Summary of the Various Branches of Spectroscopy

Branch	Frequency, Hz	Wavelength	Typical Energy Unit: Name	Typical Energy Unit: Value in Joules
Static	0–60		Joule	1
			Calorie	4.186
Low or audio frequency	10^3–10^5	3–300 km	kHz	6.62377×10^{-31}
Radio frequency	10^6–10^8	300–3 m	Joule	1
			cm^{-1}	1.98574×10^{-23}
Microwaves	10^9–10^{11}	30 cm to 3 mm	MHz	6.62377×10^{-28}
Infrared	10^{12} to 3×10^{14}	300–1 μm	cm^{-1}	1.98574×10^{-23}
			kcal/M	4.186×10^3
			Joule	1
Visible, ultraviolet	4×10^{14} to 3×10^{15}	0.8–0.1 μm	Erg	1×10^{-7}
			eV	1.60207×10^{-19}
			MHz	6.62377×10^{-28}
X rays	10^{16}–10^{19}	30–0.03 nm	eV	1.60207×10^{-19}
			keV	1.60207×10^{-16}
γ rays	10^{19}–10^{22}	3×10^{-9} to 3×10^{-12} cm	MeV	1.60207×10^{-13}
Low energy, nuclear	10^{19}–10^{23}	3×10^{-9} to 3×10^{-13} cm	MeV	1.60207×10^{-13}
High energy, nuclear	10^{23}–10^{26}	3×10^{-13} to 3×10^{-17} cm	BeV	1.60207×10^{-10}
			GeV	1.60207×10^{-7}
High-energy cosmic rays	$> 10^{25}$		BeV	1.60207×10^{-10}
			GeV	1.60207×10^{-7}

Phenomenon	Typical Radiation Generator	Typical Detector
	Battery	Ammeter Voltmeter
Dielectric absorption	Mechanical	Ammeter Voltmeter
NQR, NMR, dielectric absorption	Tuned circuit Crystal	Antenna
Molecular rotations, ESR	Klystron Magneton Solid State generator	Antenna Crystal Bolometer
Molecular vibrations	Heat source	Bolometer PbS cell
Electronic transitions	Incandescent lamp	Photocell
Electronic transitions	Discharge tube	Photocell
Inner shell electronic transitions	heavy element bombardment	Geiger counter Photomultiplier
Nuclear energy level transitions	Radioactive nuclei	Scintillation detector
Strange particle creation	Accelerator (e.g., synchrotron)	Bubble chamber Spark chamber
Extraterrestrial	Star, magnetic field in galaxy	Extensive shower detector

LHC (Large Hardron Collider): proton 7TeV/particle➔🡐 lead nuclear 574 TeV/particle

Radiation (Hecht 3.4)

1. Linearly Accelerating Charges
2. Synchrotron Radiation
3. Electric Dipole Radiation

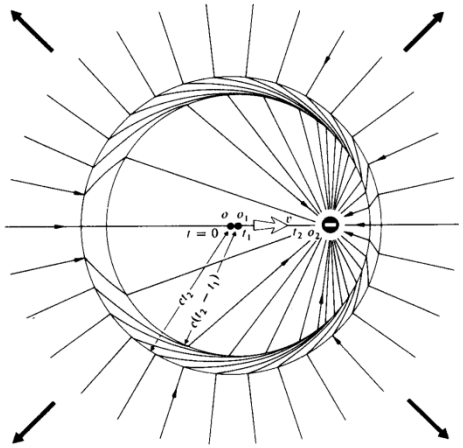


Figure 3.28 A kink in the $\vec{E}$-field lines.

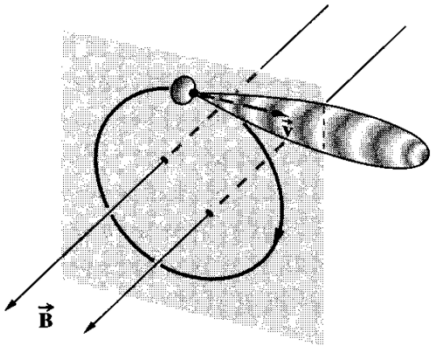


Figure 3.30 Radiation pattern for an orbiting charge.

