University of Mumbai Examination

Program: _First Year (All Branches) Engineering - SEM-II
Curriculum Scheme: Rev 2019
Engineering Physics-II

Question Bank

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Q1.	**Choose the correct option for following questions. All the Questions are compulsory and carry equal marks**
1.	In holography, which of the following optical phenomena are involved?
Option A:	interference, diffraction
Option B:	polarization, diffraction
Option C:	interference, refraction
Option D:	reflection, diffraction
	Interference, diffraction
2.	By observing the diffraction pattern, the two spectral lines are said to be just resolved when _________
Option A:	The central maxima of one coincides with central maxima of the other
Option B:	The central maxima of one do not coincide with first maxima of the other
Option C:	The central maxima of one coincides with the first minimum of the other
Option D:	The central maxima of one do not coincide with the first minimum of other
	The central maxima of one coincides with the first minimum of the other
3.	A step-index fibre has a numerical aperture of 0.26, a core refractive index of 1.5 and a core diameter of 100 μ m. Calculate the acceptance angle.
Option A:	1.47 degree
Option B:	15.07 degree
Option C:	2.18 degree
Option D:	24.15 degree
	15.07 degree
4.	Find the divergence of the field $\bar{F} = 30\hat{\imath} + 2xy\hat{\jmath} + 5xz^2\,\hat{k}$ in Cartesian co-ordinates
Option A:	2x(1+5Z)
Option B:	2x(1+5k)
Option C:	12
Option D:	10
	2x(1+5Z)
5.	Which ratio decides the efficiency of nano substances?
Option A:	Weight/volume
Option B:	Surface area/volume
Option C:	Volume/weight
Option D:	Pressure/volume
	Surface area/volume
6.	_____________ transformation are replaced by the Lorentz transformation which confirms the postulate of relativity
Option A:	Galilean
Option B:	Maxwell
Option C:	Planck's
Option D:	Newtons
	Galilean
7.	Maximum number of orders available with a grating is
Option A:	Independent of grating element.

Option B:	Directly proportional to grating element.
Option C:	Inversely proportional to grating element
Option D:	Directly proportional to wavelength.
	Directly proportional to grating element.
8.	In holography
Option A:	only phase information is recorded
Option B:	only amplitude information is recorded
Option C:	both phase and amplitude get recorded
Option D:	neither phase nor amplitude gets recorded
	both phase and amplitude get recorded
9.	Find the value of “a” for which the vector 3i+2j+9k and i+aj+3k are perpendicular
Option A:	-40
Option B:	-13
Option C:	-15
Option D:	-10
	-15
10.	Calculate acceptance angle for an optical fibre whose core R.I.is 1.48 & cladding R.I.is 1.39
Option A:	10^0
Option B:	40.5^0
Option C:	30.5^0
Option D:	20^0
	30.5^0
11.	An object whose length is 60m moves at a speed of 0.6 c. What is the length of the object according to a stationary observer?
Option A:	48m
Option B:	60m
Option C:	21m
Option D:	40m
	48m
12.	Scanning Electron Microscope (SEM) produces
Option A:	3-dimensional image
Option B:	2-dimensional image
Option C:	4-dimensional image
Option D:	6-dimensional image
	3-dimensional image
13.	What is the principle of fibre optical communication?
Option A:	Frequency modulation
Option B:	Population inversion
Option C:	Total Internal Reflection
Option D:	Doppler effect
	Total Internal Reflection
14.	The radiation emission process (emission of a photon at frequency) can occur in ___________ ways.
Option A:	Two
Option B:	Three
Option C:	Four
Option D:	One
	Two
15.	Which property of nanoparticles provides a driving force for diffusion?

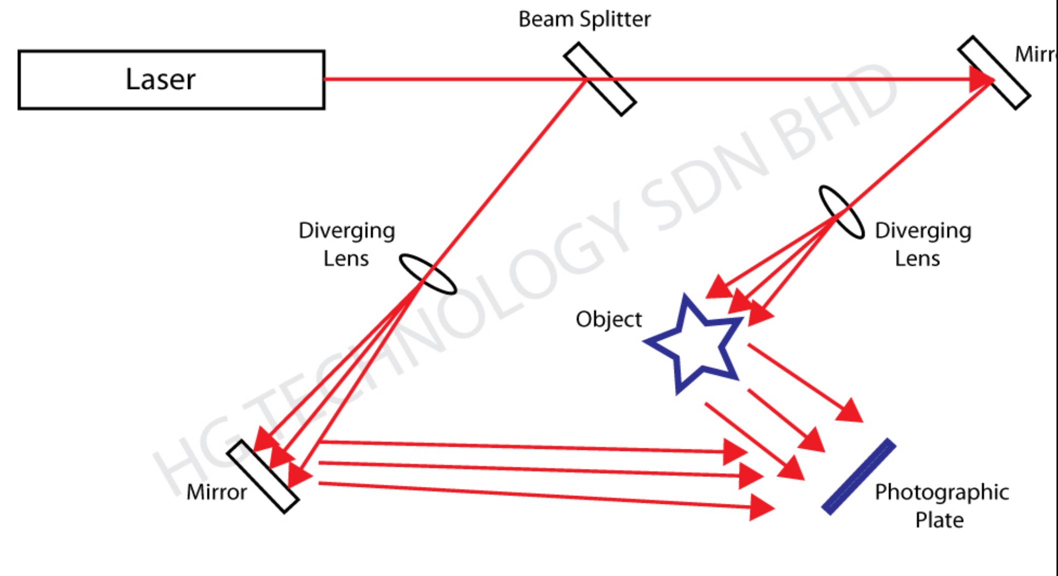
Option A:	Optical Properties
Option B:	High surface area to volume ratio
Option C:	Sintering
Option D:	There is no such property
	High surface area to volume ratio
16.	If 'a' is the width of the slits and b the distance between the slits, then a + b is called as __________
Option A:	Opacities
Option B:	Grating constant
Option C:	Transparency
Option D:	Lattice constant
	Grating constant
17.	Which of the following is not an example of bottom-up approach for the preparation of nanomaterials?
Option A:	Sol-Gel
Option B:	Molecular self-assembly
Option C:	Mechanical grinding
Option D:	Chemical Vapour Deposition
	Mechanical grinding
18.	A beam of monochromatic light is incident on a plane transmission grating having 5000 lines/cm and the second order spectral line is found to be diffracted at 30°. The wavelength of the light is ________
Option A:	4000 Å
Option B:	5000 Å
Option C:	6000 Å
Option D:	7000 Å
	5000 Å
19.	The length of a rod in a moving frame will be _____________ to the observer in a rest frame.
Option A:	Unchanged
Option B:	Dilated
Option C:	Contracted
Option D:	Doubled
	Unchanged
20.	Where type of pumping is used in ND: YAG Laser?
Option A:	Electrical pumping
Option B:	Direct conversion
Option C:	Collision of electron
Option D:	Optical pumping
	Optical pumping
21	A frame of reference has four coordinates, x, y, z, and t is referred to as the______________
Option A:	Inertial frame of reference
Option B:	Non-inertial frame of reference
Option C:	Space-time reference
Option D:	Four-dimensional plane
	Space-time reference
22.	The total electric flux through any closed surface surrounding charges is equal to the amount of charge enclosed". The above statement is associated with
Option A:	Coulomb's square law
Option B:	Gauss's law
Option C:	Maxwell's first law
Option D:	Maxwell's second law
	Gauss's law

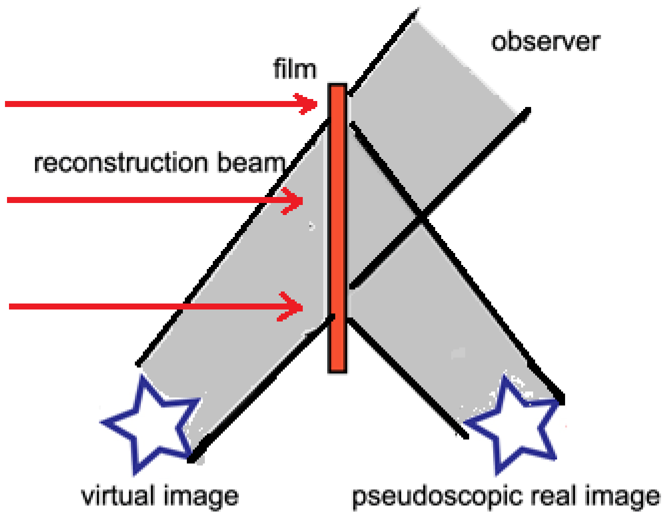
23.	Maxwell's equation derived from Faraday's law is
Option A:	$\vec{\nabla} . \vec{H}$= J
Option B:	$\vec{\nabla} . \vec{D}$= I
Option C:	$\vec{\nabla} \times \vec{E}$= −dB/dt
Option D:	$\vec{\nabla} \times \vec{B}$= −dH/dt
	$\vec{\nabla} \times \vec{E}$= −dB/dt
24.	A vector V is irrotational if
Option A:	$\vec{\nabla} . \vec{V} = 0$
Option B:	$\vec{\nabla} \times \vec{V} = 0$
Option C:	$\vec{\nabla} . \vec{V} = \vec{\nabla} \times \vec{V}$
Option D:	$(\vec{\nabla} \times \vec{V})$. V=0
25.	According to Einstein theory of relativity, _____________ in vacuum is the same in every inertial frame.
Option A:	the speed of light
Option B:	the intensity of light
Option C:	the speed of particle
Option D:	the mass of particle
	the speed of light
26.	Which of the following Einstein's coefficient represents stimulated emission
Option A:	A_{12}
Option B:	A_{21}
Option C:	B_{12}
Option D:	B_{21}
	B_{21}
27.	What is the effective distance between the source of light and the screen in Fraunhofer Diffraction?
Option A:	Focal length of the convex lens
Option B:	Less than Focal Length of the convex lens
Option C:	Greater than the focal length of the convex lens and less than infinite
Option D:	Infinite
	Focal length of the convex lens
28.	Pumping is done in order to achieve
Option A:	Steady state
Option B:	Population inversion
Option C:	Equilibrium
Option D:	Photon emission
	Population inversion
29.	The Maxwell's equation, $\vec{\nabla} . \vec{B} = 0$ signifies
Option A:	No electric field
Option B:	Non-existence of a mono pole
Option C:	Variation of magnetic field
Option D:	No magnetic field
	No magnetic field
30.	Nanomaterials are the materials with at least one dimension measuring less than
Option A:	1nm
Option B:	10nm
Option C:	100nm
Option D:	1000nm
	100nm
31.	What is the meaning of grating element for a diffraction grating
Option A:	It is the width of a single slit
Option B:	It is the width of the opaque space

