UNIT – V (Marks – 3)

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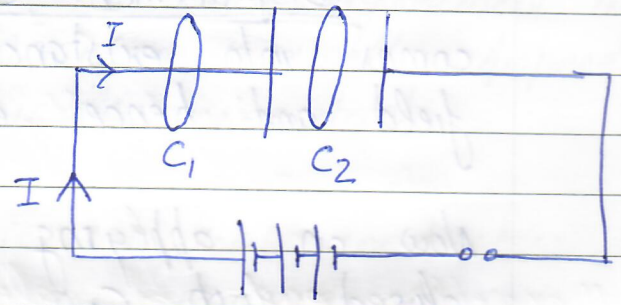
Electromagnetic Waves

Question ↦ Show that Ampere's circuital law is inconsistant. What is modified maxwell's Ampere circuital law. Show that modified maxwell's Ampere circuital law is consistant.

Ans:→ Consider a parallel plate capacitor being charged by a battery. Let I is the current flowing through the wires at any instant. Consider two close loop C_1 and C_2 as shown



On applying Ampere's Circuital law for the closed loop C_1 we get.

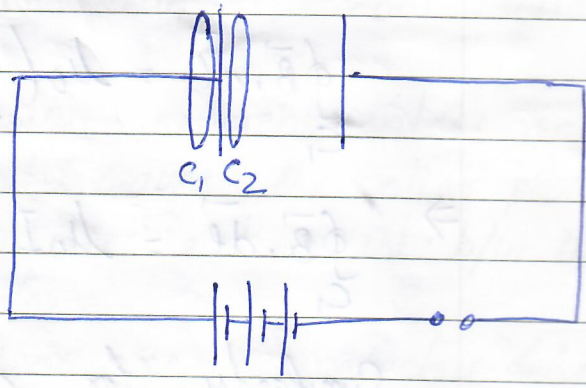
$$\oint_{C_1} \vec{B} \cdot d\vec{l} = \mu_0 I \quad \text{—①}$$

Illy for closed loop C_2,

$I = 0$

$$\therefore \oint_{C_2} \vec{B} \cdot d\vec{l} = \mu_0 (0)$$

$$\Rightarrow \oint_{C_2} \vec{B} \cdot d\vec{l} = 0 \quad \text{——②}$$



But if two loops are infinitesimally close to each other then

$\oint_{C_1} \vec{B} \cdot d\vec{l}$ must be equal to $\oint_{C_2} \vec{B} \cdot d\vec{l}$

ie $$\oint_{C_1} \vec{B} \cdot d\vec{l} = \oint_{C_2} \vec{B} \cdot d\vec{l} \quad \text{—③}$$

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But eqn ③ is not in accordance with no. ① and ②. Thus we can say A circuital law is logically inconsistant.

Thus Maxwell's gave the modifie k/a Maxwell's Ampere's circuital law. to modified law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (I + I_D) \quad \text{——}$$

where $I_D = \epsilon_0 \frac{d\phi_E}{dt}$ = Displacement Cur

Displacement Current is that curr comes into existance in a region wh field and hence electric flux changes

Now on applying modified Ampere's closed loop C_1 we have,

$$\oint_{C_1} \vec{B} \cdot d\vec{l} = \mu_0 (I + 0)$$

{ ∵ I_D = during the capacitor and electri only b/w

$$\Rightarrow \oint_{C_1} \vec{B} \cdot d\vec{l} = \mu_0 I \quad \text{——} \quad ⑤$$

Similarly for closed loop C_2

conduction current $I = 0$

$$\therefore \oint_{C_2} \vec{B} \cdot d\vec{l} = \mu_0 (0 + I_D)$$

$$\Rightarrow \oint \vec{B} \cdot d\vec{l} = \mu_0 I_D = \mu_0 \epsilon_0 \frac{d}{dt} \phi_E$$

