a unit vector perpendicular to each of the vectors $(\bar{x} - \bar{a})$ and $(\bar{x} + \bar{a})$ where $\bar{x} = \hat{i} + \hat{j} + \hat{k}$ and $\bar{a} = \hat{i} + 2\hat{j} + 3\hat{k}$

Solution:
The unit vector $\hat{n}$ perpendicular to two given vectors $\bar{a}, \bar{b}$ is given by its cross product as below:

$$\hat{n} = \dfrac{\bar{a} \times \bar{b}}{\left|\bar{a} \times \bar{b}\right|}$$

Therefore, $\bar{x} - \bar{a} = 0\hat{i} - \hat{j} - 2\hat{k}$ and $\bar{x} + \bar{a} = 2\hat{i} + 3\hat{j} + 4\hat{k}$

$\hat{n} = \dfrac{(\bar{x} - \bar{a}) \times (\bar{x} + \bar{a})}{\left|(\bar{x} - \bar{a}) \times (\bar{x} + \bar{a})\right|}$

$= \dfrac{2\hat{i} - 4\hat{j} + 2\hat{k}}{\sqrt{2^2 + 4^2 + 2^2}} = \dfrac{2\hat{i} - 4\hat{j} + 2\hat{k}}{\sqrt{24}}$

$= \dfrac{2\hat{i} - 4\hat{j} + 2\hat{k}}{2\sqrt{6}} = \dfrac{\hat{i}}{\sqrt{6}} - \dfrac{2\hat{j}}{\sqrt{6}} + \dfrac{\hat{k}}{\sqrt{6}}$

11. If θ is the angle between two vectors $\bar{a}$ and $\bar{b}$, and $\left|\bar{a}.\bar{b}\right| = \left|\bar{a} \times \bar{b}\right|$, then find the value of θ.

Solution:

$\left|\bar{a}.\bar{b}\right| = \left|\bar{a} \times \bar{b}\right| \Rightarrow ab\cos\theta = ab\sin\theta$

$\Rightarrow \tan\theta = 1 \Rightarrow \theta = \dfrac{\pi}{4}$

12. If $\hat{i} + \hat{j} + \hat{k}$, $2\hat{i} + 5\hat{j}$, $3\hat{i} + 2\hat{j} - 3\hat{k}$ and $\hat{i} - 6\hat{j} - \hat{k}$ are the position vectors of points A,B,C, and D respectively, then find the angle between AB and CD. Also deduce that vectors AB and CD are collinear.

Solution:

Given

$$\overrightarrow{OA} = \hat{i} + \hat{j} + \hat{k},$$

$$\overrightarrow{OB} = 2\hat{i} + 5\hat{j},$$

$$\overrightarrow{OC} = 3\hat{i} + 2\hat{j} - 3\hat{k},$$

$$\overrightarrow{OD} = \hat{i} - 6\hat{j} - \hat{k}$$

Hence $\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA} = \hat{i} + 4\hat{j} - \hat{k}$ and

$$\overrightarrow{CD} = \overrightarrow{OD} - \overrightarrow{OC} = -2\hat{i} - 8\hat{j} + 2\hat{k}$$

Angle between vectors AB and CD is given by

$$\cos\theta = \frac{-2 - 32 - 2}{\sqrt{1^2 + 4^2 + 1^2}\sqrt{2^2 + 8^2 + 2^2}}$$

$$= \frac{-36}{\sqrt{18}\sqrt{72}} = \frac{-36}{36} = -1$$

i.e., θ=180⁰

13. Find the value of $\hat{i}.(\hat{j} \times \hat{k}) + \hat{j}.(\hat{i} \times \hat{k}) + \hat{k}.(\hat{i} \times \hat{j})$.

Solution:

$$\hat{i}.(\hat{j} \times \hat{k}) + \hat{j}.(\hat{i} \times \hat{k}) + \hat{k}.(\hat{i} \times \hat{j}) = \hat{i}.\hat{i} + \hat{j}.(-\hat{j}) + \hat{k}.\hat{k} = 1 - 1 + 1 = 1$$

14. If $\bar{a} = \hat{i} + \hat{j} + \hat{k}$ and $\bar{b} = \hat{j} - \hat{k}$, find a vector $\bar{c}$ such that $\bar{a} \times \bar{c} = \bar{b}$ and $\bar{a}.\bar{c} = 3$

Solution:

Assume the required vector

$$\bar{c} = c_1\hat{i} + c_2\hat{j} + c_3\hat{k}$$

$$\bar{a} \times \bar{c} = \bar{b} \Rightarrow \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & 1 \\ c_1 & c_2 & c_3 \end{vmatrix} = \hat{j} - \hat{k}$$

$$\Rightarrow c_2 - c_3 = -1, c_1 - c_3 = 0, c_1 - c_2 = 0$$

And

$$\bar{a}.\bar{c} = 3 \Rightarrow c_1 + c_2 + c_3 = 3$$

On solving these equations,

$$c_1 = \frac{4}{3}, c_2 = \frac{1}{3}, c_3 = \frac{4}{3}$$

And hence the vector is

$$\bar{c} = \frac{4}{3}\hat{i} + \frac{1}{3}\hat{j} + \frac{4}{3}\hat{k}$$

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Dr S.B. Dhar, is **Editor of this Quartrerly e-Bulletin**. He is an eminent mentor, analyst and connoisseur of Mathematics from IIT for preparing aspirants of Competitive Examinations for Services & Admissions to different streams of study at Undergraduate and Graduate levels using formal methods of teaching shared with technological aids to keep learning at par with escalating standards of scholars and learners. He has authored numerous books of excellence.

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CROSSWORD PUZZLE: SIR CV RAMAN

Prof. SB Dhar
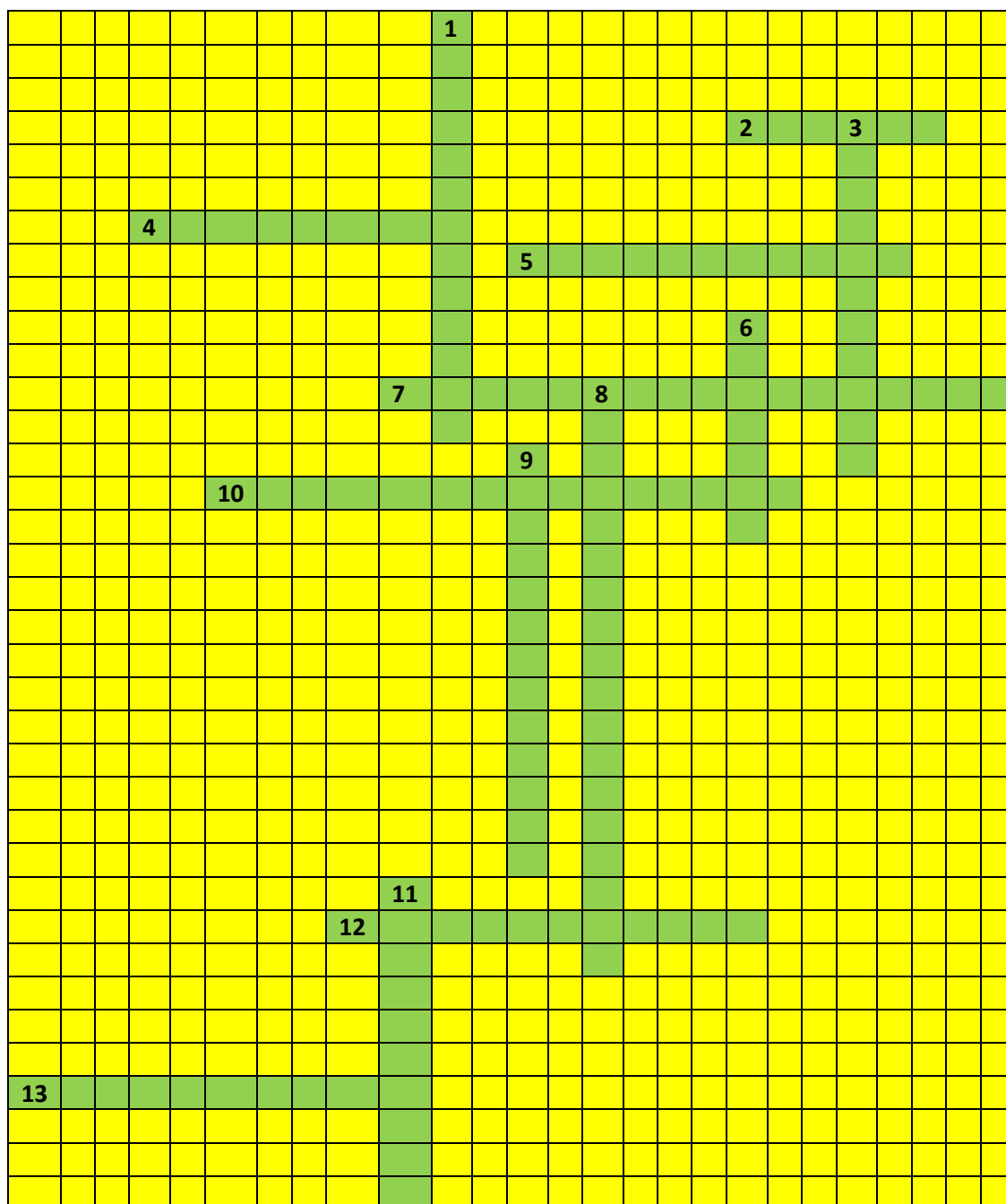
Across

2 University from where Raman got Master degree

4 Month of Birth of Raman

5 Award by which Raman was honoured in 1954

7 Govt of India appointed Raman in 1947 as

10 Name of Raman's Mother

12 Raman's Student who worked in the field of Optics

13 Raman's colleague who worked on Scattering of Light

Down

1 Sea where Raman noticed the Blue colour first time

3 For what Raman is

6 Nobel Laureate of Physics in 1930 from India

8 February 28 is celebrated in India

9 Son of CVRaman

11 Light through transparent medium changes its

—00—

ANSWER: CROSSWORD PUZZLE Jan'18: VIVEKANAND

Prof. S.B. Dhar

c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20	c21	c22	c23	c24	c25	c26	c27
									1B																	
							2J	O	H	N	H	E	N	R	Y	B	A	R	R	O	W	S				
									U																	
									3B	A	R	T	A	M	A	N	B	H	A	R	A	T				
4R	A	M	K	R	I	S	H	N	A																	5C
									6N	A	T	I	O	N	A	L	Y	O	U	T	H	D	A	Y		C
									E																	C
7W	I	L	L	I	A	M	H	A	S	T	I	E			8R					9C	H	I	C	A	G	O
									H						O						10K					U
									W						M			11M	Y	M	A	S	T	E	12R	
				13V	I	S	H	W	A	N	A	T	H	D	A	T	T	A			Y		T		A	
									R						I			X			A		A		J	
									I						N			M			S				A	
									D						R			U			T				Y	
						14N	I	V	E	D	I	T	A		O			L			H				O	
									V						L			L			A				G	
									I						L			E							A	
										15B	A	R	A	N	A	G	A	R								
															N											
												16H	I	N	D	U	I	S	M							

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Nature is an excellent example ofunity in diversity. Atom at its basic constituent level, it comprises particles of different nature. Some of them are of opposite in nature, and experience a strong force of attraction, yet they continue to exist separately and individually; particles of similar nature, having stong force of repulsion continue to exist in vicinity. This has been there since beginning of nature, and shall continue to exist indefinitely. Any unregulated infringement on the other would is disastrous. The secret of coexistence is in respecting others position.

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Growing with Concepts : Physics

Modern Physics: Part IV: Schrödinger Wave Equation and Atomic Structure

Schrödinger Wave Equation (SWE) elaborated earlier is in One Dimension along X-axis and could explain structure of single electron Hydrogen Atom. But, atoms with larger number of electrons space accommodate the particles in three dimensional space, and in turn exhibit different properties viz. magnetic, chemical bonding, including classification and organization of atoms in periodic table. Accordingly, in this section SWE is being considered in three dimensions. This section, also like the previous section on SWE is heavily based on illustrations in reference at [1].