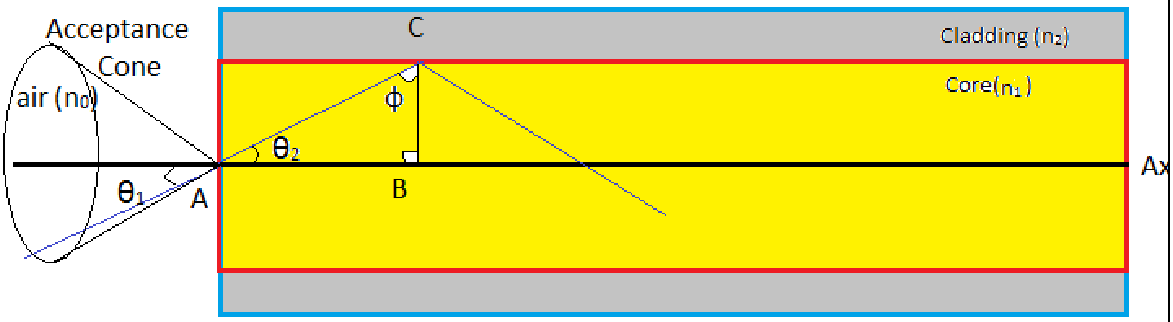
Option C:	It is the distance between two slits
Option D:	It is the width of diffraction grating
	It is the distance between two slits
32.	Which of the following is an example of top-down approach for the preparation of nanomaterials?
Option A:	Gas phase agglomeration
Option B:	Molecular self-assembly
Option C:	Ball milling
Option D:	Sol-Gel
	Ball milling
33.	The numerical aperture of a fiber if the angle of acceptance is 15 degrees, is
Option A:	0.17
Option B:	0.26
Option C:	0.50
Option D:	0.75
	0.26
34.	According to Einstein's Special Theory of Relativity, laws of physics can be formulated based on
Option A:	Inertial Frame of Reference
Option B:	Non-Inertial Frame of Reference
Option C:	Both Inertial and Non-Inertial Frame of Reference
Option D:	Quantum State
	Inertial Frame of Reference
35.	Maximum number of modes supported in step index fibre is ________.
Option A:	$\frac{V^2}{2}$
Option B:	$\frac{V^2}{3}$
Option C:	$\frac{V^2}{4}$
Option D:	$\frac{V}{2}$
	$\boldsymbol{\frac{V^2}{2}}$
36	Which type fibre can overcome multimode dispersion?
Option A:	step index fibre
Option B:	graded index fibre
Option C:	single mode step index fibre
Option D:	multi mode step index fibre
	graded index fibre
37.	Which of the following is Einstein's mass energy relation?
Option A:	$E_k = (m - m_0)c^2$
Option B:	$E = mc^2$
Option C:	$E^2 - p^2c^2 = m_0^2c^4$
Option D:	$E_k = mv^2/c^2$
	$\mathbf{E_k = (m - m_0)c^2}$
38.	What is the region enclosed by the optical cavity called?
Option A:	Optical Region
Option B:	Optical System
Option C:	Optical box
Option D:	Optical Resonator
	Optical Resonator
39.	Which of the following is not a property of emitted light in stimulated emission?
Option A:	Incoherent

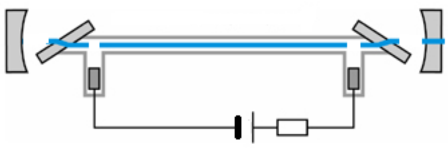
Option B:	Unidirectional
Option C:	Monochromatic
Option D:	high intensity
	Incoherent
40.	In semiconductor diode laser, the lasing action takes place when the diode is _______
Option A:	Unbiased
Option B:	reverse biased
Option C:	forward biased
Option D:	in equilibrium
	forward biased

Descriptive Questions

1.	Explain the construction and reconstruction of hologram.
ANS	Holography means complete recording. In this technique a light wave is a carrier of information and is recorded in terms of wave parameters: amplitude and phase component. The basic principle of holography can be explained in two steps. 1. Recording of Hologram 2. Reconstruction of image 1) **Recording of Hologram:** Holography is in principle an interference based technique and hence light wave with high degree of coherence are required for its realization. A laser beam is divided by a beam splitter S into two beams A and B. The transmitted beam B illuminates the object whose hologram is to be recorded and a part of the light scattered by the object impinges on a photographic plate. The reflected beam A which is called the reference beam, also falls on the photographic plate. The superposition of these two beams produces an interference pattern which is recorded on the plate. The pattern is very fine. The spacing between the fringes is as small as 0.001mm. The developed plate is known as hologram.  **Figure 1: Hologram Recording Process** **2) Reconstruction of image:** If now the object is removed and the hologram is put in the place where it was formed, the laser beam which is now known as read out

	wave interacts with the interference pattern. On the plate and two images are produced by the diffracted waves. One of them appears at original position occupied by the object and other (real image) which can be photographed directly without using lens. The virtual image is seen by looking through the hologram as if it were a window. The image will appear in complete three dimensional forms. It is possible to see the other side object as if object is really before the observer. But since it is a virtual image nobody can touch it and not possible to photograph it. 
2.	Explain top down and bottom up approaches to prepare nanomaterials.
ANS	Top-down Approach: Top-down approach is mainly an extension to microelectronics. In this method large scale object is progressively reduce its dimensions. It consists of ultra-fine micromachining of materials using lithography, epitaxy and etching. The process is similar to making a sculpture from a stone. This method is time consuming and comparatively costly. Bottom-up Approach: Bottom-up Approach is a mimic of the way how the nature builds up biological cells. In this method start by consolidation of atoms or molecules and build up into complex structure of nanomaterials. It consists of chemical synthesis such as soft chemical methods and self-assembly of molecular structure. This is relatively cheaper.
3.	Light is incident normally on a grating 0.25 cm wide with 1250 lines. Find the angular separation of the two sodium lines in the first order spectrum. Can they be seen distinctively if the lines are 5895 Å & 5901 Å.
ANS	Given: l = 0.25 cm Number of lines = 1250 lines, $\lambda_1 = 5895$ Å, $\lambda_2 = 5901$ Å $(a+b)sin\Theta = n\lambda$ $a+b = \frac{l}{number\ of\ lines} = \frac{0.25}{1250} = 2*10^{-4}cm$ $\Theta_1 = \sin^{-1}\left(\frac{n\lambda}{a+b}\right) = \sin^{-1}\left(\frac{1*5895*10^{-8}}{2*10^{-4}}\right) = 17.14^0$ $\Theta_2 = \sin^{-1}\left(\frac{n\lambda}{a+b}\right) = \sin^{-1}\left(\frac{1*5901*10^{-8}}{2*10^{-4}}\right) = 17.16^0$ Resolving power of grating = n N=1*1250 = 1250 Resolution required to see the lines distinctively = $\frac{\lambda}{d\lambda}$ Average wavelength = $\frac{5895+5901}{2} = 5898$ Å $\frac{\lambda}{d\lambda} = \frac{5898}{5901-5895} = 983$

	Since resolving power of grating is greater than $\frac{\lambda}{d\lambda}$, the lines can be seen distinctively.
4.	Derive the expression of numerical aperture for a step index fiber. A light ray enters an optical fiber from air. The fiber has core refractive index 1.52 and cladding refractive index 1.41. Find the Critical angle and Numerical aperture.
ANS	*Numerical aperture* gives us the relationship between refractive indices of the three media involved in the propagation of light and acceptance angle. So relationship between n_0, n_1, n_2 and θ_a is called numerical aperture. Consider the step index fibre in which the ray of light is incident at air core interface an angle of θ_1 which is smaller than the acceptance angle on the axis of the fibre. This ray of light is refracted through an angle θ_2.  If θ_1 is smaller than the acceptance angle θ_a, the refracted ray is incident on the core-cladding interface at an angle ϕ, which must be greater than the critical angle so the ray will totally internally reflect into the same medium. Let n_0 be the refractive index of the air medium from which the light ray is incident through optical fibre. Let n_1 & n_2 be the refractive index of core and cladding respectively. Let us apply Snell's law to the air core interface. According to the Snell's law, $$n_0 \sin\theta_1 = n_1 \sin\theta_2$$ From right angle triangle Δ ABC, the above equation can be written as, $$n_0 \sin\theta_1 = n_1 \sin(90 - \emptyset)$$ $$n_0 \sin\theta_1 = n_1 \cos\emptyset$$ By applying limiting cases to the above equation, θ_1 becomes θ_a and ϕ becomes ϕ_c. Hence the above equation can be written as, $$n_0 \sin\theta_a = n_1 \cos\emptyset_c$$ $$n_0 \sin\theta_a = n_1\sqrt{1 - \sin^2_{\emptyset_c}}$$ Since, $\sin\emptyset_c = \frac{n_2}{n_1}$ at core cladding interface, the above equation can be written as, $$n_0 \sin\theta_a = n_1\sqrt{1 - \frac{n_2^2}{n_1^2}}$$ $$n_0 \sin\theta_a = \sqrt{n_1^2 - n_2^2}$$ $$NA = n_0 \sin\theta_a = \sqrt{n_1^2 - n_2^2}$$
5.	Find the divergence and curl of a vector $\vec{A} = x^2\, y\, \hat{i} + (x-y)\, \hat{k}$.
ANS	Given: $\vec{A} = x^2\, y\, \hat{i} + (x-y)\, \hat{k}$ $$Div\,\vec{A} = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right).\left(x^2\, y\, \hat{i} + (x-y)\hat{k}\right)$$ $$= \frac{\partial\,(x^2\, y)}{\partial x} + \frac{\partial\,(x-y)}{\partial z}$$ $$= 2xy$$