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If E is the value of electric field b/w the two plate of capacitor at any instant then

$$\oint_{C_2} \vec{B}.d\vec{l} = \mu_0 \epsilon_0 \frac{d}{dt} EA \qquad \{ \Phi_E = EA \}$$

$$= \mu_0 \epsilon_0 \frac{d}{dt} \frac{q}{A\epsilon_0} A \qquad \{ \because E = \frac{q}{A\epsilon_0} \}$$

$$= \mu_0 \epsilon_0 . \frac{1}{\epsilon_0} \frac{dq}{dt}$$

$$\Rightarrow \oint_{C_2} \vec{B}.d\vec{l} = \mu_0 I \quad \text{——⑥} \qquad \{ \because I = \frac{d}{dt} q \}$$

Eqn no. ⑤ and ⑥ are in close agreement wi eqn no. ③. Thus modified Maxwell's Ampere's circuital law is logically consistant.

Ques ↦ comment on the statement that conduction a displacement currents are individually discontinuous, but their sum is continuous

Ans ↦ We know that conduction current enters on plate of the capacitor and leaves the other plat ie conduction current does not exist b/w th two plates of the capacitor.

Where as since there is no electric fiel outside the plates of the capacitor. Therefore displacement current does not exist outside the two plate and exist only b/w the two plates due to change in electric field and hence cha in electric flux.

ie between the plates conduction current

$$I_c = \frac{d}{dt} q = 0$$

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and displacement current

$$I_D = \epsilon_0 \frac{d}{dt}\phi_E = \epsilon_0 \frac{d}{dt}\frac{\epsilon A}{} = \epsilon_0 \frac{d}{dt}$$

$$\Rightarrow I_D = \frac{d}{dt} q.$$

Thus sum, $I_C + I_D = 0 + \frac{d}{dt} q =$

Coheres as outside the plates conduction exists

ie $I_C = \frac{d}{dt} q$

w/a $I_D = \epsilon_0 \frac{d}{dt}\phi_E = 0$ {

$\therefore$ Sum $I_C + I_C = \frac{d}{dt} q + 0 = I$

ie individually I_C and I_D are w/a sum is / continuous.

Maxwell's eqns of electromagnetism ↦

Basic principles of electromagne known as Maxwell's eqns of electrom

① Gauss's law of electrostatics ↦

$$\oint_S \vec{E} \cdot d\vec{S} = \frac{q}{\epsilon_0}$$

2. Gauss's law of magnetism ↦

$$\oint_S \vec{B} \cdot d\vec{S} = 0.$$

③ Faradays law of electromagnetism ↦

we know that

$$e = -\frac{d}{dt}\phi_m$$

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$$\Rightarrow \boxed{\oint_L \vec{E}.d\vec{l} = -\frac{d}{dt}\int \vec{B}.d\vec{S}}$$

$\left\{ \because e = V_B - V_A = \omega \right.$

$\left. = \oint_L \vec{E}.d\vec{l} \right.$

and $\phi_m = \int \vec{B}.d\vec{S}$

4. Modified Maxwell's Ampere's Law ↦

$$\oint_L \vec{B}.d\vec{l} = \mu_0 (I + I_D)$$

$$\Rightarrow \oint_L \vec{B}.d\vec{l} = \mu_0 \left(I + \epsilon_0 \frac{d}{dt}\phi_E\right)$$

$$\Rightarrow \boxed{\oint_L \vec{B}.d\vec{l} = \mu_0 \left(I + \epsilon_0 \frac{d}{dt}\int \vec{E}.d\vec{S}\right)}$$

Electromagnetic waves ↦

According to faraday's law of electromagnetic induction, a time varying magnetic field is a source of changing electric field.

Maxwell argued that thus time varying electric field must also be a source of changing magnetic field.

This means that change in either field will produce the other field. Maxwell further gave the theoretical idea that an accelerated charged particle produces sinusoidal magnetic field, which in turn produces sinusoidal electric field. These two mutually perpendicular electric and magnetic fields produce electromagnetic waves in the direction perpendicular to both the fields.

(ie if E.field varies along Y axis
and " " " Z "
then em wave will propagate along X axis.)