*Schrödinger Wave Equation in Three Dimensions***:** *The SWE along X-axis is simplification of analysis in one dimension. Nevertheless, situations involving multi electron atoms involves distribution of electrons in three dimension space such that each particle continues to in a state of motion, without conflicting with other particles. Since motion and force are scalar quantities, while energy is scalar quantity, the analysis becomes simple by analyzing three independent components of momentum, being vector, while total energy be it potential or kinetic taken as simple addition, being scalar, of corresponding components. Accordingly, a comparison of SWE in one and three dimension is as under –*

Quantity	SWE in One Dimension	SWE in Three Dimension
Position	*Along X-axis*	*Position along X-,Y-,Z-axis*
Momentum	$p_x = \hbar k$, here, $k = \sqrt{\frac{2\omega m}{\hbar}}$	(p_x, p_y, p_z)
Potential Energy	U_x	$U_{(x,y,z)}$
Kinetic Energy	$\dfrac{p_x{}^2}{2m}$	$\dfrac{p_x{}^2}{2m} + \dfrac{p_y{}^2}{2m} + \dfrac{p_z{}^2}{2m}$
SWE	$-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) + U(x)\Psi(x,t) =$ $i\hbar\frac{\partial}{\partial t}\Psi(x,t),$	$-\frac{\hbar^2}{2m}\left[\frac{\partial^2}{\partial x^2}\Psi(x,,y,z,t) + \frac{\partial^2}{\partial y^2}\Psi(x,,y,z,t) + \partial 2\partial z2\Psi x,,y,z,t + Ux,y,z,\Psi x,y,z,t = i\hbar\partial\partial t\Psi x,y,z,t,$
Wave function	$\Psi(x,t) = \Psi(x)e^{-i\frac{Et}{\hbar}} = Ae^{-ikx}e^{-i\frac{Et}{\hbar}}$	$\Psi(x,y,z,t) = \Psi(x,y,z)e^{-i\frac{Et}{\hbar}}$
Square of absolute value	$\lvert\Psi(x,t)\rvert^2 = \Psi(x,t)\Psi^*(x,t)$	$\lvert\Psi(x,y,z,t)\rvert^2 = \Psi(x,y,z,t)\Psi^*(x,y,z,t)$
Normalization of Wave Function	$\int_{-\infty}^{\infty}\lvert\Psi(x,t)\rvert^2\,\mathrm{d}x = 1$	$\int\lvert\Psi(x,y,z,t)\rvert^2\mathrm{d}V = 1$

Particle in Three Dimensional Box: The box, for simplicity, is taken to be a cube with each side of length L and its three edges coincide with the three axis such that $0 \le x \le L$, $0 \le y \le L$, and $0 \le z \le L$. In the space in this box an electron is free to about. Analogy of proposition in one dimensional box, considered earlier is
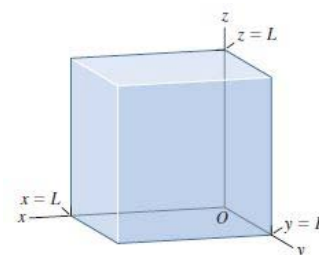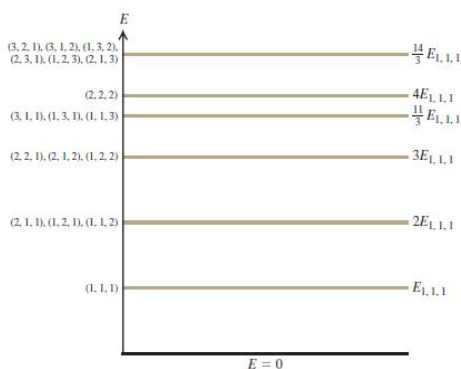
extended to this case also and accordingly, potential energy $U(x, y, z)$ inside the box is ZERO and outside the box is infinite. Accordingly, time independent wave function $\Psi(x, y, z) = 0$ outside the box, as particle is confined within the box. This makes $U(x, y, z)\Psi(x, y, z)$, product of an Zero and infinite term to be finite. Thus, time-independent SWE inside the box becomes $-\frac{\hbar^2}{2m}\left[\frac{\partial^2}{\partial x^2}\Psi(x, y, z) + \frac{\partial^2}{\partial y^2}\Psi(x, y, z) + \frac{\partial^2}{\partial z^2}\Psi(x, y, z)\right] = E\Psi(x, y, z)$.
Accordingly, boundary conditions for wave–function are $\Psi(x, y, z) = 0$, $0 \leq x \leq L$, $0 \leq y \leq L$, and $0 \leq z \leq L$. Like one dimensional box, solution of this complicated partial differential equation is $\Psi(x, y, z, t) = \Psi(x, y, z)e^{-i\frac{Et}{\hbar}}$. Extending this analogy by separating the three orthogonal variable, the time independent wave-function can be written as $\Psi(x, y, z) = X(x)Y(y)Z(z)$.

Accordingly, $-\frac{\hbar^2}{2m}\left[Y(y)Z(z)\frac{d^2}{dx^2}X(x) + X(x)Z(z)\frac{d^2}{dy^2}Y(y) + X(x)Y(y)\frac{d^2}{dz^2}Z(z)\right] = EX(x)Y(y)Z(z)$, is the new form of SWE. This further simplifies to $\left(-\frac{\hbar^2}{2m}\frac{1}{X(x)}\frac{d^2}{dx^2}X(x)\right) + \left(-\frac{\hbar^2}{2m}\frac{1}{Y(y)}\frac{d^2}{dy^2}Y(y)\right) + \left(-\frac{\hbar^2}{2m}\frac{1}{Z(z)}\frac{d^2}{dz^2}Z(z)\right) = E$, where partial derivatives are replaced with simple derivates. Next argument is that energy of the stationary state neither depends nor can depend on x, y and z and hence $E = E_x X(x) + E_y Y(y) + E_z Z(z)$. Thus equation independent in three dimensions are $-\frac{\hbar^2}{2m}\frac{1}{X(x)}\frac{d^2}{dx^2}X(x) = E_x X(x)$, $-\frac{\hbar^2}{2m}\frac{1}{Y(y)}\frac{d^2}{dy^2}Y(y) = E_y Y(y)$, $-\frac{\hbar^2}{2m}\frac{1}{Z(z)}\frac{d^2}{dz^2}Z(z) = E_z Z(z)$. The three constants E_x, E_y and E_z are the constituents of kinetic energy of particle along X-axis, Y-axis and Z-axis respectively, such that $E = E_x + E_y + E_z$. This is simplification of a complicated 3-D problem into three independent yet identical ordinary time-independent SWE with exactly same boundary conditions. Solution of these three equations are –

$X_{n_x}(x) = C_X \sin\frac{n_X \pi x}{L}$, $n_X \in N$; $Y_{n_y}(y) = C_Y \sin\frac{n_Y \pi y}{L}$, $n_Y \in N$ $Z_{n_z}(z) = C_Z \sin\frac{n_Z \pi z}{L}$, $n_Z \in N$; here C_X, C_Y and C_Z are constants and the three corresponding energies are $E_X = \frac{n_X^2 \pi^2 \hbar^2}{2mL^2}$, $n_X \in N$; $E_y = \frac{n_Y^2 \pi^2 \hbar^2}{2mL^2}$, $n_Y \in N$; and $E_Z = \frac{n_Z^2 \pi^2 \hbar^2}{2mL^2}$, $n_Z \in N$, here N is a set of Natural numbers

In one dimensional motion of a particle in a box there only One quantum number, but in three dimensional motion there are Three quantum numbers viz. n_X, n_Y and n_Z, as stated in energy along three axes E_X, E_Y and E_Z. Accordingly, time independent wave function $(x, y, z) = X(x)Y(y)Z(z)$, stated above, in 3-D space gives following stationary-state wave function $\Psi_{n_X,n_Y,n_Z}(x, y, z) = C \sin\frac{n_X \pi x}{L} \sin\frac{n_Y \pi y}{L} \sin\frac{n_Z \pi z}{L}$. Here, $C = C_X C_Y C_Z$ and vale of C is determined by normalization condition $\int |\Psi(x, y, z, t)|^2 dV = 1$.

Energy Level, Degeneracy and Symmetry: The analysis brought out above indicates that allowed energy levels for a particle of mass m in a cubical box of side L are: $E_{n_X,n_Y,n_Z} = \frac{(n_X^2 + n_Y^2 + n_Z^2)\pi^2 \hbar^2}{2mL^2}$. Six lowest energy levels in a 3-D box are shown in the figure. This degeneracy is since a consequence of symmetry, it can be removed by making 3-D space asymmetric where $L_X \neq L_Y \neq L_Z$. This leads to allowed energy levels in the asymmetric space as: $E_{n_X,n_Y,n_Z} = \left(\frac{n_X^2}{L_X^2} + \frac{n_Y^2}{L_Y^2} + \frac{n_Z^2}{L_Z^2}\right)\frac{\pi^2 \hbar^2}{2m}$. Thus, the energy states $(n_X, n_Y, n_Z) = \left((2,1,1), (1,2,1), (1,1,2)\right)$ have different energies leaving no chance to degenerate. Accordingly, crucial differences in motion of a particle in 3-D and 1-D are summarized below –

Particulars	One-Dimensional Motion	Three-Dimensional Motion
Wave function	Single function in X-coordinate	Product of Three functions, One for each of the coordinate X, Y and Z
Quantum Number to describe stationary state	Only One	Three
Degeneracy	No degeneracy	Most of the energy levels degenerate, with more than one energy state having same energy.
Stationary States	There are positions where $|\Psi(x)|^2 = 0$	There are surfaces where $|\Psi(x,y,z)|^2 = 0$

Hydrogen Atom: It is the simplest case to validate any theory, which has demonstrated experimental validation of Bohr's model through spectral lines. The model is a mix of classical and quantum mechanics, but without an explanation of the process of emission and absorption of photon. Moreover, it is not explicit in respect of atoms with more than one electron. This requires application of SWE to hydrogen atom.

In hydrogen atom, potential energy of single electron depends on its distance from origin $r = \sqrt{x^2 + y^2 + z^2}$, *and has spherical symmetry, this gives a reason to switch over the elaboration from Cartesian coordinate system* $(x,y,z,)$*to spherical coordinate system* $(r, \theta, \emptyset)$. *Accordingly,* $U(r) - \frac{1}{4\pi\epsilon_0}\frac{e^2}{r}$, *which makes wave function in polar form:* $\Psi(x,y,z) = R(r)\boxdot(\theta)\Phi(\emptyset)$, where each of the factor is orthogonal to the other Two and hence independent of the other. Accordingly, the SWE splits into three independent equations:

$$-\frac{\hbar^2}{2m}\frac{d}{dr}\left(r^2\frac{dR(r)}{dr}\right) + \left(\frac{\hbar^2 l(l+1)}{2m_r r^2} + U(r)\right)R(r) = ER(r);$$

$\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\frac{d\boxdot(\theta)}{d\theta}\right) + \left(l(l+1) - \frac{m_l{}^2}{\sin^2\theta}\right)\boxdot(\theta) = 0$;   and $\frac{d^2\Phi(\emptyset)}{d\emptyset^2} + m_l{}^2\Phi(\emptyset) = 0$. Here, **mass of electron** m is replaced by reduced mass m_r to account for motion of nucleus. While, l and m_l are the Two constants being introduced here and shall be elaborated a little later. Solution of these equations, satisfying boundary conditions, in spherical coordinates is outside domain of this manual and is being skipped. Nevertheless, inquisitive students are welcome to write through for more details at _CONTACT US_. In the process, corresponding energy levels in hydrogen are $E_n = -\frac{1}{(4\pi\varepsilon_0)^2}\frac{m_r e^4}{2n^2\hbar^2} = -\frac{13.6}{n^2}$, here $n \in I$, is the **_principal quantum number_** for the energy E_n at level n. The analysis as SWE is different, both mathematically and conceptually, from that of Bohr's model, yet results are same and thus reflect universality of nature. However, the SWE gives information about Hydrogen atom more than with Bohr's model.
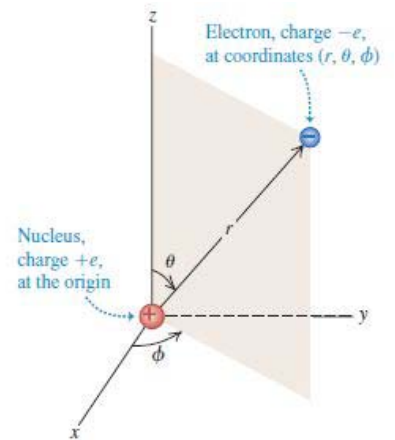
Quantization of Orbital Angular Momentum: *In Bohr's model quantization of angular momentum was at fundamental level. In SWE, it appears automatically as orbital angular momentum with discrete values of magnitude and component. The possible values of the magnitude of angular momentum $L = |\bar{L}|$ are determined by requirement of $\Theta(\theta)$ to be finite at $\theta = 0$ and $\theta = \pi$. Thus orbital angular momentum quantum number is known as* **Orbital Quantum Number (*l*)**, *as one of the constant introduced above such that $l = 0, 1, 2.., n - 1$. This is unlike Bohr's model where each energy level corresponds to a single value of angular momentum; SWE leads to **n** different possible values of L for $\boldsymbol{n}^{\textbf{th}}$ energy level.*

It is pertinent to note that in Bohr's model angular momentum of an electron orbiting around nucleus cannot be Zero. But, using SWE *orbital angular momentum* is Zero for $l = 0$ where wave function Ψ is dependent on , while $\theta(\theta)$ and $\Phi(\emptyset)$ are constants. This makes Ψ for $l = 0$ spherically symmetric without any bias to any of the directions and hence, in this case ***orbital angular momentum is Zero***.