	$$Curl\,\vec{A} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ x^2\,y & 0 & (x-y) \end{vmatrix}$$ $$= \hat{i}\left(\frac{\partial(x-y)}{\partial y} - \frac{\partial\,0}{\partial z}\right) - \hat{j}\left(\frac{\partial\,(x-y)}{\partial x} - \frac{\partial\,x^2\,y}{\partial z}\right) + \hat{k}\left(\frac{\partial\,0}{\partial x} - \frac{\partial\,x^2\,y}{\partial y}\right)$$ $$= -\,\hat{i} - \hat{j} - x^2\,\hat{k}$$
6.	State the advantages of optical fiber cables on conventional electrical cables.
ANS	I. Optical fibers are made with glass or plastic, which is abundantly available materials so low processing cost as compare to conventional cables II. Optical fiber cables are smaller in size and lighter in weight as compare to conventional electrical cables. III. There is no problem of corrosion due to air or water. Optical fibers have almost 100 years of life once installed. IV. Optical fibers are made from non-conducting materials so they do not cause short circuit, sparking or ignitions. V. As OFC are made from non-conducting materials, they do not act as antennas for unwanted external electromagnetic signals and unlike electrical wires they do not cause radio frequency noise. VI. Transmission loss for OFC is very small. A transmission network requires repeater units every 50-100km as compared to 2km for electric cables.
7.	What are different techniques to synthesize nanomaterials? Explain any one of them in detail.
ANS	Synthesis of nanoparticles can also be classified into physical and chemical methods. **Ball milling method:** This method is basically used to prepare nanoparticles of metals and alloys in the form of powder. Ball mills are equipped with grinding media composed of hardened steel balls. Ball mills rotate around a horizontal axis, partially filled with the material to be ground plus the grinding medium. The balls rotate with high speed inside a drum and then fall on the solid with the gravity force and crush the solid into nano crystallites. The significant advantage of this method is that it can be readily implemented commercially. Ball milling can be used to make carbon nanotubes. It is commonly used to prepare metal oxides nano crystals like Cerium Oxide (CeO2) and Zinc oxide (ZnO).
8.	With neat energy level diagram describe the construction and working of a He-Ne Laser. What are its merits and demerits? What is the role of helium atoms?
ANS	Gas lasers are the most widely used lasers. The first gas laser was He-Ne laser, which was invented in 1961 by Ali Javan, William R. Bennett. These lasers operate with rarefied gases as the active media and are excited by an electric discharge. **Construction:**  Helium Neon laser is a continuous wave output laser. He-Ne gas is filled in a discharge tube at a pressure 1 torr and 0.1 torr. The chamber consists of a long quartz tube of length 80cm and inside diameter is 1.5cm. At each end of the tube there was a metal chamber containing high reflection plates. The primary mechanism for excitation used in gas laser is by electron impact. The pumping used to excite the electron is electrical pumping. **Working:** When the discharge pass through the gas mixture, accelerated electrons collide with Helium atoms and excite them to different higher energy state. Some of the helium

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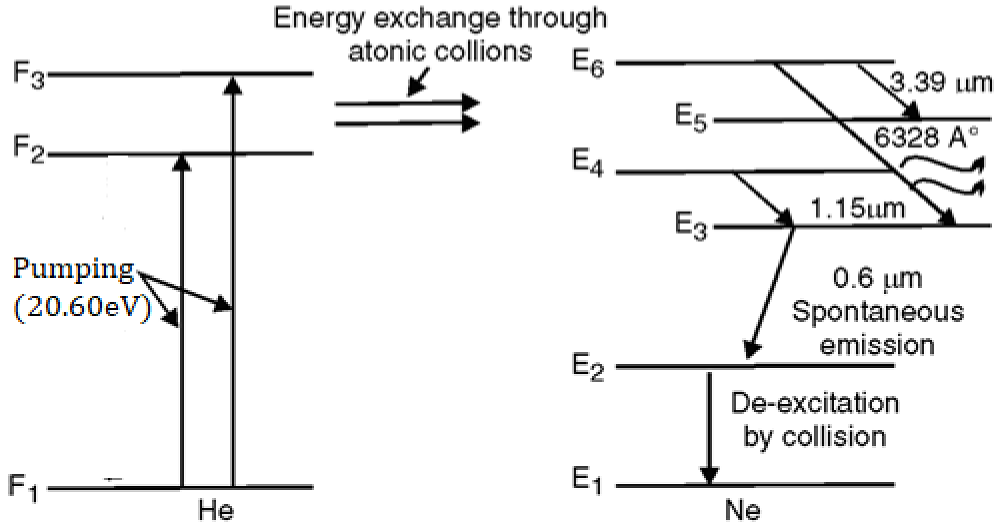
atoms are excited to the levels F_2 and F_3 which happen to be metastable state, so the helium atoms excited to those levels spend a long time before getting de-excited. Thus gradually a large number of helium atoms will accumulate in the states F_2 and F_3. Now the excited state E_6 and E_4 of neon correspond exactly same energy as F_2 and F_3 of helium. So when excited helium atoms collide with unexcited neon atoms an energy transfer takes place. The neon atoms directly excited to E_6 and E_4 energy levels and helium atoms de-excited to ground energy level. Population inversion achieved between levels E_6, E_4 and the lower levels E_5 & E_3 in neon. Once population inversion is achieved any spontaneously emitted photon can trigger laser action.

The transition E_6 - E_5 gives a laser of wavelength 3.39μm, $E_4 - E_3$ gives a laser of wavelength 1.15 μm and $E_6 - E_3$ gives a laser of wavelength 6328A^0. The first two are in the infra-red region whereas 6328A^0 is the well known red light from He-Ne laser.

He-Ne laser normally requires 5 to 10mW of excitation power and produces 0.5 to 50mW of laser output. It is also called a gas laser, since it is originating from a He-Ne gas mixture. He-Ne laser is a continuous output laser.



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<tr><td>9.</td><td>

Discuss the phenomenon of Fraunhofer's diffraction at a single slit and obtain the condition for the first minimum. Calculate the maximum order of diffraction maxima seen from plane transmission grating with 2500 lines per inch if light of wavelength 6900 Å falls normally on it.

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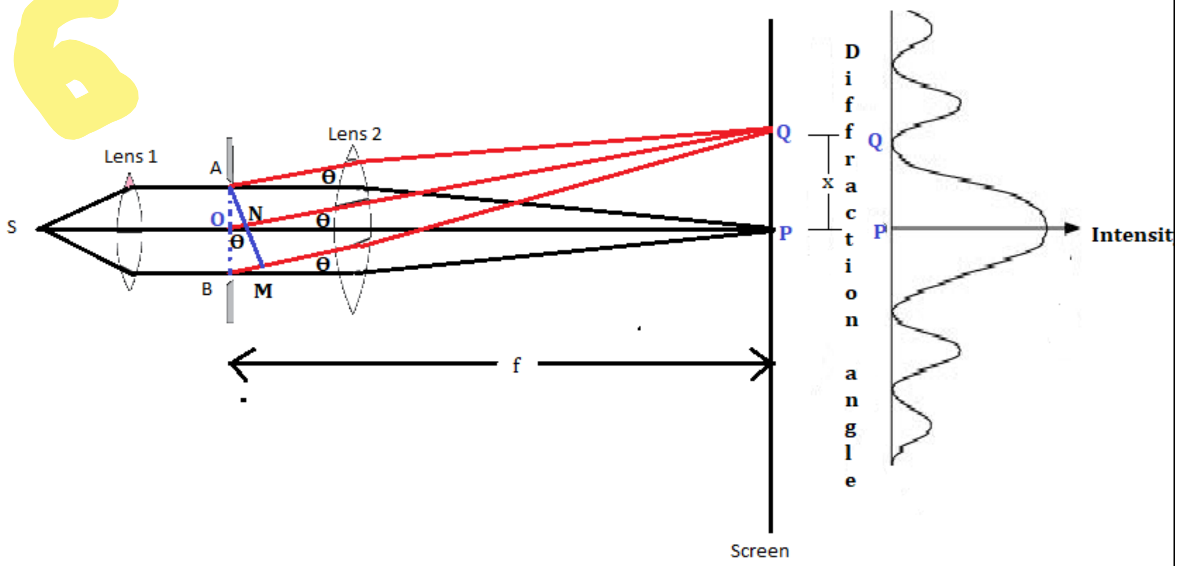

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The arrangement to obtain the diffraction condition due to single slit in Fraunhoffer diffraction is shown in the above diagram. Consider the narrow slit AB of width ‘a’ illuminated by monochromatic light of wavelength λ. The light emitted by source gives a spherical wave front which converts into plane wave front when it passes through lens 1. Plane wave front is incident on slit of width ‘a’ at normal incidence. According to the Huygens’s principle each and every point in the slit will act as the secondary source of light which will emit secondary waves in all possible (forward) direction. The secondary wavelet travelling in their original direction will focus at point P. For all the rays which focus at point P optical path difference will be zero. Hence they produce central maximum intensity at point P. It is at the centre of diffraction pattern and is also called as 0^{th} order central maxima.

The secondary wavelets deviated at an angle θ from the slit AB will come to focus at point ‘Q’. The point ‘Q’ will be a maxima or minima; it will be decided by path difference between the rays which comes to focus at point ‘Q’. Let us draw a perpendicular from point A to MQ. The rays which comes together at ‘Q’ for them path difference will be BM, hence from ΔAMB,

$$\sin\theta = \frac{BM}{AB}$$
$$BM = AB\ sin\theta$$
$$BM = a\ sin\theta$$

Hence condition for diffraction,
Minima:

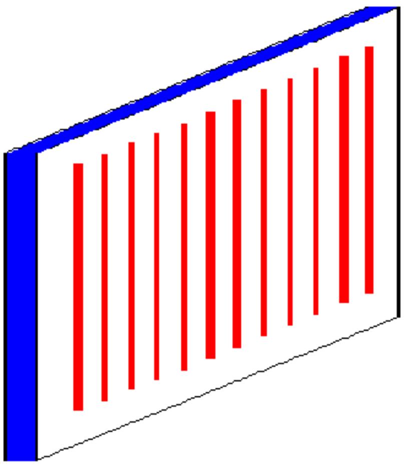
$$a\ sin\ \theta = n\lambda$$

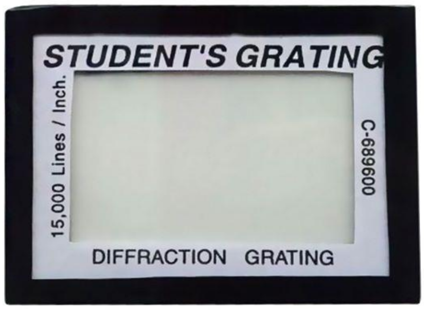
Where n = 1, 2, 3....

10. What is a grating? Define grating element? Discuss the phenomenon of Fraunhofer’s diffraction at a grating and obtain the expression for the intensity?