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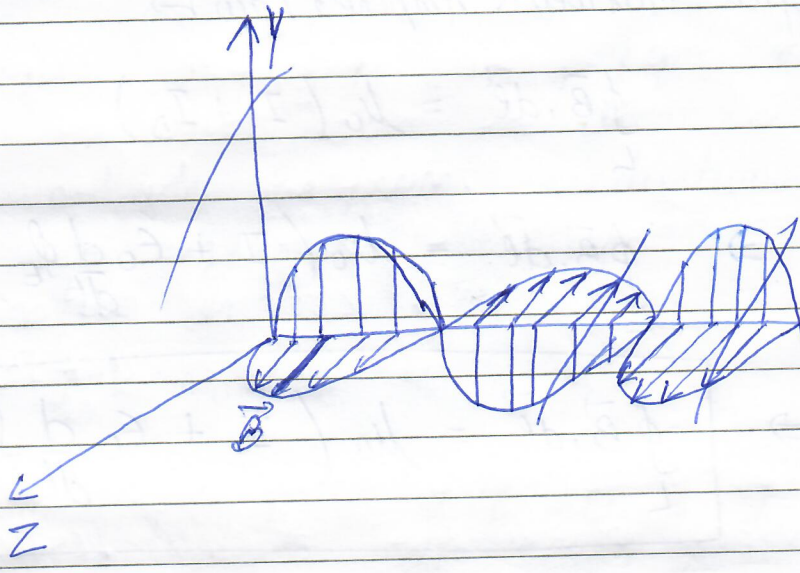
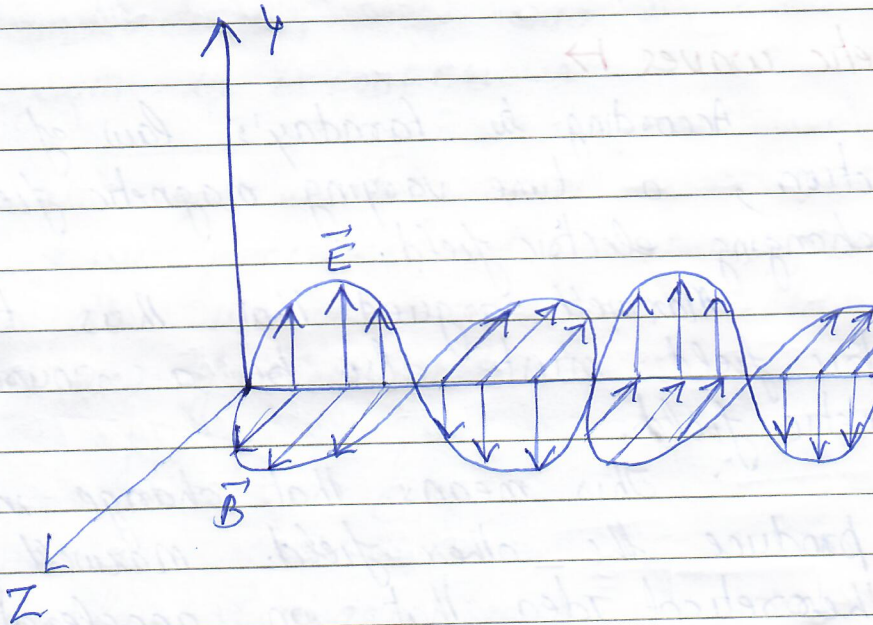
Thus whenever electric and magnetic fi
varying sinusoidally and are perpendicu
each other, we get em. waves in
~~perd~~ perpendicular to ~~the~~ both the fie





Variation in electric and magneti
in same phase. ie both attains their ma
minima at the same instant and at
place (x)

Also velocity of em wave is

classmate | $C = \frac{E}{B}$ or $C = \frac{E_0}{B_0}$ or $C =$

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Source of em waves ↦ A stationary charged particle produces only electric field. Where as a ch moving with uniform velocity can produce mag. field. But this mag. field does not change with t

Thus neither a stationary charge, nor charge moving with uniform velocity can produce em waves.

