19. MOMENTUM

The propagating electromagnetic wave also carries linear momentum with it. The linear momentum carried by the portion of wave having energy U is given by $p = \frac{U}{c}$ ... (xxvii)

Thus, if the wave incident on a material surface is completely absorbed, it delivers energy U and momentum p=U/c to the surface. If the wave is totally reflected, the momentum delivered to the surface of the material is 2U/c because the momentum of the wave changes from p to –p. It follows that electromagnetic waves incident on a surface exert a force on the surface.

20. ELECTROMAGNETIC SPECRUM AND RADIATION IN ATMOSPHERE

Maxwell's equations are applicable for electromagnetic waves of all wavelengths. Visible light has wavelengths roughly in the range 380 nm to 780 nm. Today we are familiar with electromagnetic waves having wavelengths as small as 30 fm (1 fm=10^{-15} m) to as large as 30 km. Figure 22.33 shows the electromagnetic spectrum we are familiar with.

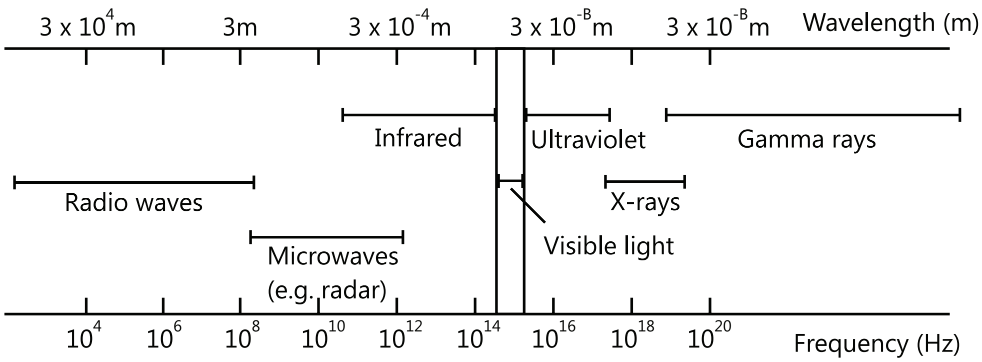

Figure 22.33

The accelerated charge is the basic source of electromagnetic wave. This produces changing electric field and changing magnetic field which constitute the wave. Among the electromagnetic waves, visible light is most familiar to us. This is emitted by atoms under suitable conditions. An atom contains electrons and the light emission is related to the acceleration of an electron inside the atom. The mechanism of emission of ultraviolet radiation is similar to that for visible light.

PROBLEM SOLVING TACTIC

You can remember a single point that when uniform field is into the paper and the rod is moving to the right, i.e. moving out of magnetic field, then higher potential is at the upper end with a difference of Bvl. By remembering this single point you can change it whenever required according to actual situation by just reversing the sign. (E.g. if field is out of the paper and all other conditions are same, then multiply a negative sign.)

FORMULAE SHEET

(a) Flux of magnetic field through a surface: $\Phi_B = \int \vec{B} \cdot d\vec{s}$

(b) Faraday's law of electromagnetic induction

(i) in coil of single loop $E = -\frac{d\Phi_B}{dt}$ (ii) in coil of N loops $E = -\frac{N \cdot d\Phi_B}{dt}$ where E is induced E.M.F.

(c) Motional E.M.F. $E = -\int \vec{E} \cdot d\vec{\ell} = \int (\vec{v} \times \vec{B}) \cdot \vec{\ell} = vB\ell$

(d) The magnitude of induced current is $I = \frac{vB\ell}{R}$

(e) Electric field induced due to changing magnetic field $\int \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$

(f) Power $P = F \times v = \frac{(\ell v B)^2}{R}$

(g) Self-inductance of a coil is $L = \frac{N\Phi_B}{I}$

(h) For infinitely long solenoid, self-inductance per unit length $L_{\text{unit length}} = \mu_0 n^2 \pi r^2$

(i) Self-Induced e.m.f. $E = -L\frac{dI}{dt}$

(j) Series Inductors: $L = L_1 + L_2 + ...$

(k) Parallel Inductors: $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + ...$

(l) For LR circuit

(i) Sourcee.m.f. is $E = L\frac{dI}{dt} + IR$ (ii) Growth of current is $I = \frac{E}{R}(1 - e^{-t/\tau})$

(iii) Decay of current is $i = \frac{E}{R}(e^{-t/\tau})$ (iv) Time constant $\tau = \frac{L}{R}$

(m) Energy stored in an Inductor is $U = \frac{1}{2} LI^2$

(n) Energy density in magnetic field is $u_B = \frac{U}{V} = \frac{B^2}{2\mu_o}$

(o) In LC circuit

(i) The p.d. across each component is $V = \frac{q}{C} = L\left(\frac{di}{dt}\right)$ (ii) Charge in capacitor $q = q_0 \cos(\omega t \pm \phi)$

(iii) Frequency of oscillation $\omega = \frac{1}{\sqrt{LC}}$

(p) E.m.f. due to Mutual Induction $E_1 = -M\frac{di_2}{dt}$ $E_2 = -M\frac{di_1}{dt}$

(q) Speed of electromagnetic wave: $c = \frac{\omega}{k} = f\lambda = \frac{E_o}{B_o} = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$

(r) Energy density in electromagnetic wave $u_{av} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2\mu_0} B_0^2$

(s) Intensity of wave in terms of maximum electric field is $I = \frac{1}{2}\varepsilon_0 E_0^2 c$