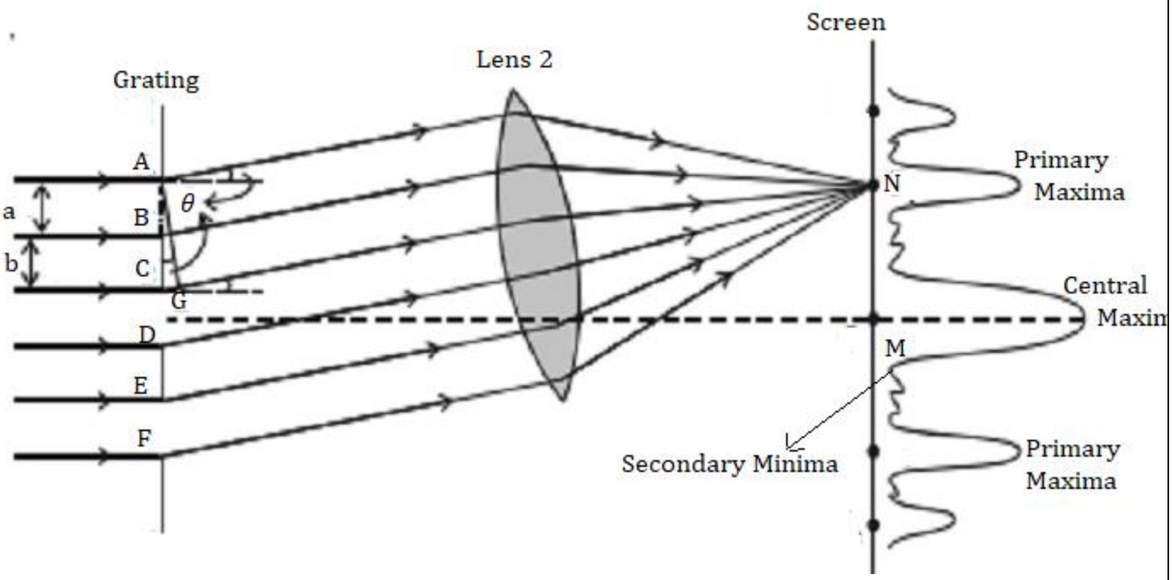
ANS

Diffraction Grating is a polished surface made up of glass (or metal), prepared a large number of very fine equidistant parallel grooves or slits by using fine diamond point and used to produce optical spectra by diffraction of light.





Student’s grating consists of 15000 lines/inches. In such small distance large numbers of lines are mounted so that the spacing between the two lines is comparable to the wavelength of the source so that the condition of diffraction is satisfied. Let ‘a’ be the width of slit and ‘b’ be the width of opaque space. Then (a+b) is known as grating element. Suppose the light from a monochromatic wavelength λ is incident normally on the grating surface. According to Huygen’s Principle, each of the slit sends secondary wavelets in forward direction. The secondary wavelets moving without any change in their original path will come to focus at point M gives a central Maximum on screen. The secondary wavelets deviated at an angle θ will come to focus at point N with different phases. The

	intensity at point N may me found by single and double slit experiment. In diffraction grating final pattern is the superposition of interference on diffraction.  The final pattern in N parallel slit consists of a central maximum, primary maxima and secondary maxima and secondary minima. **Conditions of primary or principle maxima is given as** $$(a+b)\ sin\ \theta = n\lambda$$ Where n = 1, 2, 3.... **Condition of diffraction minima in N parallel slits is given as** $$a\ sin\ \theta = m\lambda$$ Where m = 1, 2, 3.... **Condition of first secondary minima which appears after nth primary maxima is given as** $$(a+b) sin\ (\theta_n + d\theta_1) = n\lambda + \frac{\lambda}{N}$$
11.	Compute the maximum radius allowed for a fiber having core refractive index 1.5 and 1.48. the fiber is to support only one mode at a wavelength of 1500 nm.
ANS	Given : $\lambda = 1500$ nm, $n_1 = 1.5,\ n_2 = 1.48, Number\ of\ modes = 1$ $$Number\ of\ modes = \frac{V^2}{2} = 1$$ $$V^2 = 2$$ $$V = \sqrt{2}$$ $$V = \frac{\pi d}{\lambda}\sqrt{n_1^2 - n_2^2}$$ $$d = \frac{V\lambda}{\pi\sqrt{n_1^2 - n_2^2}} = \frac{\sqrt{2} * 1500}{\pi * \sqrt{1.5^2 - 1.48^2}} = 2765.8\ nm$$
12.	What is population inversion state? Explain its significance in the operation of LASER.
ANS	Under the condition of thermal equilibrium given by Boltzmann distribution the lower energy level E_1 of the two-level atomic systems contains more atoms than the upper energy level E_2. However, to achieved optical amplification it is necessary to create a non-equilibrium distribution of atoms such that the population of upper energy level is greater

than that of lower energy level i.e. $N_2 >> N_1$. This condition is known as population inversion.

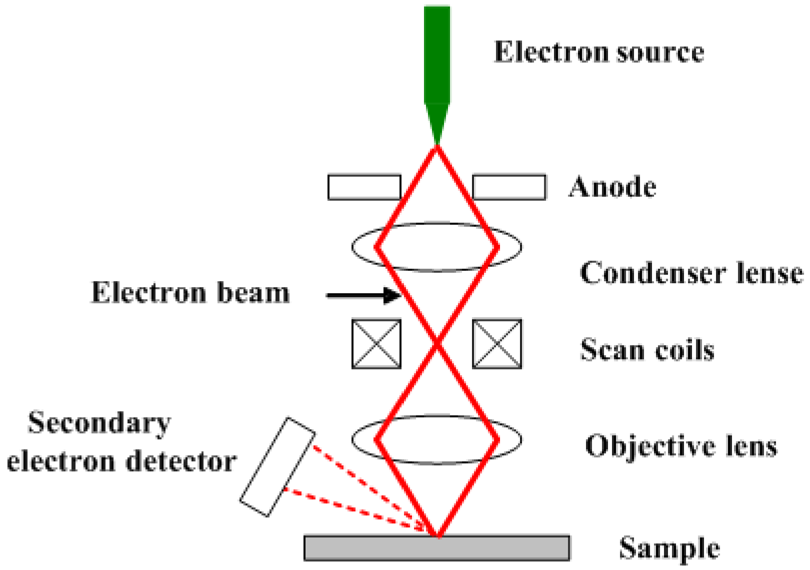
The essential Conditions for population inversion are

1. Higher energy state should possess a longer life time
2. The number of atoms in the lower energy state must be greater than the number of atoms in the higher energy state.

When population inversion is achieved probability of stimulated emission increases over absorption. Hence population inversion is must to produce laser light.

13. Draw the schematic diagram of Scanning Electron Microscope and explain its construction, working, advantages, disadvantages and applications.

ANS According to de-Broglie's hypothesis $\lambda = h/mv$. When electron is accelerated through high potential difference then we can get a wavelength which is 10^5 times shorter than wavelength of visible light. As resolving power is inversely proportional to wavelength, resolving power can be increased by decreasing wavelength.



SEM stands for Scanning Electron Microscope

Construction:

The essential parts of SEM are shown above. It consists of electron source at one point & number of lenses at other end. An electron detector is placed to receive secondary electrons from the surface of sample whose SEM image we want to produce.

Working:

i. In this electron are emitted from the electron source i.e surface of filament which travels in downward direction.

ii. After passing through condenser lens the parallel beam of electrons are produces.

iii. These electrons are allowed to fall on the object in raster pattern.

iv. When electrons are incident on object secondary electrons are emitted from the surface of it which is collected in detector.

v. Depends upon the energy of this scattered electrons the SEM Image of object will produce.

14. Derive Maxwell's third equation in integral and differential form. Given that $\vec{D} = 20x\,\hat{i} + 10\,\hat{j}$ (C/m^2). Determine the flux crossing 1 m^2 area that is normal to the x-axis at x = 5m.

ANS **Maxwell's Third equation:**

Faraday's law state that, electromagnetic force induced in a closed loop is negative rate of change of the magnetic flux.

Faraday's law states that the EMF is also given by the rate of change of the magnetic flux:

$$\varepsilon = -\frac{d\phi_B}{dt}$$

Where $\varepsilon = electromotive\ force$ and $\phi_{B=magnetic\ Flux}$

If we have one surface 'S', then total magnetic flux over surface 'S' is

$$\phi_B = \oint \vec{B}.\overrightarrow{da}$$

$$\therefore \varepsilon = -\frac{d\phi_B}{dt} = \frac{d}{dt}\oint \vec{B}.\overrightarrow{da}$$

According to faraday's law, induced magnetic flux is creates electric filed due charge flows through the closed loop

$$\therefore \oint \vec{E}.\overrightarrow{dl} = -\oint_S \frac{d\vec{B}}{dt}.\overrightarrow{da}$$

According to Stokes theorem,

$$\therefore \oint \vec{E}.\overrightarrow{dl} = -\oint_S (\nabla \times \vec{E})\overrightarrow{da}$$

Using Equation (3) and Applying to eq. (1) & (2)

$$\oint_S (\nabla \times \vec{E})\overrightarrow{da} = -\oint_S \frac{d\vec{B}}{dt}.\overrightarrow{da}$$

Both sides having same integration therefore

From equation (4)

$$\nabla \times \vec{E} = -\frac{d\vec{B}}{dt}$$

Flux $\phi = \oint \vec{D}.\overrightarrow{da} = \oint(20x\,\hat{\imath} + 10\,\hat{\jmath}).dydz\,\hat{\imath} = \oint 20x.dydz = 20x$

At x=5

$$\phi = 20 * 5 = 100\ C$$

15. Distinguish between step index and graded index optical fiber.

ANS

Sr. No.	Step Index Fibre	Graded Index Fibre
1	The refractive index of the core is uniform and step or abrupt change in refractive index takes place at the interface of core and cladding in step index fibers.	The refractive index of core is non-uniform, the refractive index of core decreases gradually from the axis of the fiber to its surface.
2	The rays travel in the fiber as meridional rays and they cross the fiber axis for every reflection.	The light rays propagate in the form of skew rays or helical rays. They will not cross the fiber axis.
3	Step index fiber is of two types; single mode fiber and multi-mode fiber.	Graded index fiber is of only one type that is multi-mode fiber.
4	Number of modes for step index fiber $\boldsymbol{N_{SI}} = \frac{\boldsymbol{V^2}}{\boldsymbol{2}}$. If V number is less than 2.405 the fiber is single mode or more than 2.405 then the fiber is multimode step index fiber.	Number of modes for graded index fiber is $\boldsymbol{N_{GRIN}} = \frac{\boldsymbol{V^2}}{\boldsymbol{4}}$.