Permitted values of component L_z of angular momentum along Z-axis in either direction is determined by the requirement that $\Phi(\emptyset) = \Phi(\emptyset + 2\pi)$. Accordingly, its possible values are $L_z = m_l\hbar$, where $m_l = 0, \pm1, \pm2 ..., \pm l$. This m_l is called orbital magnetic quantum number or magnetic quantum number, the other of the Two constants introduced above. Figure shows possible values of L_z for $l = 2$.
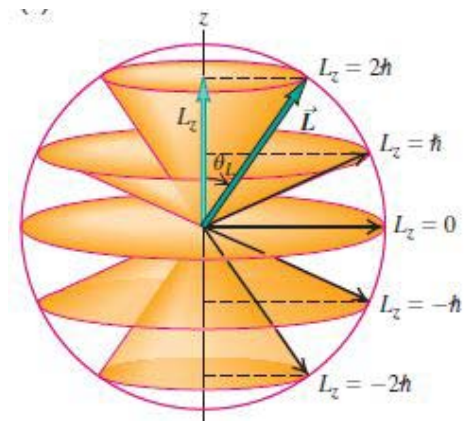
Quantum Number Notation: *Wave function for an electron in hydrogen atom is determined by Three quantum numbers n- principal quantum number quantifies energy of the electron E_n , and is independent of either l or m_l; l - orbital angular quantum number decides magnitude of orbital angular momentum, and m_l - magnetic quantum number decides quantum of l is specified direction. Thus, for each energy level there can be different set of quantum numbers leading to degeneration in the same way as that for 3-D cubical box. Accordingly, for different values of orbital angular quantum number states of are designated as-*

$l = 0$: s *states*; $l = 1$: p *states*; $l = 2$: d *states*; $l = 3$: f *states*; $l = 4$: g *states*; $l = 5$: h *states*; *and so on. Here,   nomenclature of states otherwise has no logical basis. Thus a state with $n = 2$ and $l = 1$ is designated as 2p state. Likewise, Based on principal quantum number the shells containing electrons, in multi-electron atom, are designated as: K shell for n=1; L shell for n=2; M shell for n=3; N shell for n=4; and so on in alphabetical order.*

Electron Probability Distributions: In contrast to Bohr's model, SWE predicts probability of finding an electron in the entire space around nucleus expressed as $\int|\Psi|^2 dV = 1$. Visualization of this probability distribution in 3-D is difficult as much as its graphical representation. Nevertheless, recourse is to consider spherical symmetry and accordingly take $P(r)$ as radial probability of an electron from proton in hydrogen atom. In thin shell of radial thickness dr having volume $dV = 4\pi r^2 dr$, the probability of finding an electron shall be $P(r)dr = |\Psi|^2 dV = |\Psi|^2 4\pi r^2 dr$. Here, $|\Psi|^2$ is the average value at all angles θ and $\emptyset$. In the figure radial probability distribution of finding an electron is shown upto Four shells, with values of *orbital angular quantum number l* ranging from Zero to
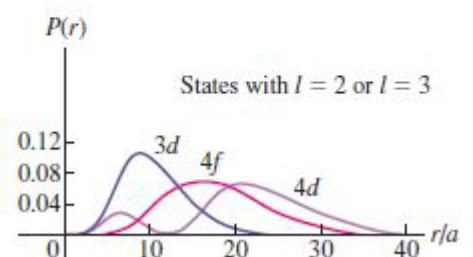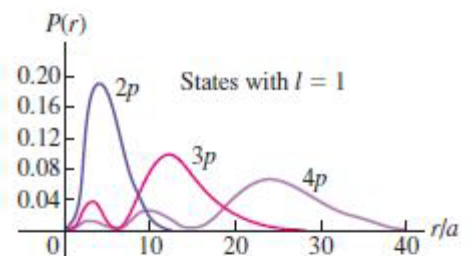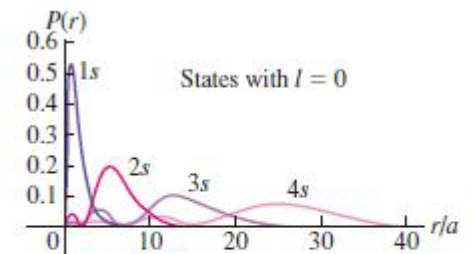
Three. As a function of $\frac{r}{a}$ where, a is the minimum distance of an electron from proton in Bohr's model $\Big[a =$
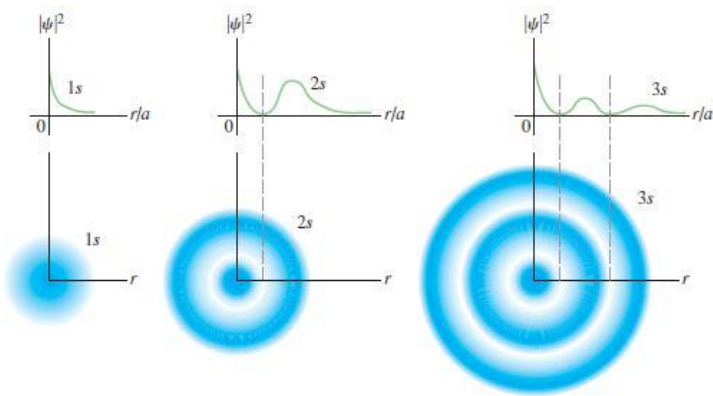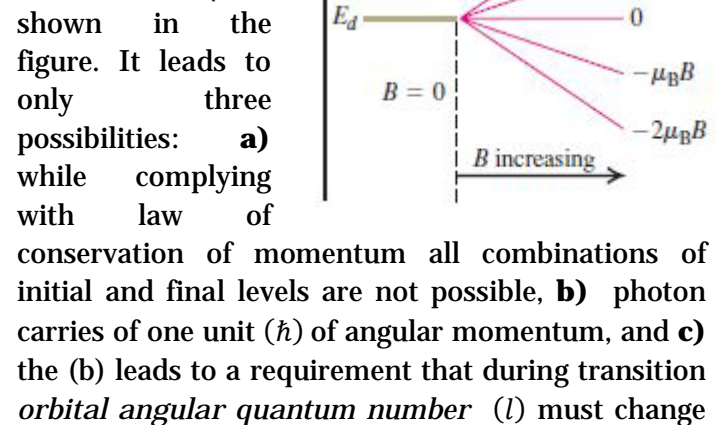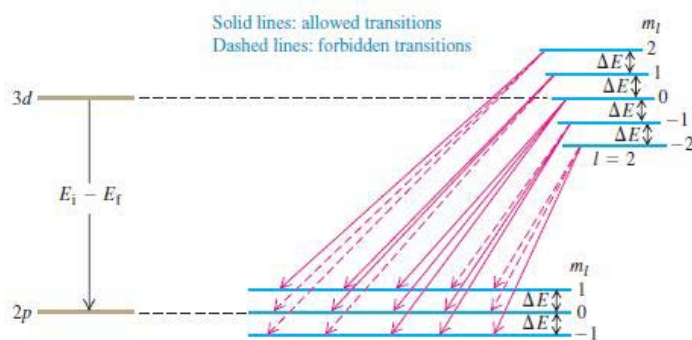

$\frac{\epsilon_0 h^2}{\pi m_r e^2} = \frac{4\pi\epsilon_0 \hbar^2}{m_r e^2} = 5.29 \times 10^{-11} m\Big]$. Three dimensional representation of probability distribution on a plane is also shown for Three **s** sub-shells, with cross-section of the cloud of electron having dependence of $|\Psi|^2$ on angles θ and $\emptyset$, in the following figure. Evidence of orbital angular momentums is available from Zeeman Effect which demonstrates splitting of energy levels and associated spectral lines when atoms are placed in magnetic field. Elaboration of this effect is excluded in present text being out of its domain. Nevertheless, inquisitive students are welcome to write through for more details at *CONTACT US*.
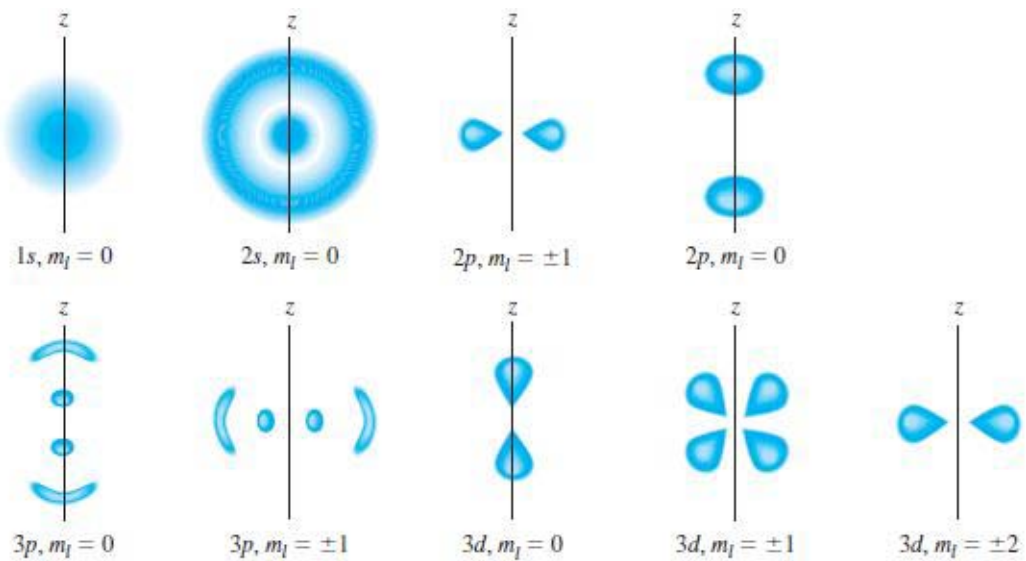
Selection Rule: Effect of magnetic field on d state ($l = 2$) splitting five states with $m_l = -2, -1, 0, 1$ and 2 is shown in the figure. Likewise splitting of $3d$ and $2p$ states is shown in the next figure. Energy difference separating adjacent energy levels, in presence of magnetic field (B), after splitting is $\Delta E = \frac{e\hbar}{2m} = \mu_B B$. In absence of magnetic field the spectral lines are decided by energy difference: $E_i - E_i = E_d - E_p$, as shown in the figure. It leads to only three possibilities: **a)** while complying with law of

conservation of momentum all combinations of initial and final levels are not possible, **b)** photon carries of one unit ($\hbar$) of angular momentum, and **c)** the (b) leads to a requirement that during transition *orbital angular quantum number* (l) must change by One (1) and thus possible values for *magnetic quantum number* (m_l) are 0 or ± 1. These requirements of *allowed transition* are called **Selection Rules**, and any transition not consistent with this is *forbidden*

transition. This brings to another important aspect for exploration is **spin of electrons**, in their orbit, while revolving around nucleus in their orbit.