Maxwell pointed out that an accelera charged ~~par~~ particle produces time varying magne field and hence time varying electric field. Th accelerated charged particle produces em wave.

eg. in LC oscilations a charge osci harmonically with time. ie charge ~~beha~~ is an accelerating charge and hence produce em w

Whenever an electron jumps from higher to lower orbit, its velocity changes hence prod em waves.

History of em waves ↦ In 1865 Maxwell gave a theoretical idea of em. waves. He said an accelerated charged produces time varying mag which in turns produces time varying electric field. two fields are mutually ⊥ar to each other and hence produce em waves in a direction ⊥ar to both t fields.

Later on in 1887 Hertz experimentall produces the em waves by using spark oscillator. The wavelength of these waves was very high an was of the order of 6m.

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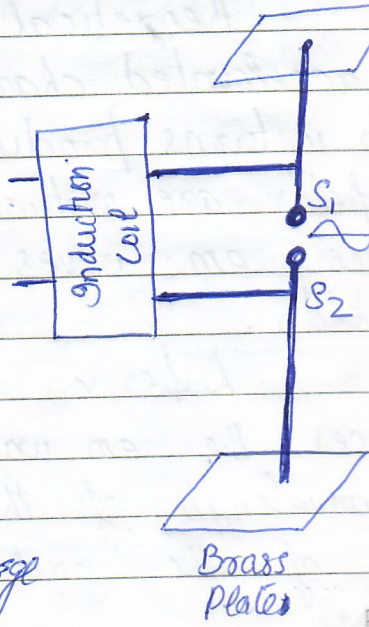
In 1894. Indian scientist J. C. Bo produced em wave of comparitively sh wave length ~~and hence of high energy~~ in range of 5mm to 25mm.

In 1896 Marconi ~~was~~ become ab transmit em waves over the long dis making use of antenna.

Marconi first established wire communication across the English chan width 50 kms.

Hertz Expt ⇒ Hertz used spark oscillator em waves. Hertz experimental arrang consist of two large square brass sides of length 40 cm and held at of 60 cm from each other. These two p connected two highly polished brass spher S_2 with the help of thick copper wi separation b/w the two spheres is 3 cms. Thick copper wire are attached coil as shown. Induction coil sets up a very high potential diff. across S_1 and S_2. This high Pot. diff. ionizes the air b/w the spheres and makes the gap conducting. The ions and electrons so produced oscillates back and forth. Thus an oscillatory discharge



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of the plates occurs through the conducting gap, resulting in production of em waves.

The electromagnetic waves so produced are detected noticing the spark produced b/w two spheres D_1

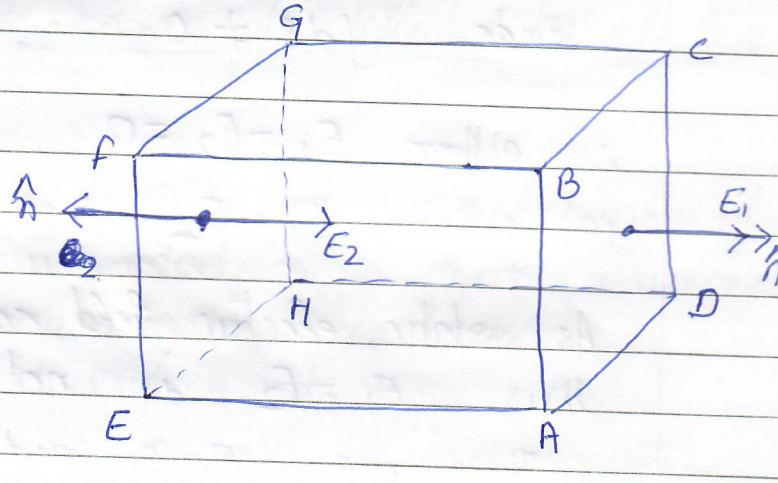
In Hertz experiment metal plates forms a capacitor of low capacitance C and connecting wire offer a low inductance L. Thus em waves of high frequency $\nu = \frac{1}{2\pi\sqrt{LC}}$ are generated.

Transverse Nature of em waves ↦

Consider a plane electromagnetic wavefront propagating along X axis.