5	Modal dispersion affects signal quality in step index fiber.	Graded index fiber provides zero dispersion as the velocity of modes is changed by changing R.I in core.

16. Distinguish between single mode and multimode optical fiber.

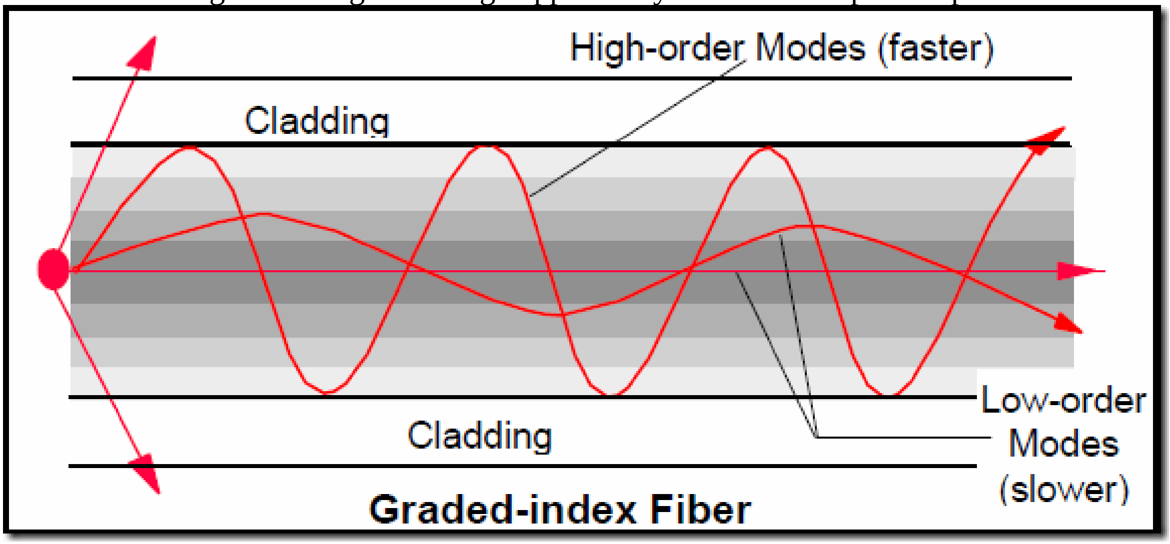
ANS

Sr. No.	Single Mode Fiber	Multimode Fiber
1	Propagation of only one mode takes place	Many modes propagate at the same time
2	Due to single mode, there is no intermodal dispersion	Many modes travel with different speeds, intermodal dispersion occurs.
3	Due to small core diameter, launching of optical power is difficult	Due to large core diameter, launching of optical power is easy.
4	V number is less than 1.15	V number is greater than 1.15
5	Applicable for short distance	Applicable for long distance.

17. How is multipath dispersion overcome in Graded index fibre?

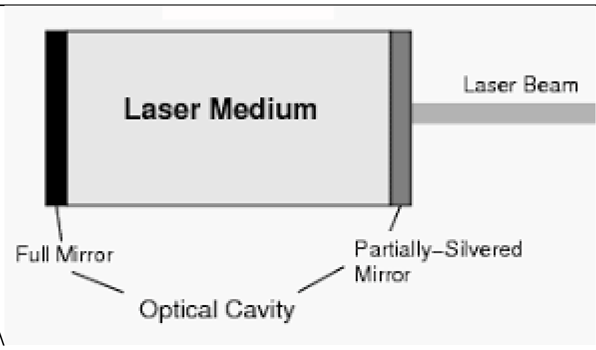
ANS Multipath dispersion deals with the path (mode) of each light ray. Most transmitters emit many different modes. Some of these light rays will travel straight through the centre of the fibre (axial mode) while others will repeatedly bounce off the cladding/core boundary to zigzag their way along the waveguide.

The modes that enter at sharp angles are called high-order modes. These modes take much longer to travel through the fibre than the low-order modes and therefore contribute to modal dispersion. One way to reduce multipath dispersion is to use graded-index fibre. Unlike the two distinct materials in a step-index fibre, the graded-index fibre's cladding is doped so that the refractive index gradually decreases over many layers. With a graded-index fibre, the light follows a more curved path. The high-order modes spend most of the time traveling in the lower-index cladding layers near the outside of the fibre. These lower-index core layers allow the light to travel faster than in the higher-index centre layers. Therefore, their higher velocity compensates for the longer paths of these high-order modes. A good waveguide design appreciably reduces multipath dispersion.



18. What is importance of resonant cavity in the operation of laser?

ANS Laser is a light source which is analogous to an electronic oscillator with positive feedback. A part of output of the amplifier is taken and fed back at its input when an amplifier is switched ON. In laser the active medium is the amplifier, which converted into an oscillator though the feedback mechanism established by optical resonator. A pair of optically plane parallel mirrors enclosing laser medium in between them is a resonant cavity.



The photons bounce back and forth between the end mirrors, causing more and more stimulated emission during each passage. The strength of the stimulated photons travelling along the axis of the optical cavity builds up rapidly while the photons travelling at angles to the axis are lost.

19. A diffraction grating used at normal incidence gives a line, λ1 = 6000 A˚ in a certain order superimposed on another line λ2 = 4500 A˚ of the next higher order. If the angle of diffraction is 30˚, how many lines are there in a cm in the grating?

ANS

Given: λ1 = 6000 A˚, λ2 = 4500 A˚, $\theta = 30˚$

Let n be the order.

$$(a+b)\sin\theta = \mathrm{n}\lambda_1$$
$$(a+b)\sin\theta = (\mathrm{n}+1)\lambda_2$$

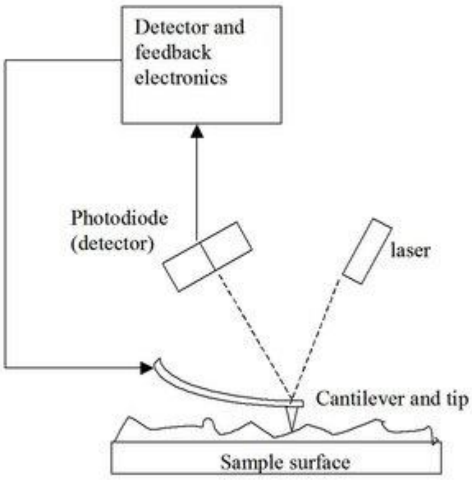
Hence, $\mathrm{n}\lambda_1 = (\mathrm{n}+1)\lambda_2$

$$n = \frac{\lambda_2}{\lambda_1 - \lambda_2} = \frac{4500}{6000-4500} = 3$$
$$(a+b)\sin\theta = \mathrm{n}\lambda_1$$
$$(a+b) = \frac{\mathrm{n}\lambda_1}{\sin\theta} = \frac{3*6000*10^{-8}}{\sin 30} = 3.6*10^{-4}cm$$

Lines per cm $=\frac{1}{3.6*10^{-4}} = 2778$

20. Explain the working of atomic force microscope in detail.

ANS



AFM is a scanning microscope whose resolution is 1000 times better than any optical unit.

Construction:

1. As shown in diagram AFM consist of a micro scale cantilever tip usually made up of silicon which is used to scan surface.

2. A LASER source is used for continuous light and to receive reflected light from cantilever a photodiode is used.

3. Feedback mechanism is also used to adjust the tip to sample distance to maintain

	constant force between tip & sample. **Working:** i. When tip is brought into proximity of the sample surface then there exist force between tip and sample which leads to deflection. ii. This deflection is measured by using laser spot which is reflected from top of cantilever. iii. The light which is reflected is incident on photodiode which measure the deflection to an accuracy of < 1 nm. iv. AFM is operated in constant current mode because if we use constant height mode that will damage the tip.
21.	If $\phi(x,y,z) = 3x^2y - y^3z^2$, Find $\vec{\nabla}\phi$ at the point (-1, -2, 1).
ANS	Given: $\phi(x,y,z) = 3x^2y - y^3z^2$ $$\nabla\emptyset = \left(\frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}\right)(3x^2\mathrm{y} - y^3z^2)$$ $$= \left(\frac{\partial(3x^2\mathrm{y} - y^3z^2)}{\partial x}\hat{\imath} + \frac{\partial(3x^2\mathrm{y} - y^3z^2)}{\partial y}\hat{\jmath} + \frac{\partial(3x^2\mathrm{y} - y^3z^2)}{\partial z}\hat{k}\right)$$ $$= 6xy\,\hat{\imath} + (3x^2 - 3y^2z^2)\hat{\jmath} - 2y^3\mathrm{z}\hat{k}$$ At (-1, -2, 1) , x=-1, y=-2, z=1 $$\nabla\emptyset = 12\,\hat{\imath} - 9\,\hat{\jmath} + 16\,\hat{k}$$
22.	Given $\vec{A} = x^2y$ i +(x-y) k, find $\vec{\nabla}.\vec{A}$
ANS	Given:$\vec{A} = x^2y$ i +(x-y) k $$\vec{\nabla}.\vec{A} = \left(\frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}\right).(x^2\mathrm{y}\,\mathrm{i} + (\mathrm{x}-\mathrm{y})\mathrm{k})$$ $$\vec{\nabla}.\vec{A} = \frac{\partial x^2\mathrm{y}}{\partial x} + \frac{\partial(0)}{\partial y}\hat{\jmath} + \frac{\partial(\mathrm{x}-\mathrm{y})}{\partial z}\hat{k}$$ $$\vec{\nabla}.\vec{A} = 2xy$$
23.	A step index fiber has a core diameter of 29 x10^{-6} m. the refractive indices of core and cladding are 1.52 And 1.5189 respectively. If the light of wavelength 1.3 µm is transmitted through the fiber, determine. Normalized frequency of the fiber.
ANS	Given: d = 29 x10^{-6} m, , $n_1 = 1.52$, $n_2 = 1.5189$, λ = 1.3 µm=$1.3 * 10^{-6}m$ $$V = \frac{\pi d}{\lambda}\sqrt{n_1^2 - n_2^2} = \frac{\pi * 2.9 * 10^{-6}}{1.3 * 10^{-6}m}\sqrt{1.52^2 - 1.5189^2} = 0.4$$
24.	Derive Gauss law for static electric and magnetic field in differential and integral form.
ANS	Let us assume a an any surface bounding an any volume V in a dielectric medium for any dielectric medium, the total charge density present is the sum of free charge density (ρ) And polarized charge density (ρ_P. $$\rho_{total} = \rho + \rho_P$$ The total electric flux $\emptyset_E$ crossing the closed surface is equal to the total charge enclosed by that surface (Gauss law). $$\oint_S \vec{E}.\overrightarrow{da} = \frac{Q_{total}}{\epsilon_0}$$ According to divergence theorem, $$\oint_S \vec{E}.\overrightarrow{da} = \oint_V (\nabla.\vec{E})dv$$ But right-hand side of the above equation is electric flux i.e

$$\frac{Q_{total}}{\epsilon_0} = \oint_V \frac{\rho + \rho_P}{\epsilon_0} dv$$

$$\frac{Q_{total}}{\epsilon_0} = \oint_V \frac{\rho_{total}}{\epsilon_0} dv$$

Therefore comparing eq. (1),(2),(3)
We have

$$\oint_V (\nabla . \vec{E}) dv = \oint_V \frac{\rho_{total}}{\epsilon_0} dv$$

Integrating on both side

$$\nabla . \vec{E} = \frac{\rho_{total}}{\epsilon_0}$$

This is Gauss law for Static electric field.