Electron Spin: Increase in precise spectroscopic exploration revealed fine spectral lines beyond those explained by SWE, These spectral lines while resembled with those observed during Zeeman effect but occurred in absence of magnetic field as shown in figure.
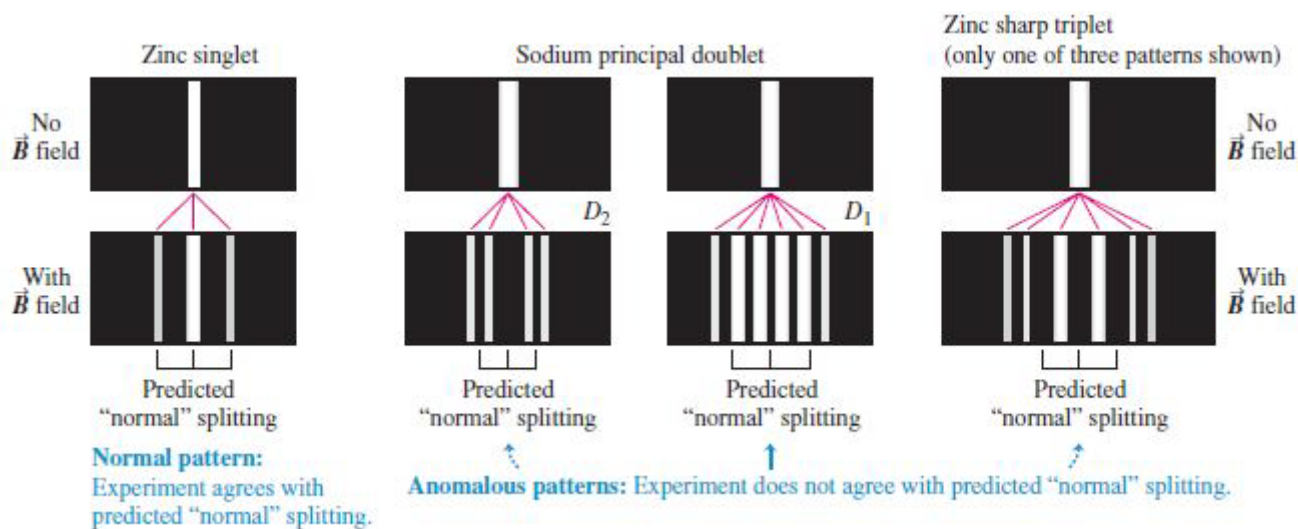
Similar anomalies, in 1922, were observed by Otto Stren and Walter Gerlach during experiment of passing beam of neutral atoms, through a non-uniform magnetic field, which had shown deflection of atoms based on their orientation w.r.t. magnetic field. If deflection were to be on angular momentum split beam shall have odd number of components $= 2l + 1$. However, splitting of some beams into even number of components was resolved using a different symbol j for *angular momentum quantum number* with values $j = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \ldots$, taking *half-odd-integer angular momentum* leads to $2j + 1$ leads to an even number. In 1926, Samuel Goudsmidt and George Uhlenbeck proposed that electron while performing orbital motion is spinning around its axis like a sphere, instead of a point mass in consideration so far. Such a motion is analogous to the planets in solar system in an effort to explain anomalies observed in energy levels. Electron since carries charge, the spin motion would create current loops out of the uniformly charged sphere, and would eventually create a magnetic field as per Bio-Savart's Law. Thus in presence of magnetic field this *spin magnetic moment* involves energy interaction which is in addition to the *orbital magnetic moment* creating an additional Zeeman shift. The origin of spin angular momentum is in quantum mechanics and therefore considering electron as a spinning charged sphere is not correct, but it is just to draw an analogy.

Spin Quantum Number: Like orbital angular momentum the *spin angular momentum* $(\bar{S})$ is also quantized with possible values of its z-component are $S_z = \pm \frac{1}{2} \hbar$. This relationship leads to $L_z = m_l \hbar$ for *z-component of orbital angular momentum*. It also suggests that $S = \sqrt{\frac{1}{2}\left(\frac{1}{2} + 1\right)} \cdot \hbar = \sqrt{\frac{3}{4}} \cdot \hbar$ is magnitude of spin angular momentum and is analogous to *orbital quantum number* (l) *which is replaced by* **spin quantum number** $\left(s = \frac{1}{2}\right)$. Thus electron is also called a "**spin** $-\frac{1}{2}$ **particle**". This can be visualized with an electron cloud around the nucleus with a probability distribution $|\Psi|^2$.

In this spin vector is considered to be distributed throughout the cloud with its component either along $+z$ direction as "*spin up*" or $-z$ direction as "*spin down*". Drawing an analogy with *orbital magnetic quantum number* (m_l), the *spin magnetic quantum number* (m_s) its possible values are $(+)\frac{1}{2}$ or $(-)\frac{1}{2}$ and that $S_z = m_s \hbar$.

The spin magnetic moment (μ_z) relates to *spin angular momentum* along *z*-axis as: $\mu_z = -(2.00232)\frac{e}{2m}S_z$, here, e and m are charge and mass of electron, respectively. In the of an atom placed in magnetic field ($\bar{B}$)energy consumed in interaction of spin magnetic dipole moment with external magnetic field is $(-)\bar{\mu}.\bar{B}$ causing further splitting in energy levels manifested in corresponding spectral lines. In 1928, Paul Dirac in his though experiments on relativistic generalization of SWE propounded gyrometric ratio for electron spin twice the value of $\frac{e}{2m}$. This is in close approximation with the value 2.00232. It took nearly Two decades to integrate the results of thought experiment by Dirac in Quantum Electro-Dynamics (QED).

Coupling between spin and orbital motion of electron needs to be viewed as a motion of (+) vely charged nucleus proton, relative to electron orbiting around it. This is analogous to experience of motion of Sun to observer on the earth, except that in instant case it is motion of charges, which produces magnetic field at the location of electron. The electron itself being a moving frame of reference, which interacts with the magnetic field and thus results into *spin magnetic moment*. This spin magnetic moment in turn causes splitting of the energy levels into two which corresponds to the Two directions of spins. This is called **spin-orbit coupling** and interaction energy is expressed as scalar product of the Two angular momentum vectors ($U = \bar{L} \cdot \bar{S}$). However, total angular momentum, a new term is, $\bar{J} = \bar{L} + \bar{S}$. The possible magnitudes of $\bar{J}$ are given by a quantum number (j) such that : $J = \sqrt{j(j+1)}\hbar$. Here, $j = \left|l \pm \frac{1}{2}\right|$; in case of L and S vectors have parallel *z*-components being parallel it is $l + \frac{1}{2}$ and when *z*-components are anti-parallel it is $l - \frac{1}{2}$.

Any change of state is associated with the change in momentum and hence energy associated with the change. This leads to emission of spectral lines while an electrons descends from higher energy state of higher momentum to lower momentum and absorption in vice versa. These spectral lines has served the purpose of experimental validations of the various theoretical inferences discussed above.

Exclusion Principle: All previous discussion on atomic structure were focused on Hydrogen atom, being simplest to evolve theoretical platform needed for analyzing multi-electron atoms, which otherwise would have been too complex for understanding to start with the atomic structure. In this background, the inferences on structure of atom were extended to an atom, in general, having number of proton and electron to be Z also called as **atomic number**, to retain its electrical neutrality. Nevertheless, with increasing Z complexity in applying SWE increases because each of the electron interacts with the other $Z-1$ electrons and nucleus, in a state of relative motion in $3Z$ coordinate system, while each equation has second derivative w.r.t. remaining particles. *This complexity is of such a high order that it is open for exploration even to Helium atom, next in higher order to Hydrogen.*

In this context various approximations have been made by scientists, among them simplest, yet drastic, approximation is to consider to consider each electron as point charge, moving around nucleus having a wave function, like that of electron in Hydrogen atom with Four characteristic quantum numbers $n, l, m_l,$ and m_s, charge on nucleus as Ze and not e. This makes it possible to replace each occurrence of e^2 in wave function and energy levels is replaced with Ze^2 and correspondingly e^4 is replaced with Z^2e^4. Thus energy levels in multi-electron atoms turn out to be $E_n = -\frac{1}{(4\pi\epsilon_0)^2}\frac{m_r Z^2 e^4}{2n^2\hbar^2} = -13.6\frac{Z^2}{n^2}$ eV. This too simplified model is not useful in quantitative predictions.

Considering dynamics of electrons, a more realistic approximation is to consider $Z-1$ electron as a *spherically symmetrical cloud* around nucleus, and accordingly the potential energy function U_r is arrived at. This model is called **central-field approximation** in evolving atomic structure with *One electron-wave function*. In this model potential energy function $\left(\frac{1}{r}\right)$ is replaced with U_r which in differential equation is unaffected by either

$\theta(\theta)$ or $\Phi(\emptyset)$. Thus angular functions remain same as that for Hydrogen atom and so also states orbital angular momentum. Thus, quantum numbers $l, m_{l,}$ and m_s and so also z-component, in multi-electron atom remain unchanged. *Thus, in this model basic difference with hydrogen atom lies in radial wave function and associated probabilities*. Energy of a state is since dependent on n and l, restrictions in allowed values of quantum numbers remain as that for hydrogen atom: $n \geq 1$; $0 \leq l \leq n-1$; $|m_l| \leq l$; $m_s = \pm\frac{1}{2}$.

This has ground for introducing **Pauli Exclusion Principle** necessary to define structure of many-electron atoms a land mark contribution, in 1925, by **Wolfgang Pauli**. His hypothesis was based on simple observation of distinct difference in properties of elements Fluorine $(Z = 9)$, Neon $(Z = 10)$ and Sodium $(Z = 11)$, having a gradual increase in Z. In case all electrons were to occupy ground state $(n = 1)$ there should have been gradual drift in the properties of these elements. This leads an inference that there must be something forbidding electrons to exist in same state. This mystery was solved by Pauli stating

n	l	m_l	Spectroscopic Notation	Number of States	Shell
1	0	0	1s	2		K
2	0	0	2s	2	8	L
2	1	-1, 0, 1	2p	6		
3	0	0	3s	2		
3	1	-1, 0, 1	3p	6	18	M
3	2	-2, -1, 0, 1, 2	3d	10		
4	0	0	4s	2		
4	1	-1, 0, 1	4p	6	32	N
4	2	-2, -1, 0, 1, 2	4d	10		
4	3	-3, -2, -1, 0, 1, 2, 3	4f	14		

that – **no two electrons can occupy the same quantum-mechanical state having in an atom same values of quantum numbers $n, l, m_l,$ and m_s** . This goes further to state that *not more than Two electrons with opposite quantum number m_s can occupy same region*. Thus number of states in an atom are same as number of electrons (Z) . In table below set of quantum numbers for atoms having $Z = 2, 8, 18$ and 32, with number of energy levels have been indicated.

On average, the 2s electron is considerably farther from the nucleus than the 1s electrons. Therefore, it experiences a net nuclear charge of approximately $+3e - 2e = +e$ (rather than $+3e$).
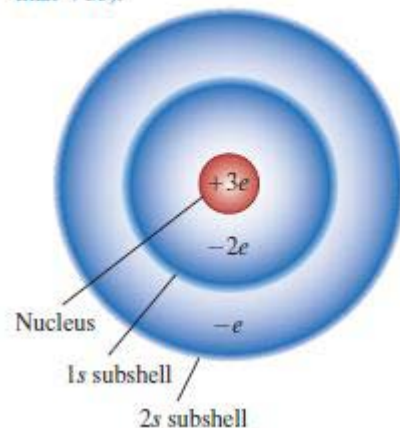
Periodic Table: In 1869, **Dimitri Mendeleev**, published organization of various elements then known based on their atomic mass, atomic number and periodicity of their chemical properties. Based on this logical organization of atoms he also lef some empty spaces for elements discovered later. Deeper understanding of atomic structure, has contributed to refinement and a structured organization of atomic table. It starts bare nucleus with Z protons and electrons incremented from the lowest energy state in an atom until its ground state Z electrons as per *Pauli Exclusion Principle*. Electrons in outermost orbit are principally involved in chemical interactions and are called **valence electrons**. Detailed discussions on periodic tables are excluded from this part on Physics, being central to part on Chemistry.