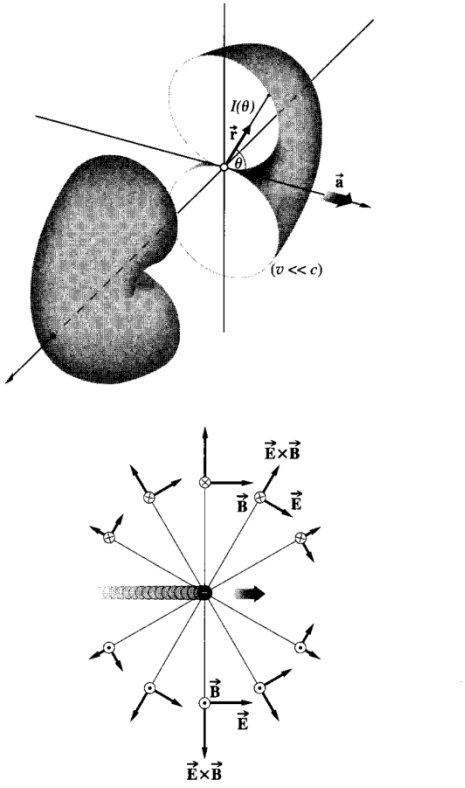


Figure 3.29 The toroidal radiation pattern of a linearly accelerating charge (split to show cross section).

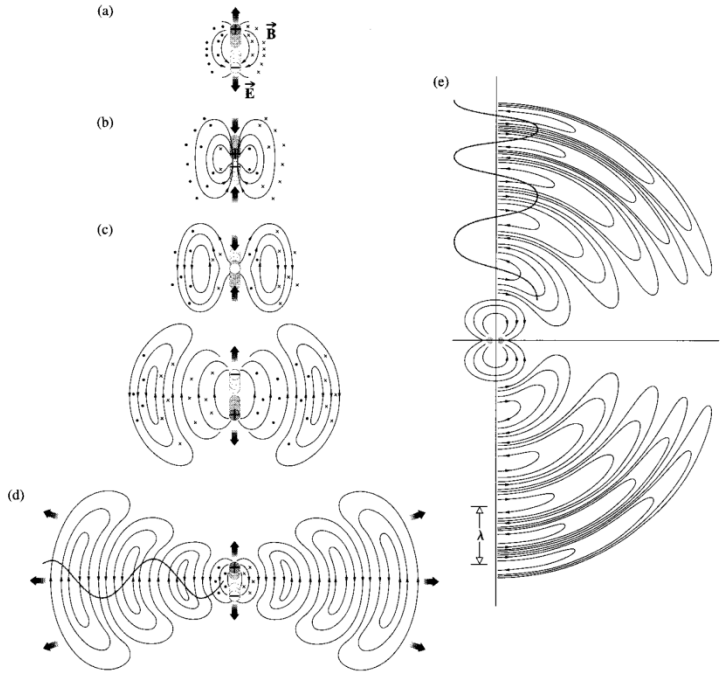
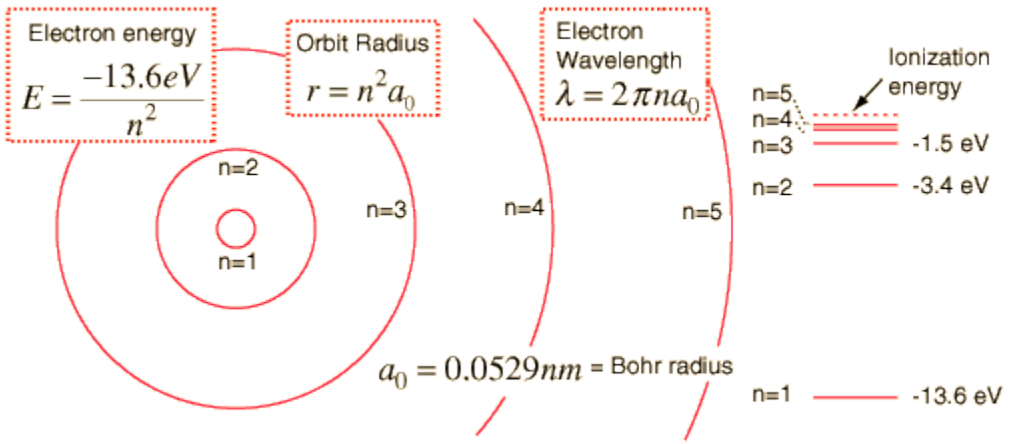
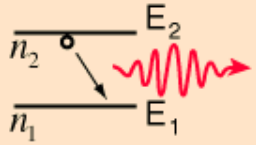


Figure 3.32 The $\vec{E}$-field of an oscillating electric dipole.