~~Let the plane wave front~~

Let ABCD is the portion of plane wave front after time t. Since wave is propagating along X axis therefore the value of electric field E and magnetic field B will depend only upon the x co-ordinate.



Since closed surface ABCDEFGH does not enclose any charge, therefore from Gauss's law,

$$\oint_{ABCDEFGH} \vec{E}.d\vec{S} = 0$$

$$\Rightarrow \int_{ABCD} \vec{E}.d\vec{S} + \int_{EFGH} \vec{E}.d\vec{S} + \int_{EADH} \vec{E}.d\vec{S} + \int_{FBCG} \vec{E}.d\vec{S} + \int_{EABF} \vec{E}.d\vec{S} + \int_{HDCG} \vec{E}.d\vec{S} = 0$$

Since value of E does not depend upon y and z coordinates $\int \vec{E}.d\vec{S}$ for the faces normal to Y and Z axis will cancel out in pairs.

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$$\Rightarrow \int_{ABCD} \vec{E}\cdot d\vec{s} + \int_{EFGH} \vec{E}\cdot d\vec{s} = 0$$

Let the value of E is E_1 for face ABCD face EFGH. Thus we get.

$$\int_{ABCD} E_1 ds \cos 0 + \int_{EFGH} E_2 ds \cos 180 = 0$$

$$\Rightarrow \int_{ABCD} E_1 ds - \int_{EFGH} E_2 ds = 0$$

$$\Rightarrow (E_1 - E_2)\int ds = 0 \qquad \{\because \int_{ABCD} ds$$

since $\int ds \neq 0$

$\therefore$ ~~either~~ $E_1 - E_2 = 0$

ie either $E_1 = E_2$ or $E_1 = 0$ and

As static electric field can't produce em
Thus $E_1 = E_2$ is not possible

Thus we $E_1 = 0$ and $E_2 = 0$ ie the
no electric field along X axis or in
Electric field is $\perp$ar to X axis. ie
$\perp$ar to the direction of propagation of

Similarly by using Gauss's law
magnetism ie $\oint_{ABCDEFGH} \vec{B}\cdot d\vec{s} = 0$, we can p
magnetic field is $\perp$ar to the direct
propagation of wave.

Thus em waves are transverse

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Properties of em waves ↦

① Electromagnetic waves are produced by accelerated charge.

2. em waves donot require any material medium for their propagation.

3. Electric field and magnetic field are ⊥ to each other as well as direction of propagation of waves

4. Velocity of em waves is equal to velocity of light

$$\text{i.e. } C = \frac{E}{B} \quad \text{or} \quad C = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \, ms^{-1}$$

5. Electromagnetic waves are not deflected by electric & magnetic fields.

Electromagnetic spectrum ↦ The orderly distribution of different em wave having different properties in accordance with their wavelength or frequencies is called em spectrum.

S.No.	Name	Wavelength Range	How it is produced	Uses
1.	γ-Rays	~~$< 10^{-3}$ nm~~ $< \frac{1}{100} A^0$	Radioactive decay of the nucleus.	(1) In radiotherapy for treatment of cancer 2. To study the struc of atomic nucleus
2.	X-Rays	~~1nm to 10^{-3} nm~~ ~~10^{-3} nm to $10 A^0$~~ $\frac{1}{100} A^0$ to $10 A^0$.	when a fast moving e^- beam is allowed to fall on a heavy metal	① In medical diagno 2. to ionize the gas 3. for photoelectric emi
3	U.V. Rays	~~$4000 A^0$ to $10 A^0$~~ $10 A^0$ to $4000 A^0$.	when an electron jumps from higher orbit to lower orbit.	① In food preservatio 2. To detect the forge documents or cuts on 3) To reveal finger print

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1/1000 1A° ⟷ 10^{-10} m, 1mm, 1atom, 1/1000

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S.No	Name	Wavelength Range	How it is produced	Us
4.	Visible light	4000Å° to 7000Å°	when an electron jumps from higher orbit to lower orbit	(1) To see around (2) to cau
5.	Infrared Rays	7000Å to 1mm	—do—	(1) In rem (2) In gree
6.	Microwaves	1mm to 100mm	In vacuum Tubes.	(1) In RA (2) In mi (3) In Lon telecon
7.	Radiowaves	>100 mm	In L-C oscillatory circuits	(1) In ra telecom (2) Wirele

Electromagnetic waves in the decreasing ord energy and hence frequency:—

γ-Rays > X Rays > UV Rays > Visible > I.R rays

Highest freq.