Bonding of Atoms: Presence of matter at atomic level is a reality, but not of immediate use unless it exists as a mass with ability to handle for better purposes. Thus coexistence of atoms, both similar and dissimilar, as a molecules has gained importance in study as **Molecular Bonds** and **Structure of Solids**. Molecular Bonds are classified as : **a)** *Ionic Bonds*, **b)** *Covalent Bonds*, **c)** *van der Walls Bonds*, **d)** *Hydrogen Bond*. This portion has an overlap with Chemistry, but in this part limits to only physics of bonds.

Ionic Bonds: Atoms in their natural form are electrically neutral. Nevertheless, dislodging of an electrons makes atom (+)ve ion and likewise, a free-electron on acceptance by another atom into its orbit makes negatively charged makes it (-) ion. Thus, two dissimilar ions develop an electrical affinity to co-exist as molecule and this type of bonding of atoms forming a molecule is called **Ionic Bonds**. Sodium Chloride (NaCl), known as common salt is an excellent example of Ionic Bond. The physics of this bond involves energy

balance in transaction of an electron between atoms of Sodium (looser of an electron) and Chlorine (gainer of an electron). Removing single electron in outermost orbit ($3s$ shell) of Sodium atom requires 5.138 eV of energy, and is called ***ionization energy*** of sodium atom. The neutral Chlorine atom attract an extra electron to fill in a vacancy in its outermost orbit ($3p$ shell) at a lower energy 3.613 eV, the ***electron affinity***. Thus combining two separated atoms of of Sodium and Chlorine creates an energy balance of 1.525 eV (=5.138-3.1613). When the electrons are brought together, electron clouds of both tend to overlap and thus creating a repulsion. This causes distortion of shells in accordance with *exclusion principle*. Minimum potential energy of NaCl atom is (-)5.7 eV. Thus net energy released in formation of NaCl molecule is 4.24 eV (=-5.7+1.525); the –ve value is expressed as release of energy. This net energy is also called ***binding energy*** of the molecule. Separation of constituent atoms from NaCl molecules would require 4.24 eV energy per molecule. Ionic Bond can involve more than One Electron for example magnesium chloride $Mg^{2+}(Cl^-)_2$.

Covalent Bond: egalitarian This type of bond is formed by equal sharing of electron and simplest of it is that of Hydrogen atom. When Two atoms of hydrogen, each having one electron in 1s shell, yet with a single vacancy, are brought together the electron cloud, and in turn the wave-function is distorted, thus it increases   concentration of protons in the region
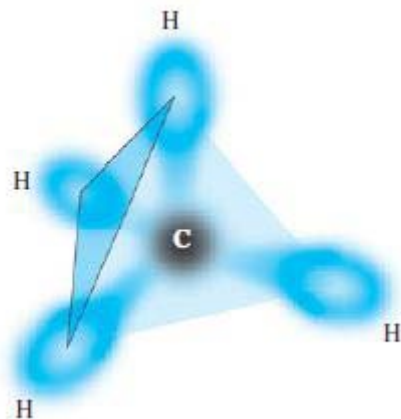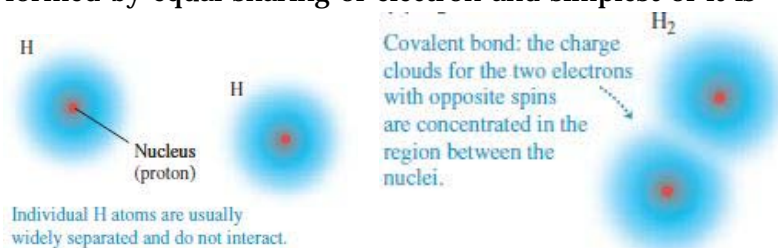
between two atoms. Net attraction of electron towards protons over powers repulsion of of the Two nuclei. *Bonding Energy* of Hydrogen molecule H_2 is (-)4.48 eV. Another, most commonly encountered example of covalent bond is between two dissimilar atoms viz. Carbon, with several electrons, and Hydrogen is Methane CH_4. Each of the Four electrons in L shell of carbon atom form covalent bond one Hydrogen atom. Wave function of four electrons of Carbon atom in $2s$ and $2p$ shells, *a hybrid wave function*, leads to lobes at vertices of a regular tetrahedron, maintaining spherical symmetry, as shown in the figure. This symmetry minimizes overlap of wave functions for electron pairs so as to minimize repulsive potential energy.

Ionic and covalent bonds are strong bonds based on co-sharing of electrons. But, covalent bonds forming lobes of atoms have partial transfer of electrons by dissimilar atoms leading to distinct concentration of (+) charges and (-) charges forming a ***electric dipole***, and corresponding *electric dipole moment*. Hydrogen atom is an excellent example and is shown in the figure.
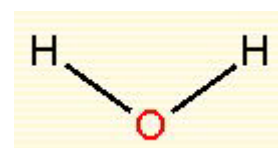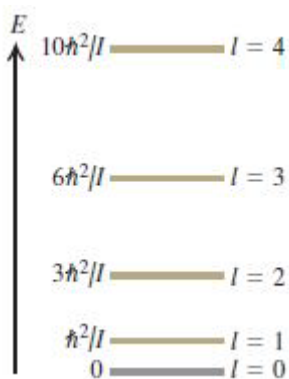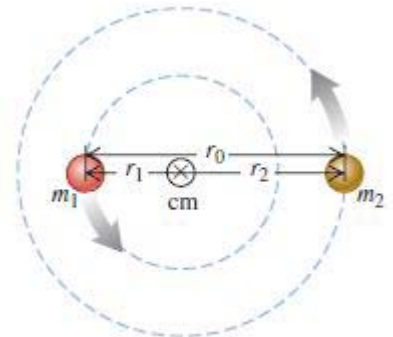
van der Walls Bonds: It is a weak bond and is based on dipole-dipole interaction of atoms or molecules having energy typically ≤ 0.1 ev. It occurs because of fluctuating charge distribution. The interaction potential energy being proportional to $\frac{1}{r^6}$ drops drastically with increase of r. Liquefaction of gases s due to induced dipole van der Walls interaction at low temperature, and little thermal agitation is enough to break this bond.

Hydrogen Bond: A proton is an ionized hydrogen atom (H^+). It combines with Two atoms polarizing them by means of induced dipoles. This is unique to hydrogen when ionized is left with no electron cloud. The bond energy is 0.5 ev and leads to cross linking of long chain of organic molecules.

Molecular Spectra: Molecular have energy associated with rotational energy of molecules as a whole and vibrational energy due to relative motion of atoms constituent atoms. Transition of energy between rotational and vibrational levels leads to molecular spectra.

Rotational Energy Levels: Diatomic molecules are considered for simplification of illustration As shown in the figure The Two molecules of mass m_1 and m_2 separated at a distance r_0 are like dumbbell, which is revolving with an angular velocity ω around their centre of mass (COM) of the two molecules. Each masse has radius as r_1 and r_2 of their orbits around COM. Thus angular momentum (L) of the rotating masses is $L = I\omega$, and its kinetic energy is $K = \frac{1}{2}I\omega^2 = \frac{L^2}{2\omega}$. Total energy of molecules since does not depend upon its coordinates and hence solution of SWE for rigid-body rotation is same as that for Hydrogen atom leading to quantization of angular momentum on identical lines $L = \sqrt{l(l+1)}\hbar$. Combining these two equations, leads to rotational energy levels (E_l) of diatomic molecules as $E_l = l(l+1)\frac{\hbar^2}{2I}$. These energy levels are shown in the diagram. The ground level has $l = 0$. As per principle of moments $m_1 r_1 = m_2 r_2$, and $r_0 = r_1 + r_2$. Accordingly, $r_1 = \frac{m_2}{m_1+m_2}r_0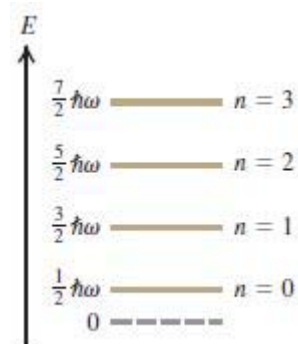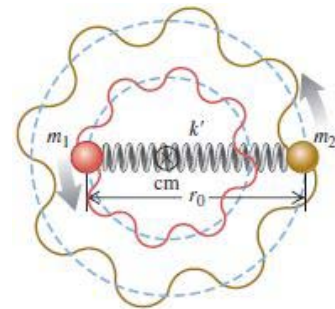$ and $r_2 = \frac{m_1}{m_1+m_2}r_0$. Thus moment of inertia of the system is $I = m_1\frac{m_2^2}{(m_1+m_2)^2}r_0^2 + m_2\frac{m_1^2}{(m_1+m_2)^2}r_0^2$. Thus, moment of inertia $I = \frac{m_1 m_2}{m_1+m_2}r_0^2 = m_r r_0^2$, accordingly, the effective mass is expressed as reduced mass $m_r = \frac{m_1 m_2}{m_1+m_2}$. Thus as per conservation of angular momentum, emitted or absorbed photon accounts for transition of state of atom such that $\Delta l = \pm 1$.

Vibrational Energy Levels: Molecules are like atoms connected at ends of a spring as shown in the figure, and are not rigidly coupled. This sets in vibrational motion, in addition to the rotational motion, of atoms of molecule, along the line of equilibrium. Since these motions are small, and hence for small oscillations resulting forces are taken in accordance with Hook's Law with a force constant k' and hence simple harmonic motion. Thus, energy levels with reduced mass (m_r) are given by $E_n = \left(n + \frac{1}{2}\right)\hbar\omega = \left(n + \frac{1}{2}\right)\hbar\sqrt{\frac{k'}{m_r}}$. This represents series of energy levels as shown below in the energy level diagram. Typically, for CO_2 molecule energy difference spacing $\Delta E = \hbar\omega$ between vibrational energy level is 0.2690 eV corresponding to a force constant $k' = 1.90 \times 10^3$ N/m, and it corresponds to a fairly loose spring. This force constant for diatomic molecules is about 100 to 2000 N/m. This elastic vibration of atoms in a molecules can be of different kinds viz bending mode, or stretching mode. In stretching mode it can be symmetrical stretching or asymmetrical stretching and is left for inquisitive readers to write through _CONTACT US_.