Electronic transitions and Bohr Model



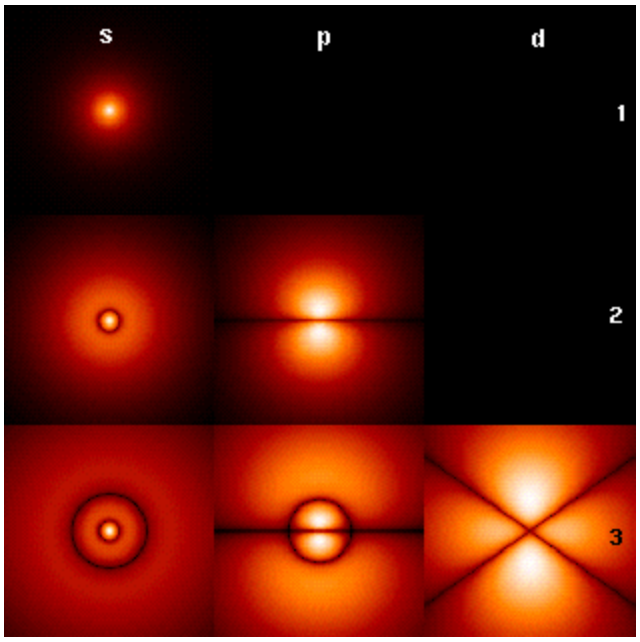


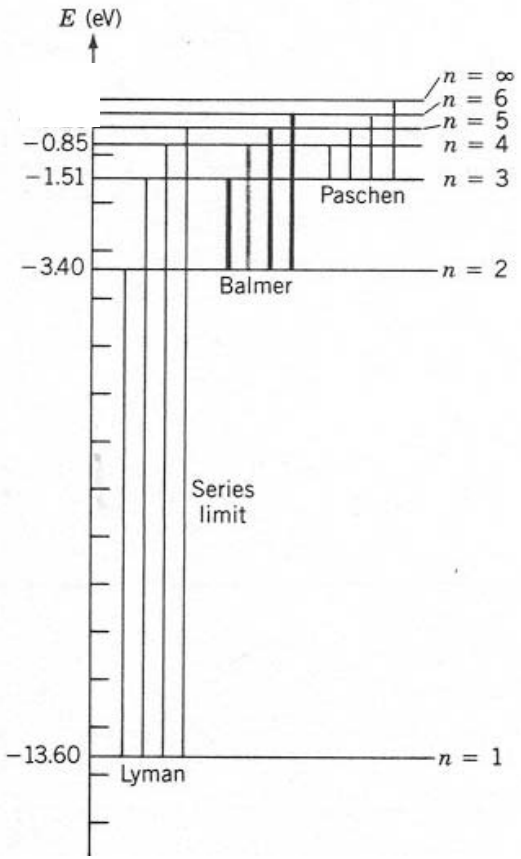
A downward transition involves emission of a photon of energy:

$E_{photon} = h\upsilon = E_2 - E_1$

Given the expression for the energies of the hydrogen electron states:

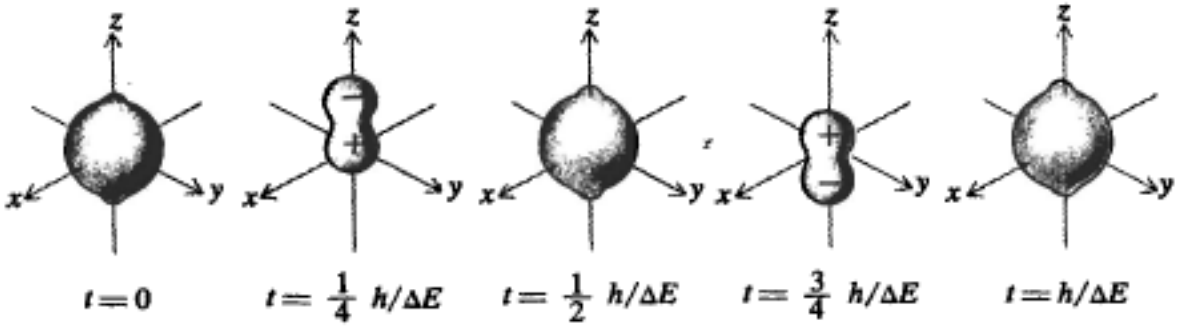
$$h\upsilon = \frac{2\pi^2 me^4}{h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = -13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{eV}$$