As the magnetic lines of force are closed, the no. Of magnetic lines of flux entering any surface is exactly the same as leaving.

$$\oint \vec{B} . \overrightarrow{da} = 0$$

∴ Using divergence theorem, convert surface integral to volume integral

$$\oint_V \vec{B} . \overrightarrow{da} = \oint_V \nabla . \vec{B} dv = 0$$

$$\therefore \nabla . B = 0$$

This is Gauss law for Static magnetic field

25. What is the highest order spectrum, which may be seen with monochromatic light of wavelength 6000 A° by means of a diffraction grating with 5000 lines/cm?

ANS Given: λ= 6000 A°=6000*10^{-8} cm, Number of lines= 5000 lines/cm

$$(a + b) = \frac{1}{5000}$$

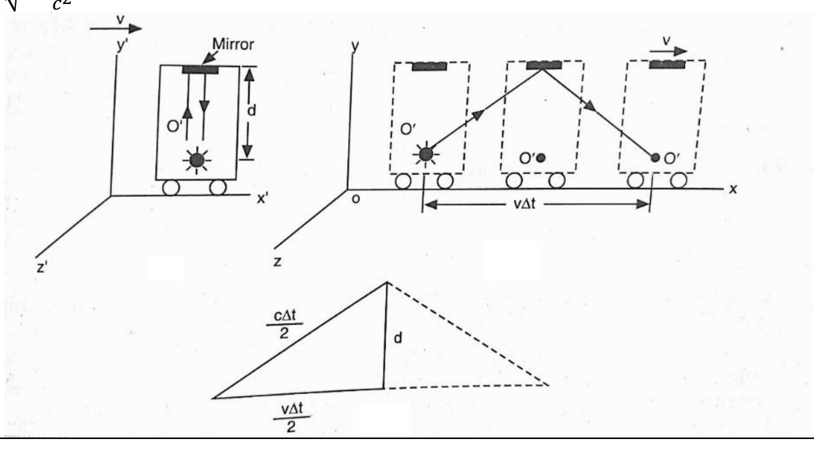
$$(a + b) \sin \theta = \mathrm{n}\lambda$$

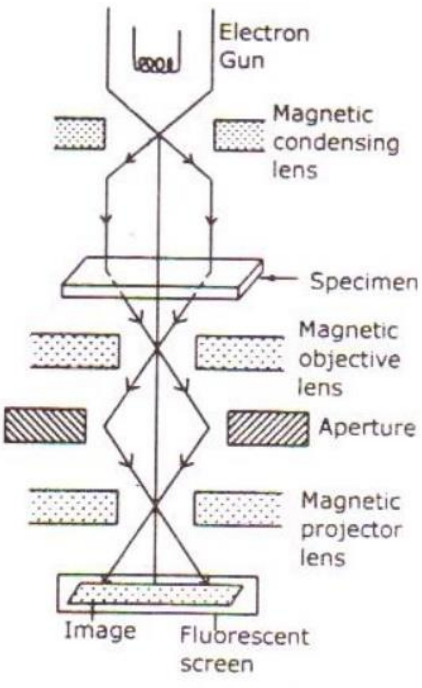
$$n_{max} = \frac{(a + b)}{\lambda} = \frac{1}{5000 * 6000 * 10^{-8}} = 3.33 \approx 3$$

26. Explain the concept of time dilation and deduce an expression for it. A particle moving with a speed of 0.7c. Calculate the ratio of the rest mass and mass while in motion.

ANS **Time dilation:**

When an observer in a stationary frame of reference observes the time interval of any event of moving frame of reference, the time interval appears to be slowed down by a factor of $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$. This effect is known as time dilation.



	Let us consider a railcar S' moving to the right with a speed v. let car have a mirror fixed to the ceiling as shown in the fig.an observer at rest in the car sends off a light pulse at some instant toward the mirror. Observer measures the time interval $\Delta t'$ for round trip of the pulse, it is the proper time T_0. $\Delta t'$ is given by $$\Delta t' = \frac{2d}{c}$$ Where d is the distance between the source of the light pulse and the mirror at the ceiling. With reference to an observer on the stationary frame S, the mirror and the light source are moving to the right with a speed v. When the light pulse strikes the mirror, the mirror will have moved a distance equal to $(v\Delta t/2)$. Where Δt is the time taken by the light pulse for its round trip as measured in S frame. From the geometry of the situation, we find that, $$\left[\frac{c(\Delta t)}{2}\right]^2 = \left(\frac{v\Delta t}{2}\right)^2 + d^2$$ $$(c^2 - v^2)(\Delta t)^2 = (2d)^2$$ $$\Delta t = \frac{2d}{\sqrt{c^2 - v^2}} = \frac{2d/c}{\sqrt{1 - v^2/c^2}}$$ $$\Delta t = \frac{\Delta t'}{\sqrt{1 - v^2/c^2}}$$ $$T = \frac{T_o}{\sqrt{1 - v^2/c^2}}$$ **Numerical:** Given: v = 0.7c $$m = \frac{m_o}{\sqrt{1 - v^2/c^2}}$$ $$\frac{m_o}{m} = \sqrt{1 - v^2/c^2} = \sqrt{1 - \frac{(0.7c)^2}{c^2}} = 0.71$$
27.	Explain the construction and working of a Transmission Electron microscope with a schematic diagram.
ANS	**Diagram:**  **Construction:**

	It consists of an electron gun to produce electrons. Magnetic condensing lens is used to condense the electrons and is also used to adjust the size of the electron that falls on to the specimen. The specimen is placed in between the condensing lens and the objective lens as shown. The magnetic objective lens is used to block the high angle diffracted beam and the aperture is sued to eliminate the diffracted beam (if any) and in turn increases the contrast of the image. The magnetic projector lens is placed above the fluorescent screen in order to achieve higher magnification, The image can be recorded by using a fluorescent screen or CCD – Charged Coupled device. **Working:** Stream of electrons are produced by the electron gun and is made to fall over the specimen using the magnetic condensing lens. Based on the angle of incidence the beam is partially transmitted and partially diffracted. Both these beams are recombined to form the image. The combined image is called the phase contrast image. In order to increase the intensity and the contrast of the image, an amplitude contrast has to be obtained. This can be achieved only by using the transmitting beam and thus the diffracted beam can be eliminated.
28.	State Maxwell's equations in differential form in a medium, in the presence of charges and currents.
ANS	all Four maxwell equations can be written as: Differential form $\nabla.\vec{E} = \frac{\rho_{total}}{\epsilon_0}$ $\nabla.B = 0$ $\nabla \times \vec{E} = -\frac{d\vec{B}}{dt}$ $(\nabla \times \vec{B}) = \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{d\vec{E}}{dt}$
29.	Describe any two methods to synthesize nanomaterials.
ANS	**Ball Milling:** In this physical mechanical technique, synthesis of nanomaterials is carried out using top-down method. It is a type of mechanical grinder, cylindrical in shape. It consists of stainless steel are ceramic small balls known as milling balls. They are allowed to rotate around, the inside of a drum and then allowed to fall on solid with gravitational force an internal cascading technique is used to reduce the material into a fine powder, so that required nanocrystal material is produced. **Sol-Gel:** The solgel process is a bottom-up approach technique. In this process the starting material is processed to form a dispersible oxide and a colloidal suspension of the particle off the metal compound is prepared first and then converted into a gel. The gelation off the soul in the liquid to form a network it's called gel. Step 1: a stable solution of the alkoxide or solvated metal precursor(sol) is formed. Step 2: an oxide or alcohol bridged network (gel) forms by a polycondensation or polyesterification reaction. Step 3: the polyesterification reaction continues till the gel transforms into a solid mass, accompanied by contraction of the gel network and slowly the solvent gets evaporated from the gel pores. Step 4: The gel is dried so that the water and other volatile liquids are removed. The powder obtained by thermal evaporation is called xerogel.

<table>
<tr><td></td><td>Step 5: calcining the xerogel at temperatures upto 800 C stabilizes the gel against rehydration.</td></tr>
<tr><td>30.</td><td>Describe the physical significance of gradient, Divergence and Curl.</td></tr>
<tr><td>ANS</td><td>

Gradient of a scalar point function:

f be a any scalar point function. The Gradient of f is denoted by ∇f and defined by

$$\nabla f = \left(\frac{\partial}{\partial x}\,\hat{x} + \frac{\partial}{\partial y}\,\hat{y} + \frac{\partial}{\partial z}\,\hat{z}\right) f$$
$$= \hat{x}\frac{\partial f}{\partial x} + \hat{y}\frac{\partial f}{\partial y} + \hat{z}\frac{\partial f}{\partial z}$$

A gradient is a directional derivative. In simple terms it is the rate of change of a function in a specified direction. The gradient of a scalar function is a vector quantity.