Rotational and Vibrational Energy Levels Combined: Photon of visible spectrum of light have energy in the range of 1.65 eV to 3.26 eV. Energy difference 0.2690 eV corresponds to a photon of $\lambda = 4.613 \ \mu m$. This wavelength is in the infrared region and is much closer to visible region. In general molecular spectra corresponds to much higher energy difference than that produced by transition of molecular vibrations and much lower than those produced by transition of molecular rotation. The combined energy of a diatomic molecule is arrived

at $E_{nl} = l(l+1)\frac{\hbar^2}{2I} + \left(n+\frac{1}{2}\right)\hbar\sqrt{\frac{k'}{m_r}}.$ Each value of n there are many values

of l and it leads to a series of closely spaced energy levels as shown in the figure. Each band corresponds to a particular vibrational transition, and each individual line in a band represents a particular rotational transition, in accordance with the selection rule $\Delta l = \pm 1$. Each molecule can exist in an excited state together with corresponding rotational and vibrational sates as discussed above. Energy associated with the excited states, called **electronic states**, are higher than the rotational and vibrational states. Thus, during transition between electronic states, the selection rule $\Delta n = \pm 1$ for vibrational states is not valid.
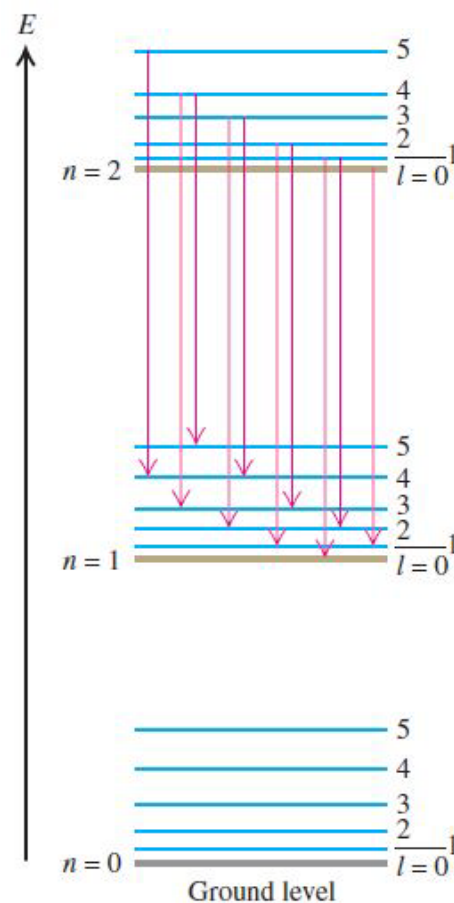
Structure of Solids: Solids and liquids, unlike gases, have strong interaction between atoms and molecules rendering them fixed volume for a given mass and are almost incompressible. Such a state of matter is called *condensed matter.* In this state distance between adjacent atoms are about 0.1 to0.5 nm and is of the order diameter of the atoms. This distance corresponds to distance between centre of nucleus of adjacent atoms. Solids retain definite shape with an exception to liquid which can flow to take shape of the container. Solids have arrangement of atoms and molecules in a definite arrangement called **crystals**, with an exception of amorphous solids like glass. Most common types of crystal are around square or hexagonal shapes in formations either of *face centered cube* (fcc), or *body centered cube* (bcc) or hexagonal close packed (hcp). Crystals in repeating patterns are called **lattice**, in which each point is a mathematical abstraction. Forces responsible for arrangement of atoms in crystal are like those in molecular bonds.
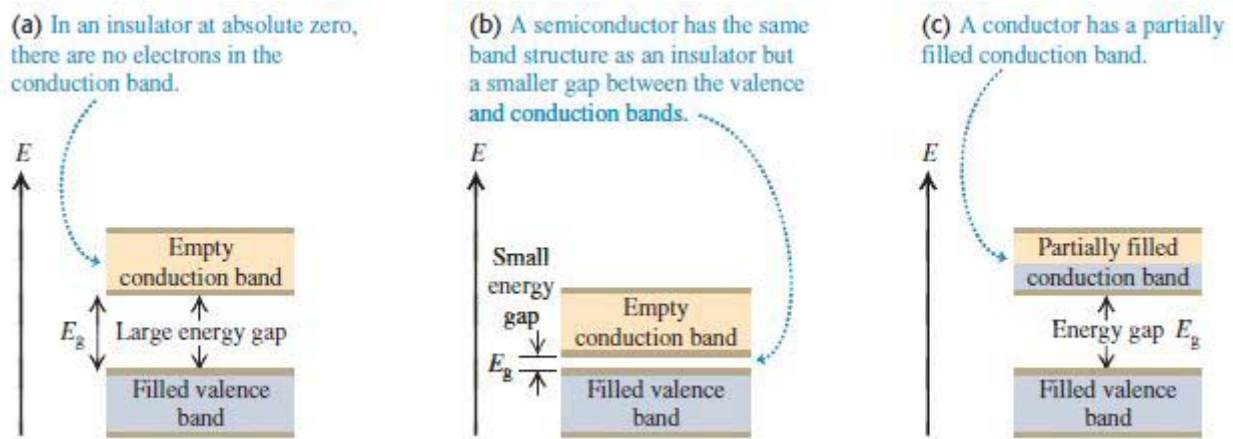
Carbon (C), silicon (Si), Germanium (Ge) and Tin (Sn) in diamond structure are simple examples of *covalent crystals* where each atom in the lattice bound to Four atoms at the vertices of the tetrahedron. The *tetrahedral diamond structure* is formed by strong directional bonds . It is a result of asymmetrical electron distribution regulated by exclusion principle.

Another type of crystal called metallic crystal in which One or more electron in each atom gets detached from parent atom leaving it to be (+)ve. These free electrons contribute to electrical and thermal conductivity of metals. In metallic crystals these free electrons are not localized and shared among many atoms. These detached electron move around like gas and is called *electron-gas model* of *free-electron model.*

Energy Bands: In 1928 Felix Bloch introduced concept of Energy Bands which helped to explain several properties of solids. It is based on large number of atoms in a material, at a distance far enough to make interaction negligible. In this system every atom has same energy-level diagram and is enough to consider as a single energy-level diagram of the entire system. Next, distance between atoms are reduced uniformly. This causes electrical interaction and brings in effect exclusion principle. It results in distortion of wave function of electrons and more so of the valence electrons. It causes shift in corresponding energies some upward and some

downward. Further increase in proximity of atoms make the wave function less localized and gradually extend from more atoms to whole metal as band containing large number of levels as much as the number of closely spaced atoms. The number being very large of the order of Avogadro's Number (10^{24}) the energy levels are treated as continuous distribution of energy within the band. Electrons in this band behave like **free electrons** in **conduction band** distinctly different from **valence band**. In this rearrangement electrons below valence shell are nearly unaffected so much so their sharp energy levels.

Electrical classification of material as **insulators, semiconductors and conductors** is based on its resistivity which was discussed and derived in section on **current electricity.** This was based on a premise of existence of *free electrons,* which has been discussed above. Explanation for distinct resistivity and its dependence on temperature for the three types of electrical materials is derived from energy gap between their conduction band and valence band, as shown in the figure.

(a) In an insulator at absolute zero, there are no electrons in the conduction band.

(b) A semiconductor has the same band structure as an insulator but a smaller gap between the valence and conduction bands.

(c) A conductor has a partially filled conduction band.

Free-Electron Model of Metals: Study of energy states is like discovering mystery of of electrical, magnetic, heat and other properties of matter. This study relates to *free-electron model* which assumes free electrons are completely free inside the material and do not interact with ions or other free electrons in the materials. It implies that these free electrons possess *uniform potential-energy function* giving them capability of *free-fast-random motion*. Nevertheless, there is a finite potential-energy barrier at the surface of the material which keeps them off from jumping out of surface in a normal way. Going back to quantum-mechanical model of cubical box, stationary states of definite energy are $E_{n_X, n_Y, n_Z} = \frac{(n_X{}^2 + n_Y{}^2 + n_Z{}^2)\pi^2\hbar^2}{2mL^2}$, here L is the side of cubical box, and n_X, n_Y, n_Z are three quantum numbers signifying state of free electron. Next is number of states Δn for a variation in energy in range ΔE which leads to density of states for a given energy is $\frac{dn}{dE} = \frac{\Delta n}{\Delta E}\Big|_{\Delta E \to 0}$. In a 3-D space with coordinates n_X, n_Y, n_Z shown in the figure, radius $n_{rs} = \sqrt{n_X{}^2 + n_Y{}^2 + n_Z{}^2}$ is of a sphere having centre at the origin in the space. Each point in the space with integer coordinates represent one *spatial-quantum-state*. Total number of points having integer coordinates in the spherical space having volume $= \frac{4}{3}\pi n_{rs}{}^3$. Considering spherical symmetry of volume of an octant shall be $\frac{1}{8}\left(\frac{4}{3}\pi n_{rs}{}^3\right) = \frac{1}{6}\pi n_{rs}{}^3$. Particles are electrons corresponding Two states with opposite, total number electrons shall be $n = 2 \times \frac{1}{6}\pi n_{rs}{}^3 = \frac{1}{3}\pi n_{rs}{}^3$. Energy of of states at the surface of the sphere, in terms of n_{rs} shall be $E = \frac{n_{rs}{}^2\pi^2\hbar^2}{2mL^2}$. It leads to number of states with energies $\leq E$ are $n = \frac{1}{3}\pi\left(\frac{2mL^2E}{\pi^2\hbar^2}\right)^{\frac{3}{2}} = \frac{(2m)^{\frac{3}{2}}VE^{\frac{3}{2}}}{3\pi^2\hbar^3}$, here volume of the cube $V = L^3$. Accordingly, **density of states** $g(E)$ of free electrons is $g(E) = \frac{dn}{dE} = \frac{(2m)^{\frac{3}{2}}V}{2\pi^2\hbar^3}E^{\frac{1}{2}}$.

Fermi-Dirac Distribution: Next mystery is about the distribution of electrons across various quantum states. The Maxwell-Boltzmann function defines relationship between average number of particles $n = e^{-\frac{E}{kT}}$, here E is the state of energy, T is the absolute temperature, and k is the Boltzmann's Constant. But, this distribution has not found use in analyzing *free-electrons* due to Two reasons. Firstly, it suggests that at *absolute Zero temperature* all electrons would occupy ground state and it is in contravention to the *exclusion principle.* Secondly, this distribution assumes all particles to be distinguishable to the extent that it is possible to tag each particle. But, overlapping of electrons in metals renders them indistinguishable. In 1926, **Enrico Fermi and Paul Dirac** combined Maxwell-Boltzmann statistical function with the indistinguishability criterion and is known as **Fermi-Dirac distribution** and is expressed as $f(E) = \frac{1}{e^{\frac{E-E_F}{kT}}+1}$, here, E_F is called **Fermi Energy** or **Fermi Level.** Typical graph of Fermi-Dirac distribution is shown in figure.
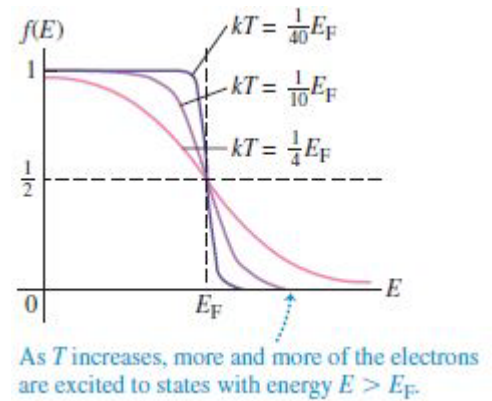
As T increases, more and more of the electrons are excited to states with energy $E > E_F$.

Electron Concentration and Fermi Energy: Probability of occupancy of any specific state with an electron with energy E at temperature T, determined by $f(E)$ given above. However, number of electrons dN, with their energies in range $dN = g(E)f(E)dE = \left(\frac{(2m)^{\frac{3}{2}}VE^{\frac{1}{2}}}{2\pi^2\hbar^3}\right)\left(\frac{1}{e^{\frac{E-E_F}{kT}}+1}\right)dE$. Fermi Energy E_F is determined by total number electrons to required to fill all electron-states. Simple relationship between E_{F0} at absolute Zero temperature and number of electrons N is $N = \frac{(2m)^{\frac{3}{2}}VE_{F0}^{\frac{3}{2}}}{3\pi^2\hbar^3} \rightarrow E_{F0} = \frac{3^{\frac{2}{3}}\pi^{\frac{4}{3}}\hbar^2}{2m}\left(\frac{N}{V}\right)^{\frac{2}{3}} = \frac{3^{\frac{2}{3}}\pi^{\frac{4}{3}}\hbar^2 n^{\frac{2}{3}}}{2m}$. Here, $\frac{N}{V}$ is called **electron concentration**, i.e. number of electrons per unit volume and is usually denoted by n. In this expressions, electron concentration n should be should be distinguished separately and not to be confused with quantum number n. So also number of states in general is not the number of electrons n

Average Free-Electron Energy: The concept of arriving at E_{F0} is extended to determine *average free-electron energy.* Energy of electrons in the energy range dE is $E \cdot dN = E \cdot (g(E)f(E)dE)$. At absolute Zero $f(E) = 1$ in the range of energy $0 \le E \le E_{F0}$ and $f(E) = 0$ for $F > E_{F0}$. Total energy of N electrons is:

$$E_{tot} = \int_0^{E_{F0}}(E \cdot g(E) \cdot 1)dE + \int_{E_{F0}}^{\infty}(E \cdot g(E) \cdot 0)dE = \int_0^{E_{F0}} E \cdot g(E)dE .$$

Using value of *Fermi Energy* $E_{F0} = \frac{3^{\frac{2}{3}}\pi^{\frac{4}{3}}\hbar^2 n^{\frac{2}{3}}}{2m}$ in *Electron Density* $g(E) = \frac{dn}{dE} = \frac{(2m)^{\frac{3}{2}}V}{2\pi^2\hbar^3}E^{\frac{1}{2}}$, leads to $g(E) = \frac{3NE^{\frac{1}{2}}}{2E_{F0}^{\frac{3}{2}}}$.