∴ Highest energy

Earth's atmosphere ↦ The thick envelop of air th earth is called earth's atmosphere. upto 400km above the surface of e atmosphere can be divided in four

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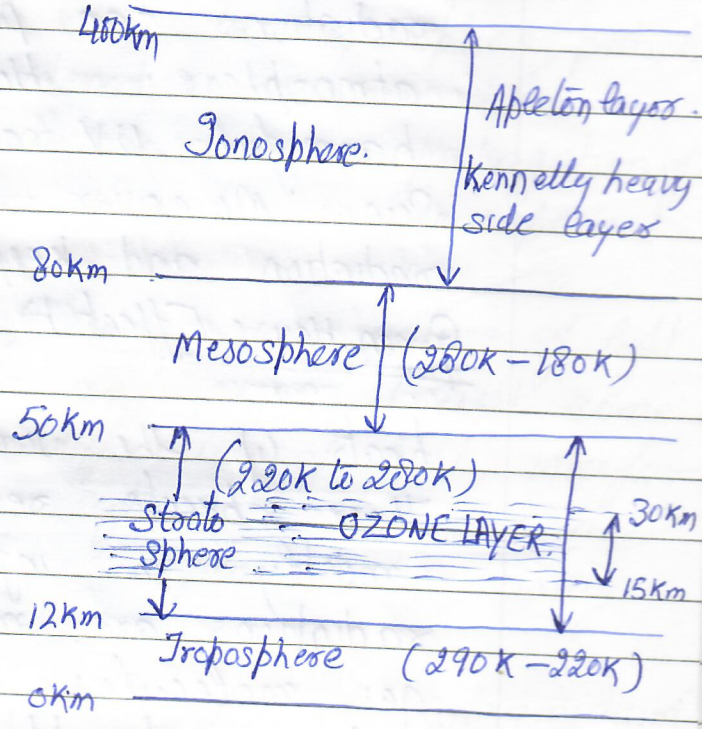
① Troposphere ↦ It extends upto 12km from the surface of earth. Temperature falls with height from 290K to 220K. This layer is responsible for all the weather phenomenons that affect our environment.

2. Stratosphere ↦ It extends from 12kms to 50 kms. This portion of the atmosphere also contains ozone layer which protects us from harmful UV radiations. The temp. of stratosphere rises from 220K to 280K

3. Mesosphere ↦ It extends from 50km to 80kms. The temp. of this region falls from 280K to 180K.



4. Ionosphere ↦ This layer extends ~~upto~~ from 80km to 400km. Its temp. increases with height from 180K to 700K. In this layer most of the gases are in ionized form. This ionization is caused by high energy cosmic rays, U.V rays and X rays coming from the sun. In this region beyond 110km concentration of electrons suddenly increases and extends upto few kms. This layer of electrons of high electron density is called Kennely heavyside layer. Beyond this layer electron density decreases with height and at about 250kms above the surface of earth another layer of electrons known as Appleton layer is met.

Radiowaves
Lowest freq
Lowest energy.

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Behaviour of earth's atmosphere towards em

Earth's atmosphere is transparen
of the em radiations. ie most of
radiations can pass through the e
atmosphere. However ozone layer
harmful UV radiations ~~con~~ coming
Sun. Moreover it also traps the
radiation and keeps the earth war

Green House Effect :-

The radiation from
heats up the varios objects on
These objects re-radiate the radi
mostly in infra red region. Th
radiations are ~~mostly~~ reflected b
gas molecules and clouds lyin
lower atmosphere. Thus earths
atmosphere become richer in
radiation causing Green House
makes the earths surface warm

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