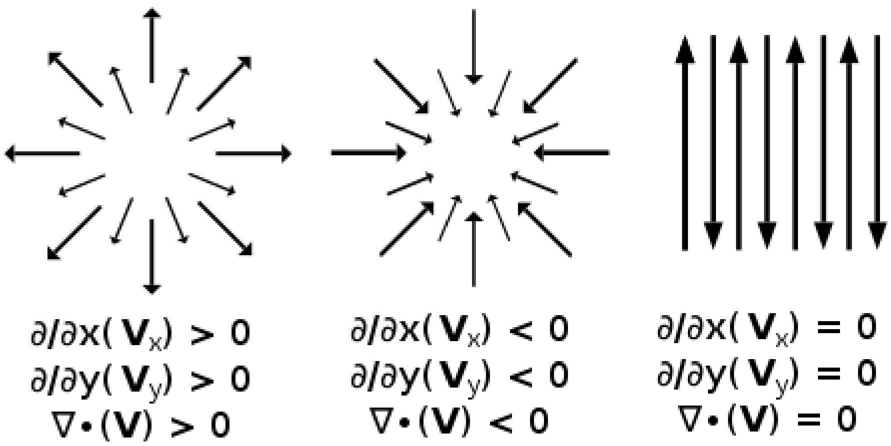
Divergence of a vector point function:

Let $\vec{F}(x,y,z)$be a continuous differentiable vector point function. The divergence of $\vec{F}(x,y,z)$ is denoted by Div $\vec{F}$ & defined as $\nabla.\vec{F}$

If $\vec{F} = F_1\hat{x} + F_2\hat{y} + F_3\hat{z}$

Then

$$\nabla.\vec{F} = \left(\frac{\partial}{\partial x}\,\hat{x} + \frac{\partial}{\partial y}\,\hat{y} + \frac{\partial}{\partial z}\,\hat{z}\right)(F_1\hat{x} + F_2\hat{y} + F_3\hat{z})$$
$$= \left(\frac{\partial F_1}{\partial x} + \frac{\partial F_2}{\partial y} + \frac{\partial F_3}{\partial z}\right)$$



The above diagram represents the Physical Meaning of Divergences.

Curl of a vector point function:

Let $\vec{F} = F_1\hat{x} + F_2\hat{y} + F_3\hat{z}$ be a vector point function. The curl of $\vec{F}$ is denoted as $\nabla \times \vec{F}$ and defined as

$$\nabla \times \vec{F} = \left(\frac{\partial}{\partial x}\,\hat{x} + \frac{\partial}{\partial y}\,\hat{y} + \frac{\partial}{\partial z}\,\hat{z}\right) \times (F_1\hat{x} + F_2\hat{y} + F_3\hat{z})$$
$$= \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ F_1 & F_2 & F_3 \end{vmatrix}$$

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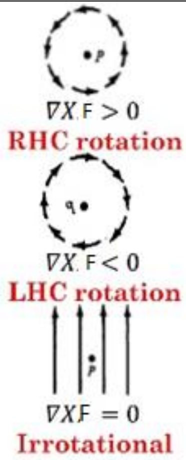


Curl of $\vec{F}$ represents the angular velocity at any point of the vector point function.

31. If $\vec{A}$ = xy $\boldsymbol{i}$ – 8xy^2$\boldsymbol{z^2}$ $\boldsymbol{j}$ + 2$\boldsymbol{xyzk}$. Find $\vec{\nabla}\,.\,\vec{A}$ at point (1,-2, 4).

ANS Given: $\vec{A}$ = xy $\boldsymbol{i}$ – 8xy^2$\boldsymbol{z^2}$ $\boldsymbol{j}$ + 2$\boldsymbol{xyz}$ $\boldsymbol{k}$

$$\vec{\nabla}\,.\,\vec{A} = \left(\frac{\partial}{\partial x}\hat{\mathrm{i}} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{\mathrm{k}}\right).\,(\mathrm{xy\ i} - 8\mathrm{xy}^2\mathrm{z}^2\ \mathrm{j}\ +\ 2\mathrm{xyz\ k})$$

$$\vec{\nabla}\,.\,\vec{A} = \left(\frac{\partial(\mathrm{xy})}{\partial x} + \frac{\partial(8\mathrm{xy}^2\mathrm{z}^2)}{\partial y} + \frac{\partial(2\mathrm{xyz})}{\partial z}\right)$$

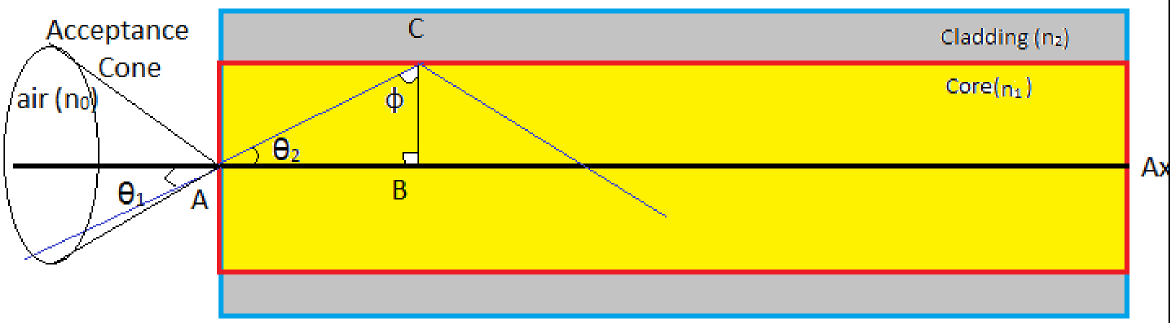
$$\vec{\nabla}\,.\,\vec{A} = y + 16xy\mathrm{z}^2 + 2xy$$

At x=1, y=-2, z=4

$$\vec{\nabla}\,.\,\vec{A} = -2 - 512 - 4 = -518$$

32. Derive the expression for the Numerical aperture for a step index fiber.

ANS *Numerical aperture* gives us the relationship between refractive indices of the three media involved in the propagation of light and acceptance angle. So relationship between n_0, n_1, n_2 and θ_a is called numerical aperture. Consider the step index fibre in which the ray of light is incident at air core interface an angle of θ_1 which is smaller than the acceptance angle on the axis of the fibre. This ray of light is refracted through an angle θ_2.



If θ_1 is smaller than the acceptance angle θ_a, the refracted ray is incident on the core-cladding interface at an angle ϕ, which must be greater than the critical angle so the ray will totally internally reflect into the same medium.

Let n_0 be the refractive index of the air medium from which the light ray is incident through optical fibre. Let n_1 & n_2 be the refractive index of core and cladding respectively. Let us apply Snell's law to the air core interface. According to the Snell's law,

$$n_0 \,\mathrm{Sin}\, \theta_1 = n_1 \sin \theta_2$$

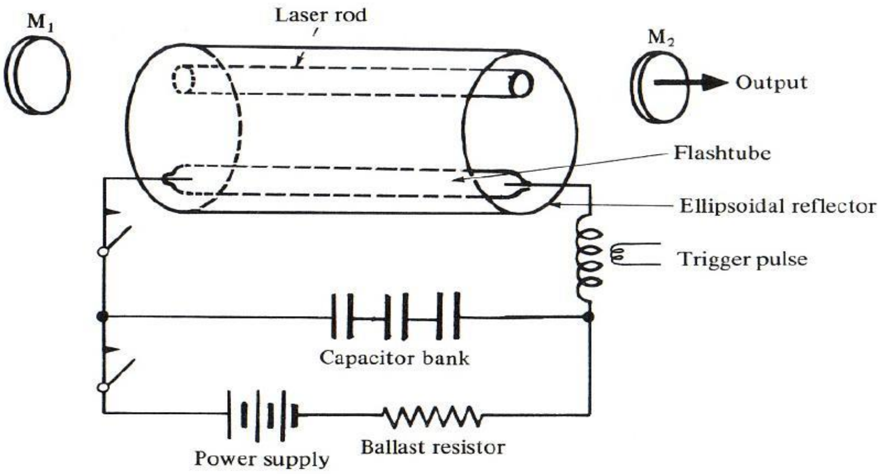
From right angle triangle Δ ABC, the above equation can be written as,

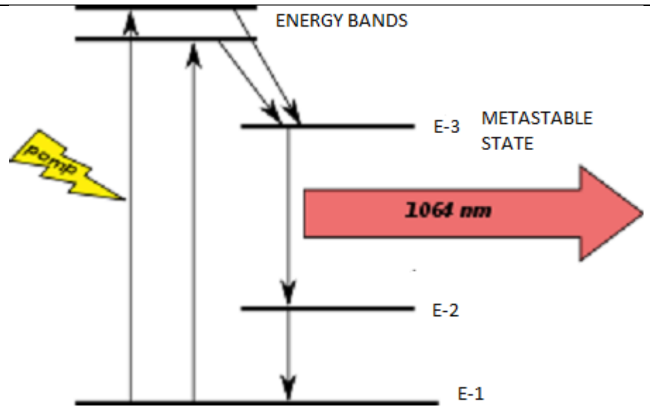
$$\mathrm{n}_0 \sin \theta_1 = \mathrm{n}_1 \sin\,(90 - \emptyset)$$

$$\mathrm{n}_0 \sin \theta_1 = \mathrm{n}_1 \cos\emptyset$$

By applying limiting cases to the above equation, θ_1 becomes θ_a and ϕ becomes ϕ_c. Hence the above equation can be written as,

$$\mathrm{n}_0 \sin \theta_a = \mathrm{n}_1 \cos\emptyset_c$$

	$$n_0 \sin\theta_a = n_1\sqrt{1-\sin^2_{\emptyset_c}}$$ Since, $\sin\emptyset_c = \frac{n_2}{n_1}$ at core cladding interface, the above equation can be written as, $$n_0 \sin\theta_a = n_1\sqrt{1-\frac{n_2^2}{n_1^2}}$$ $$n_0 \sin\theta_a = \sqrt{n_1^2-n_2^2}$$ $$NA = n_0 \sin\theta_a = \sqrt{n_1^2-n_2^2}$$
33.	Draw and explain energy level diagram of Nd: YAG Laser.
ANS	Solid state lasers operate in the infrared are the most common because of their use in compact disc players. Lasers of the kind are also ideal for fiber optics telephone lines. Yttrium Aluminum Garnet ($Y_3Al_5O_{12}$) which is commonly called YAG is an optically isotropic crystal. Nearly 1.5% of the Y^{3+} ions in the crystal are replaced by Nd^{+3}. Nd: YAG laser is one of the most popular solid state lasers and is a four level laser system. In Nd: YAG laser, crystal atoms do not participate in lasing action but acts as host lattice in which ***Nd^{+3} ions (active centers)*** are present. **Construction:** The length of the Nd: YAG laser rod varies from 5 cm to 10 cm depending upon the power of laser and its diameter is generally 6 mm to 9 mm. The laser rod and xenon flash lamp are housed in an  Elliptical reflector cavity. The ends of the rod are polished and made optically flat and parallel. The optical cavity is formed either by silvering the two ends of the rods or by using two external reflecting mirrors. One mirror is made hundred percent reflecting while the other is slightly transmitting to draw the output. The system is cooled either by air or water circulation. **Working:** The energy level diagram of Nd: YAG is shown in figure. The pumping of Nd^{+3} ions to the upper states is done using krypton arc lamp. ***Optical pumping*** with light of wavelength 7600 A^0 to 8000 A^0 excites the ground state of Nd^{+3} ions to higher states. E_3 corresponds to Meta stable state and E_2 corresponds to lower laser level. E_3 level is rapidly populated as Nd^{+3} ions quickly. So population



inversion is achieved by between E_3 and E_2 level and laser emission occurs in the infrared region i.e. about 10640 A^0. $\lambda = 1.06\ \mu m$

Nd: YAG laser can be operated in CW mode also using tungsten halide lamp for optical pumping. Continuous output powers of over 1KW are obtainable. In recent years Nd:YAG lasers are efficiently pumped by GaAs diode lasers.