Simple definition of *Average Free-Electron Energy* provides $E_{av} = \frac{E_{tot}}{N} = \frac{3}{2E_{F0}^{\frac{3}{2}}}\int_0^{E_{F0}} E^{\frac{3}{2}}dE = \frac{3}{5}E_{F0}$. Thus an important conclusion derived here is that **Average Free-Electron Energy is equal to $\frac{3}{5}$ of Fermi Energy.**

Conclusion: The SWE, despite being outside the domain of the Mentors' Manual, this tpic has been stretched to the possible extent, within the domain of its mathematics. It has sufficiently laid-down concepts involved in remaining part of modern physics to covered in following section.

References:
1. *H.C. Verma; Concepts of Physics, (Vol 1 & 2).*
3. *Resnick, Halliday, Resnick andKrane; Physics (Vol I and II).*
4. *Sears &Zemansky; University Physics with Modern Physics.*
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Swamiji harmonized the East and the West, religion and science, past and present. And that is why he is great. Our countrymen have gained unprecedented self-respect, self-reliance and self-assertion from his teachings.

- *Netaji Subhash Chandra Bose*

GROWING WITH CONCEPTS - Chemistry

# VALENCE BOND THEORY

Kumud Bala

No doubt, VSEPR theory is able to explain the shapes of simple molecules but theoretically, it does not explain them and also it has limited applications. To overcome these limitations the two important theories based on quantum mechanical principles are commonly used. These are: Valence bond (VB) theory and Molecular orbital (MO) theory.

VALENCE BOND THOERY:- this theory was put forward by Heitler and London in 1927 and developed further by Pauling and J.C. Slater in 1931. The valence bond theory is based on the knowledge of atomic orbitals and electronic configuration of elements, the overlap criteria of atomic orbitals and stability of molecules. The basic assumptions of this theory are: (i) Atoms do not lose their identity even after the formation of the molecules. (ii) The bond is formed due to the interaction of only valence electrons as two atoms come close to each other. The inner electrons do not participate in the bond formation. (iii) During the formation of bond, only the valence electrons from each bonded atom lose their identity. The other electrons remain unaffected. (iv) The stability of bond is accounted by the fact that the formation of bond is accompanied by the release of energy. A stable molecule has minimum energy at a certain distance between atoms known as internuclear distance. Larger the decrease in energy, stronger will be the bond formed.

Formation of hydrogen molecule: Valence bond treatment for H_2 molecule:

(i) In terms of energy consideration- Consider two hydrogen atoms A and B approaching each other having nuclei H_A and H_B and the corresponding electron e_A and e_B respectively. When the two atoms are at large distance from each other, no interaction between the two atoms takes place. When two atoms come closer, new attractive and repulsive forces begin to operate.

(a) attractive forces between electron of atom A (e_A) and nucleus of atom B (H_B) and electron of atom B (e_B) and nucleus of atom A (H_A).
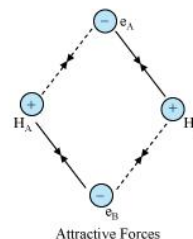

Attractive Forces

(b) repulsive forces between the nuclei H_A- H_B and electrons of atoms e_A- e_B .
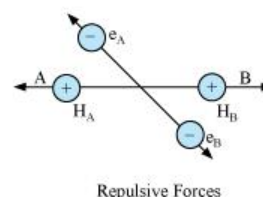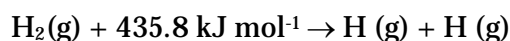

Repulsive Forces

Now, we know that attractive forces tend to bring the atoms closer while repulsive forces tend to push them apart. It has been observed experimentally that the magnitude of the new attractive forces is more than the new repulsive forces. As a result, the two atoms approach each other and the potential energy of the system decreases. As the two atoms come closer and closer, the system becomes more and more stable due to decrease of energy. Ultimately, a stage is reached where the total forces of attraction balance the forces of repulsion and the system acquires minimum energy. At this stage, the two hydrogen atoms are said to be bonded together to form a stable molecule and the distance (r_o) between the atoms is known as bond length.
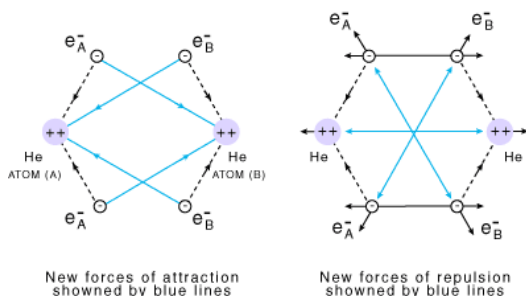

Electron-pair bond
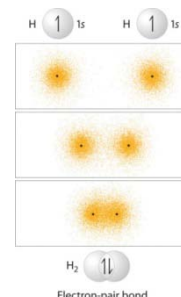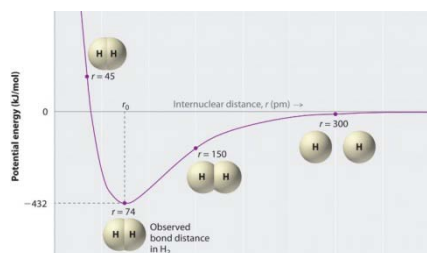
In case of hydrogen, it is 74 pm. When the two atoms are far apart, there is no attractive or repulsive interactions between them and the potential energy of the system (isolated atoms) is assumed to be zero. Thus, when the bond is formed, energy is released (H+H →H_2 +435.8 kJmol^{-1}) and therefore, the hydrogen molecule is more stable than the individual hydrogen atoms. The energy corresponding to minimum in the curve is called bond energy. When one mole of H_2 molecule is dissociated to hydrogen atoms, 435.8kJ of energy is needed.

$$H_2(g) + 435.8 \text{ kJ mol}^{-1} \rightarrow H(g) + H(g)$$

It may be remembered that the two hydrogen atoms cannot be brought closer than 74 pm because then the repulsive forces will become large and the potential energy would rise and causing unstability to H_2 molecule.

Why is helium molecule (He_2) not formed?
In case of helium molecule, each helium atom has two electron in its 1s orbital.When the two atoms start moving closer to each other, four new attractive forces and five new repulsive forces come into play. The attractive forces are between the two nuclei and the four electrons of the two atoms while out of the repulsive forces, one is between nuclei of the two atoms and the remaining four are among the electrons. As a result of these new interactions, repulsive force dominate over the attractive forces and so that energy of the system increases which leads to unstability. Thus, He_2 represent unstable state and a chemical bond is not formed between helium atoms. Hence, He_2 moleclue is not formed.

New forces of attraction
showned by blue lines

New forces of repulsion
showned by blue lines

(ii) **In terms of orbital overlap concept**:- According to this concept, lowering of energy takes place when two atoms approach each other and their outer orbitals merge partially . The overlapping of orbitals results in the pairing of electrons. The strength of a covalent bond depends upon the extent of overlapping. The greater the overlapping, the stronger is the bond formed between two atoms. let us consider the following examples:

a. **Formation of hydrogen molecule**:- When two hydrogen atoms having electrons with opposite spin come close to each other,their s-orbitals overlap with each other resulting in the union of two atoms to form a molecular orbital. The molecular orbital contain both the electrons. As a result, the two hydrogen atoms are held together in the form of a molecule.
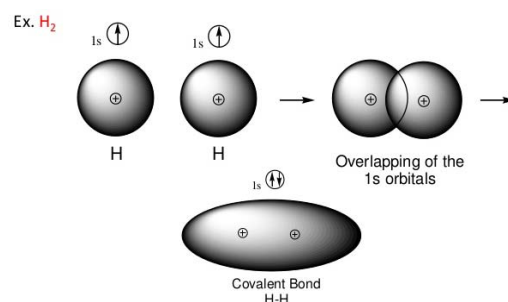
b. **Formation of hydrogen fluoride molecule:**- In case of formation of hydrogen fluoride molecule, when one atom of fluorine(electronic configuration: $1s^2 \, 2s^2 \, 2p_x^2 \, 2p_y^2 \, 2p_z^1$) having one unpaired electron in its p-orbital comes closer to hydrogen atom with electron of opposite spin in its 1s-orbital, then the two half-filled orbitals overlap each other and a chemical bond is formed between the two atoms.
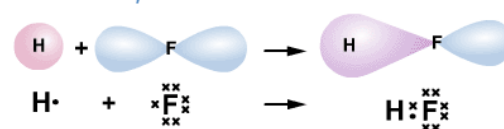

c. **Formation of fluoride molecule**:- when an atom of fluorine approaches another atom of fluorine having an electron of opposite spin in $2p_z$-orbital, the half-filled orbitals overlap each

other resulting in the formation of a fluorine molecule.

C. *p* orbital + *p* orbital ('head-on' overlap)
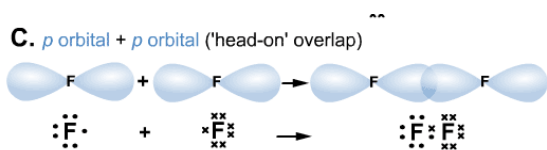
As the orbital involved in the overlaps are different, the extent of overlap is different and hence the strength is different. Their bond strength are in the order:

F-F<H-H<H-F
126<436< 566 (kJmol^{-1})
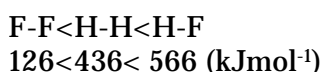
Type of overlapping and nature of covalent bonds

Depending upon the type of overlapping, the covalent bonds are divide mainlyin of two categories: Sigma(σ) bond and Pi (π) bond

Sigma bond :- when a bond is formed between two atoms by the overlap of their atomic orbital along the internuclear axis(end to end or head on overlap), the bond formed is called sigma(σ) bond. The overlapping along the internuclear axis can takes place in any one of the following ways:
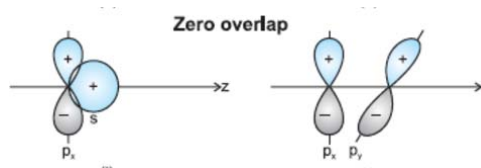
(a) s-s overlapping:- This type of overlapping takes place between atoms having half- filled s-orbital in their outer most energy shell. For example, in the formation of hydrogen molecule, 1s orbital of one hydrogen atom overlap with 1s orbital of other hydrogen atom thus forming a sigma bond.

(b) s- p overlapping :- in this case, half- filled s-orbital of one atom overlap with the half-filled p-orbital of another atom. A simple example of this type is the formation of hydrogen fluoride. Here, 1s orbital of hydrogen overlaps with $2p_z$ orbital of fluorine.

(c) p-p overlapping:- this type of overlapping occurs when p-orbital of one atom overlaps with the p-orbital of the other as in case of fluorine molecule. There is overlapping between $2p_z$ orbitals of the two fluorine atoms.
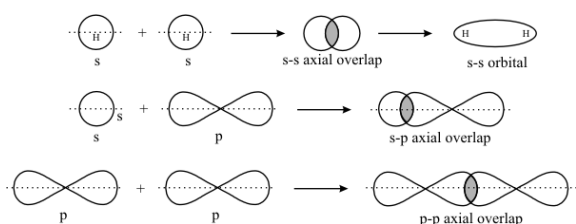

Note : If Z-axis is chosen as the internuclear axis, no overlapping can take place between s and p_x or p_y orbital or p_x and p_y orbitals, i.e., there is zero overlapping

Zero overlap

Pi(π) bond:- This type of covalent bond is formed by the sidewise (lateral) overlapping of half-filled p-orbitals of bonding atoms in a direction at right angles to the internuclear axis. The orbital obtained as a result of sidewise overlap consists of two saucer type charged clouds above and below the plane of the participating atoms.

p-orbital   *p*-orbital   *p-p* overlapping
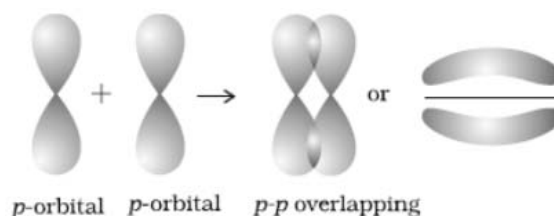
For example:- In case of oxygen molecule, the two oxygen atoms are held together by one σ bond and one π bond. (each oxygen atom having electronic configuration, $1s^2\ 2s^2\ 2p_x^2\ 2p_y^1\ 2p_z^1$)
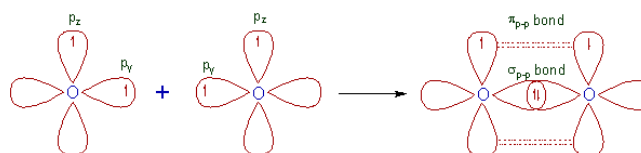

Strength of σ and π bonds:- strength of a bond depends upon the extent of overlapping. Since in the formation of σ bond, overlapping is along the internuclear axis, therefore there is considerable overlapping. Hence, the σ bond is a strong bond. On the other hand, in case of the formation of a π bond, sideway overlapping takes place which is only to a small extent. Hence,π bond is a weak bond. Further, as p-orbitals under greater overlapping than s-orbital, the expected order of the strength of sigma bond is: p-p > p-s > s-s

Symmetry of σ and π electron clouds:- Another important aspect about the σ and π-bonds is that where as in case of σ- bond, the electron cloud is symmetrical about the internuclear axis, in

case of π- bond, it is unsymmetrical, being more concentrated above and below the plane of the atomic nuclei.