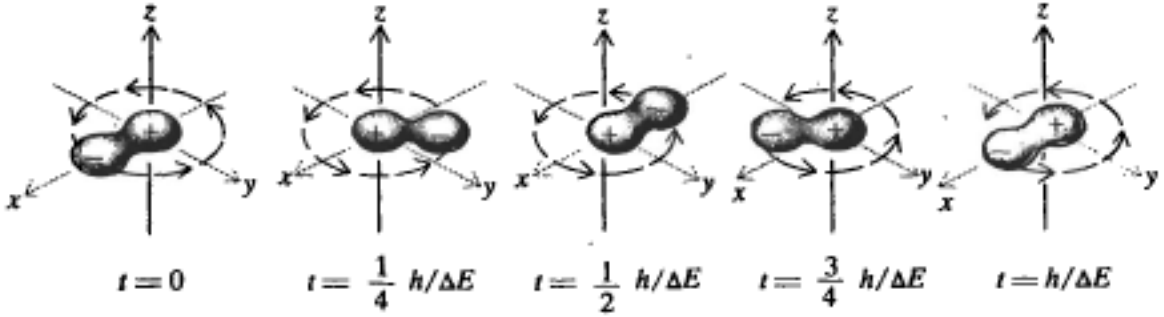


Graphical ("classical") description of optical transitions

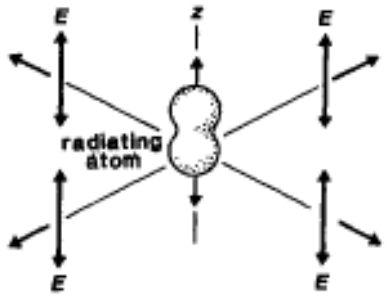
linear dipole: $S(M=0) + P(M=0)$ states



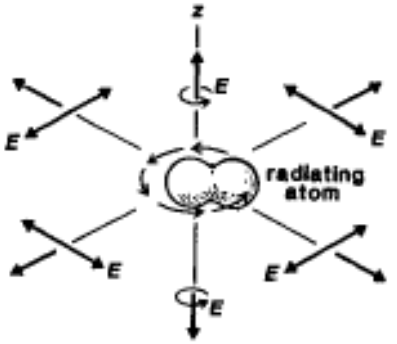
circular dipole: $S(M=0) + P(M=\pm1)$ states



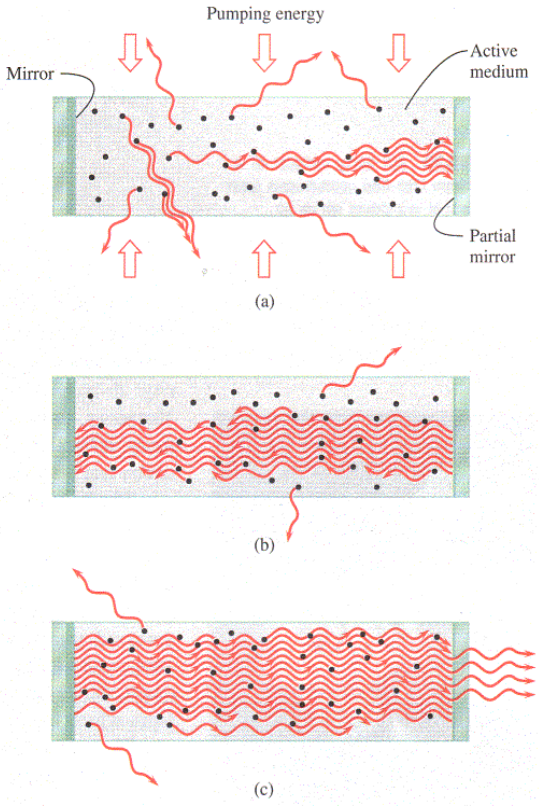
π transitions

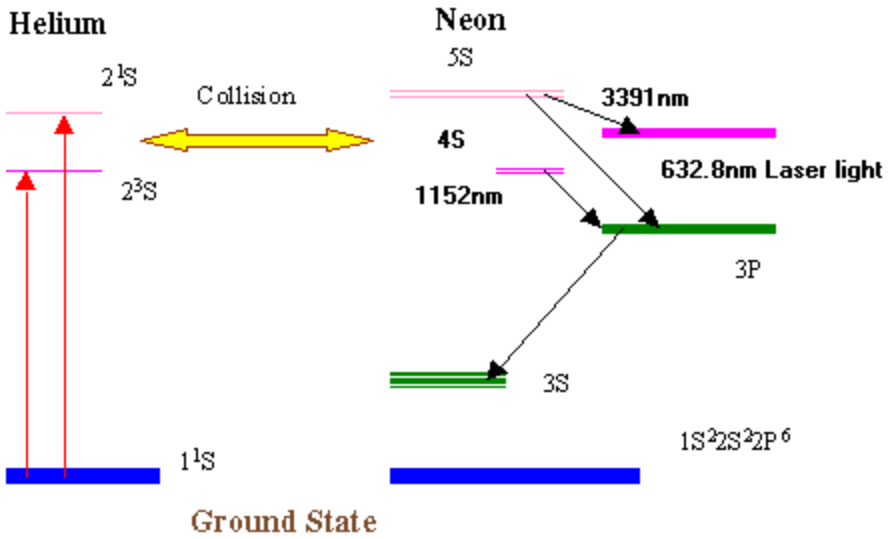


σ transitions



HeNe Lasers


Pumping energy
Mirror
Active medium
Partial mirror
(a)
(b)
(c)


Helium
Neon
2 1S
Collision
5S
3391nm
4S
632.8nm Laser light
1152nm
2 3S
3P
3S
1S 2 2S 2 2P 6
1 1S
Ground State