Applications:

1. They used in materials processing such as welding, cutting drilling etc.
2. Fiber optics endoscopes with YAG lasers are used to treat gastrointestinal bleeding.
3. YAG beams also penetrate the lens of the eye to perform intraocular procedures, without opening the eye.
4. YAG lasers are used in military as range finders and target designators.

34. Prove that $x^2+y^2+z^2-c^2t^2$ is invariant under Lorentz transformation.

ANS Lorentz transformation is given as

$$x' = \gamma(x - vt)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$

Invariance means the form of equation $x^2+y^2+z^2-c^2t^2$ remains same in S' frame also.

$$x'^2 + y'^2 + z'^2 - c^2t'^2$$
$$= \gamma^2(x - vt)^2 + y^2 + z^2 - c^2\gamma^2\left(t - \frac{vx}{c^2}\right)^2$$

$$= \gamma^2(x^2 + v^2t^2 - 2xvt) + y^2 + z^2 - c^2\gamma^2\left(t^2 + \left(\frac{vx}{c^2}\right)^2 - 2t\frac{vx}{c^2}\right)$$
$$= \gamma^2\left(x^2 + v^2t^2 - 2xvt - c^2t^2 - \frac{v^2x^2}{c^2} + 2xvt\right) + y^2 + z^2$$
$$= \gamma^2\left(x^2 - \frac{v^2x^2}{c^2} - c^2t^2 + v^2t^2\right) + y^2 + z^2$$

$$= \gamma^2\left(x^2\left(1 - \frac{v^2}{c^2}\right) - c^2t^2\left(1 - \frac{v^2}{c^2}\right)\right) + y^2 + z^2$$
$$= \gamma^2\left(x^2\frac{1}{\gamma^2} - c^2t^2\frac{1}{\gamma^2}\right) + y^2 + z^2$$
$$= x^2 + y^2 + z^2 - c^2t^2$$

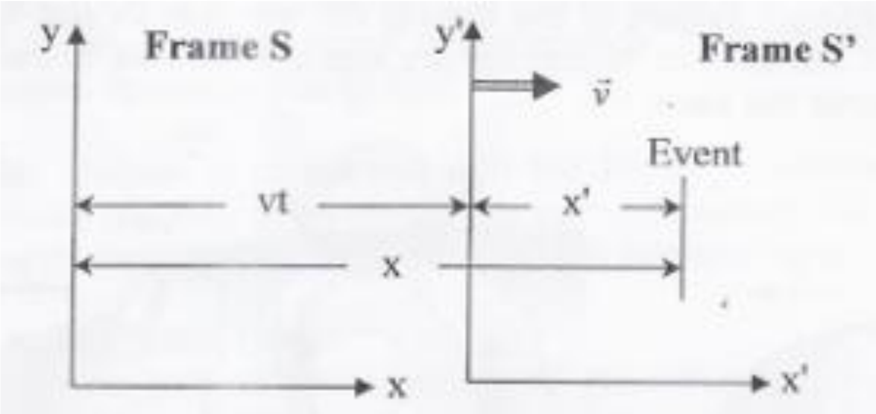
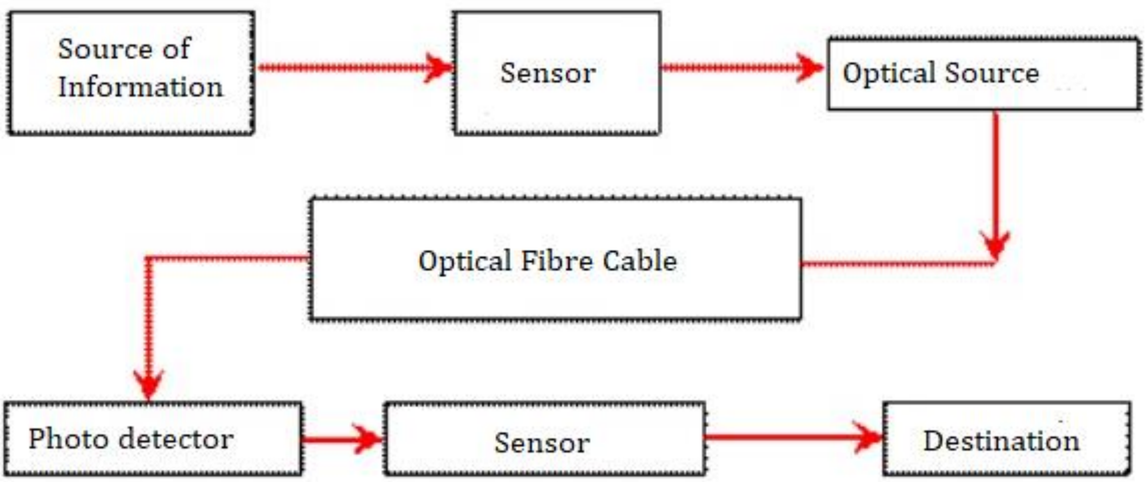
Hence, $x^2+y^2+z^2-c^2t^2$ is invariant under Lorentz transformation

35. What is length contraction? Derive the expression for the same?

ANS **Length contraction:**

Any object moving with a constant velocity, when observed by an observer from a stationery frame of ref

	-*`erence, the length of the object appears to be contracted by the factor $\sqrt{1-\frac{v^2}{c^2}}$, This is called as Length contraction. Let us consider a rigid rod at rest in a moving frame S', say a spaceship, along the x-axis with a speed v. Thus, the observer in the spaceship measures the length of the rod to be $$L_0 = x_2' - x_1'$$ L_0 is called the proper length of the rod. The proper length of the body is defined as the length of the body measured in the reference frame in which the body is at rest. According to Lorentz coordinate transformation, $$x_1' = \gamma(x_1 + vt)$$ $$x_2' = \gamma(x_2 + vt)$$ $$x_2' - x_1' = \gamma(x_2 - x_1)$$ $$L_0 = \gamma L = \frac{L}{\sqrt{1-\frac{v^2}{c^2}}}$$ $$L = L_0\sqrt{1-\frac{v^2}{c^2}}$$
36.	State Maxwell's all four equations and give the significance of each.
ANS	all Four maxwell equations can be written as: $$\nabla.\vec{E} = \frac{\rho_{total}}{\epsilon_0}$$ Maxwell's first equation signifies that: The total electric field through the surface enclosing a volume is equal to the total charge within the volume. $$\nabla.B = 0$$ Maxwell's second equation signifies that: The total outward flux of magnetic induction B through any closed surface S is equal to zero. $$\nabla \times \vec{E} = -\frac{d\vec{B}}{dt}$$ Maxwell's third equation signifies that: The electro motive force around a closed path is equal to negative rate of change of magnetic flux linked with the path. $$\left(\nabla \times \vec{B}\right) = \mu_0\vec{J} + \mu_0\epsilon_0\frac{d\vec{E}}{dt}$$ Maxwell's fourth equation signifies that: The magneto motive force around a closed path is equal to the conduction current plus displacement current through any surface bounded by the path.
37.	Calculate the number of modes of a step index optical fibre of diameter 40 $\boldsymbol{\mu m}$ if its core and cladding refractive indices are 1.5 and 1.46, respectively. Wavelength of light used is 1.5 $\boldsymbol{\mu}$m
ANS	Given: d = 40 $\boldsymbol{\mu m}, n_1 = 1.5,\ n_2 = 1.46, \lambda = $ 1.5 µm $$V = \frac{\pi d}{\lambda}\sqrt{n_1^2 - n_2^2} = \frac{\pi * 40}{1.5}\sqrt{1.5^2 - 1.46^2} = 28.83$$ $$Number\ of\ modes = \frac{V^2}{2} = \frac{28.83^2}{2} = 415$$
38.	When a frame of reference is said to be a non-inertial frame of reference? Give an example.
ANS	**Non-inertial frame of references:** The systems in which the Newton's laws of motion does not holds good are called non-inertial frame of reference. In short, A frame of reference which is in accelerated motion with respect to an inertial frame is called non-inertial frame of reference. **Example:** If we are in an automobile when the brakes are abruptly applied, then we will feel pushed toward the front of the car. However, there is really no force pushing us forward.

	The car, since it is slowing down, is an accelerating, or non-inertial, frame of reference, and the law of inertia no longer holds if we use this non-inertial frame to judge our motion.
39.	What is Galilean transformation? Derive Galilean transformation equations for position and time.
ANS	**Galilean Transformations**  The Galilean transformation establishes the relationship between the coordinates x,y,z and t of an event in system S and coordinates x',y',z' and t' of the same event in system S'. Let an event occur in an inertial frame of reference S and let the event be located by the coordinates (x,y,z and t) in the system S. Let us consider another inertial frame of reference S', which moves in a straight line with respect to the frame S at a constant speed v. Let us assume that the reference frame S' moves so that x and x' are in one straight line and have the same positive direction. Let the origins O and O' coincide at the moment t=0. The coordinate x' depends on time, since the system S' moves with velocity v. During the time t, the moving system covers a distance equal to vt. Hence $x'=x-vt$ $y'=y$ $z'=z$ $t'=t$
40.	Describe the fiber optics communication system with block diagram
ANS	 Optical fibres are used in communication to transmit signals for long distances. An optical signal derived from electrical analog signal is transmitted through the optical fibre. At the other end again the optical signal is converted into electrical signal. First voice is converted into electrical signal using a transducer. It is digitized using a Coder. The digitized signal, which carries the voice information, is fed to an optical transmitter. The light source in optical transmitter (L E D or Laser Diode) emits modulated light, which is transmitted

	through optical fibre. At the other end the modulated light signal is detected by a photo detector and is decoded using a decoder. Finally the information is converted into analog electrical signal and is fed to a loud speaker, which converts the signal to voice (sound).