Overlap of atomic orbitals:- the overlap between different types of s and p- orbital can be positive, negative or zero depending upon the properties of the overlapping atomic orbitals. For example, when two $2p_z$ orbitals overlap along the internuclear axis with the lobes of same sign, then positive overlapping occurs. On the other hand, when these two $2p_z$ orbitals overlap along the internuclear axis with the lobes of opposite sign, negative overlap occurs because lobes of opposite sign, cannot combine. Similarly, the different arrangements of s and p-orbitals overlap resulting in positive, negative and zero overlaps are shown below:
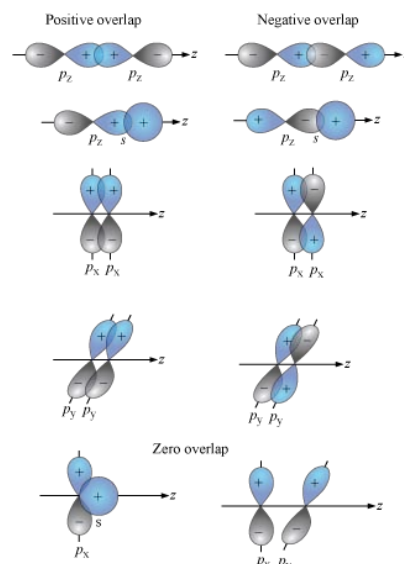
ASSIGNMENT

1. Out of σ and π- bonds, which one is stronger bond and why?
2. Considering z-axis as the internuclear axis, which of the following will not form sigma bond?
   (a) 2s and 2s (b) $2p_y$ and $2p_y$
   (c) 2s and $2p_z$ (d) $2p_x$ and $2p_z$
   (e) $2p_z$ and $2p_z$
3. Explain the formation of H_2 molecule on the basis of valence bond theory.
4. Why does type of overlap given in the following figure not result in bond formation?

5. Which one of the following statement is not correct for sigma and pi bond formed between two carbon atoms?
   (a) Sigma bond is stronger than pi bond.
   (b) bond energies of sigma and pi- bond are of the order of 264 kJ mol^{-1}
   (c) Free rotation of atoms around a sigma bond is allowed but not in case of a pi-bond.
   (d) Sigma bond determines the direction between carbon atoms but a pi-bond has no primary effect in this regard.

Answers: 2...(b) and (d)   5. (b)
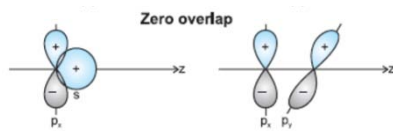
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—oo—

INVITATION FOR CONTRIBUTION OF ARTICLES

Your contribution in the form of an article, story poem or a narration of real life experience is of immense value to our students, the target audience, and elite readers of this Quarterly monthly e-Bulletin **Gyan-Vigyan Sarita:** *शिक्षा, and thus create a visibility of the concerns of this initiative. It gives target students a feel that you care for them, and they are anxiously awaiting to get benefitted by your contributions. We request you to please feel free to send your creation, by* **20th of this month** *to enable us to incorporate your contribution in next bulletin,* subhashjoshi2107@gmail.com.

We will be pleased have your association in taking forward path our plans as under-

➢ *With the start of Second year of operation, and reach to 2ⁿᵈ Supplement of 6ᵗʰ Quarterly e-Bulletin **Gyan-Vigyan Sarita: शिक्षा** shall be brought out 1ˢᵗ March'18.*

➢ *Theme of the e-Bulletin is Pi (π)Day*

➢ *And this cycle of monthly supplement sandwitching consecutive Quarterly e-Bulletin **Gyan-Vigyan Sarita: शिक्षा** is aimed to continue endlessly*

We believe that this monthly supplements to quarterly periodicity of e-Bulletins shall make it possible for our esteemed contributors to make contribution rich in content, diversity and based on their ground level work and/or experiences.

—00—

I have gone through his works very thoroughly, and after having gone through them, the love that I had for my country became a thousand-fold.
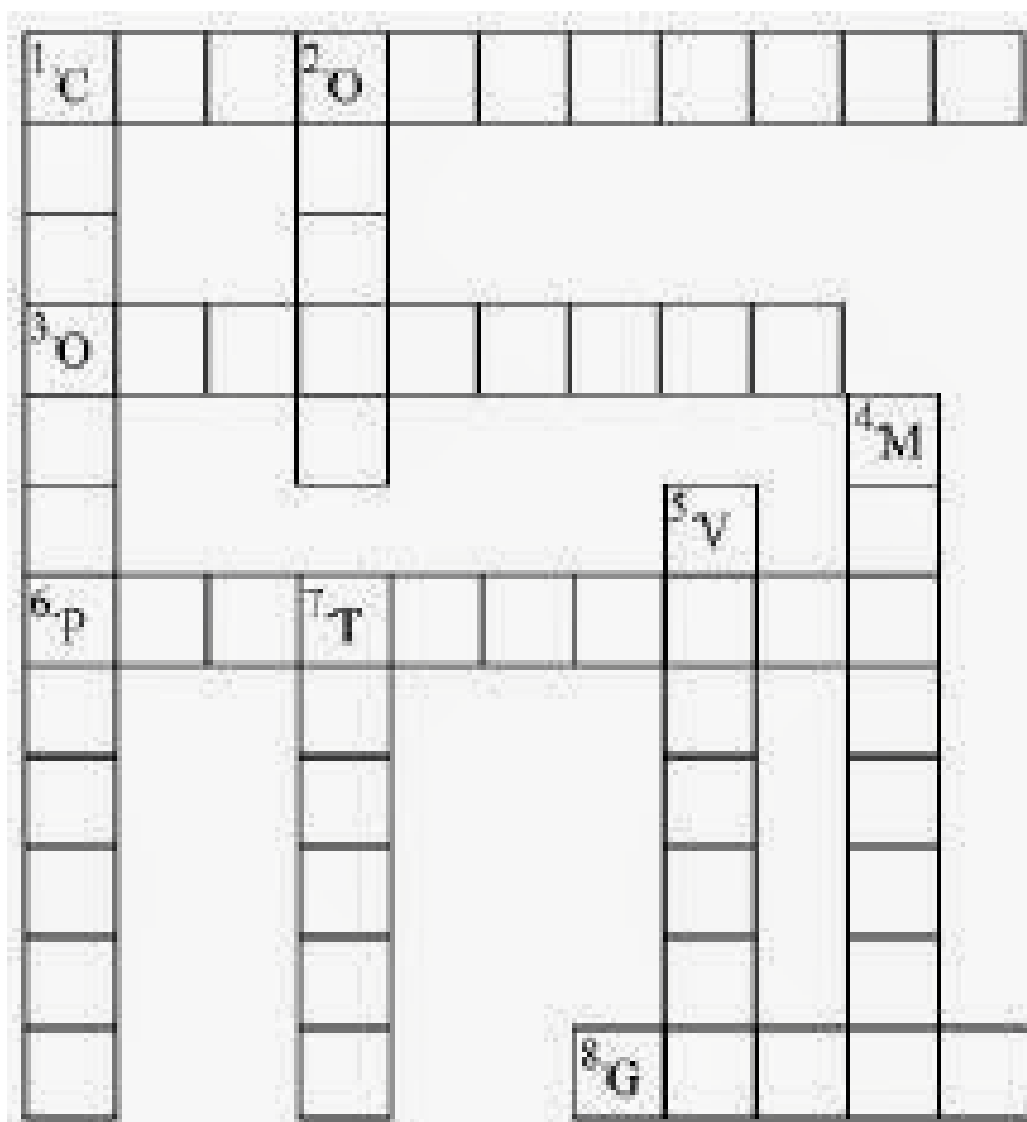
-Mahtma Gandhi

—00—

Answers to Science Quiz in Jan'17

Kumud Bala

1. (ii)   2. (i)   3. (iii)   4. (ii)   5. (i)   6. (iii)   7. (i)   8. (ii)   9. (i)   10. (i)   11. (ii)
12. (iii)   13. (ii)   14. (ii)   15. (iii)

—00—

SCIENCE QUIZ (Crossword Puzzle):Feb'18

Kumud Bala

Across

1.   This is necessary for photosynthesis

3.   Term for component present in the cytoplasm
6.   The living substance in the cell

8.   Unit of inheritance present on the chromosomes

Down

1.   Green plastids.

2.   Formed by collection of tissues
4   It separates the contents of the cell from the surrounding medium.

5.   Empty structure in the cytoplasm

8. A group of cells

(Answers to this Science Quiz (Crossword Puzzle) Feb'18shall be provided in Supplement e-Bulletin dt. 1st March'18)

—OO—

Theme Song :

<u>PREMISE:</u>*We are pleased to adopt a song*" इतनीशक्तिहमेंदेनादाता.….."*from a old Hindi Movie*Do Aankhen Barah Haath दोआँखेंबारहहाथof year 1957, directed by The Late V. Shantaram. The lyrics are by Shri Bharat Vyas, singer Melody Queen Sushri Lata Mangeshkar, and Music Direction by Vasant Desai. It has become a widely accepted inspirational song and/or prayer in many educational institutions and socially inspired initiatives engaged in mentoring of unprivileged children. This newly formed non-organizational initiative, being selflessly operated by a small set ofcompassionate persons, finds its philosophy in tune with the song and conveys its gratitude to all he eminent persons who brought out the song in a manner that it has attained an epitome of popularity. While working its mission and passion, the group invites one and all to collectively complement in grooming competence to compete among unprivileged children. The song/prayer goes as under -*

इतनीशक्तिहमेंदेनादाता, मनकाविश्वासकमजोरहोना

हमचलेनेकरस्तेपेहमसे, भूलकरभीकोईभूलहोना ||

दूरअज्ञानकेहोअंधेरे, तूहमेंज्ञानकीरोशनीदे

हरबुराईसेबचतेरहेंहम, जितनीभीदेभलीज़िन्दगीदे

बैरहोनाकिसीकाकिसीसे, भावनामनमेंबदलेकीहोना ||

इतनीशक्तिहमेंदेनादाता, मनकाविश्वासकमजोरहोना

हमचलेनेकरस्तेपेहमसे, भूलकरभीकोईभूलहोना ||

हमनासोचेंहमेंक्यामिलाहै, हमयेसोचेकियाक्याहैअर्पण

फूलखुशियोंकेबाँटेसभीको, सबकाजीवनहीबनजाएमधुबन

अपनीकरुणाकाजलतूबहाके, करदेपावनहरएकमनकाकोना ||

इतनीशक्तिहमेंदेनादाता, मनकाविश्वासकमजोरहोना

हमचलेनेकरस्तेपेहमसे, भूलकरभीकोईभूलहोना ||

Together Each Achieves More (TEAM)

Every end, so also end of this e-Bulletin, is a pause for a review, before resumingof the journey far beyond …