Since acceleration has the dimensions of length per time squared, the dimensions of force are

$$\frac{\text{Mass} \times \text{Length}}{\text{Time}^2}$$

or in dimensional symbols

$$\text{Force} = \frac{ML}{T^2}$$

Such *dimensional analysis* is also useful for determining the dimensions of a quantity.
The wavelength (λ) and frequency (f) are related to the velocity as

$$v = f\lambda \tag{1.1}$$

The velocity of light $c = 3 \times 10^8$ m/s

In free space $\boxed{v = c = 3 \times 10^8 \text{ m/s}}$

Equation (1.1) can be confirmed by using the chart of Table 1.2.

TABLE 1.2 Frequencies and wavelengths of the electromagnetic spectrum

	Frequency	f = c /	Wavelength	= c / f	Relevant dimensions
	1 Hz —	1 — 300			
	Hz	10 — 30	Mm		
		100 — 3			— Earth diameter
			— 10^6 m		
	10^3 Hz —	1 — 300			
	kHz	10 — 30	km		
		100 — 3			— Mt. Everest
Radio			— 10^3 m		
	10^6 Hz —	1 — 300			
	MHz	10 — 30	m		
		100 — 3			— Redwood tree
			— 1 m		— Human
	10^9 Hz —	1 — 300			— Hydrogen line
	GHz	10 — 30	mm		— O_2 line
		100 — 3			Molecular lines
			— 10^{-3} m		— Sand grain
	10^{12} Hz —	1 — 300			
Infrared	THz	10 — 30	μm		
		100 — 3			— Bacterium
			— 10^{-6} m		
Visible	10^{15} Hz —	1 — 300			
UV	PHz	10 — 30	nm		— Virus
		100 — 3			
			— 10^{-9} m		— Atomic spacing
X-ray	10^{18} Hz —	1 — 300			
	EHz	10 — 30	pm		— Atom
		100 — 3			
			— 10^{-12} m		
Gamma ray	10^{21} Hz —	1 — 300			
		10 — 30	fm		
		100 — 3			
			— 10^{-15} m		— Atomic nucleus

1.5 The Electromagnetic Spectrum

LO5
Discuss electromagnetic spectrum and the radio frequency bands

According to an American military general, the third World War (if ever fought) will be won by the side that will have a better command over the electromagnetic spectrum (given in Table 1.2). Theoretically, the spectrum encompasses all frequencies ranging from 0+ to infinity. The spectrum shown, however, includes a limited (finite) range along with relevant known objects to fit into the human imagination.

1.5.1 Radio Frequency Bands

Besides, the sphere of present-day communication involving antennas is confined to still a limited segment of the spectrum. The frequencies of SHF segment are further divided into a number of bands and subbands in Table 1.3. This table also includes the principal applications corresponding to different bands.

TABLE 1.3 Radio frequency, band designation and principal applications

Radio-frequency band names†					
Name	*Frequency*	*Principle use*			
ELF†	3–30 Hz				
SLF	30–300 Hz	Power grids			
ULF	300–3000 Hz		*Microwave band*		
VLF	3–30 kHz	Submarines	*"Old"*	*"New"*	*Frequency*
LF	30–300 kHz	Beatons	L	D	1–2 GHz
MF	300–3000 kHz	AM broadcast	S	E, F	2 – 4 GHz
HF	3–30 MHz	Shortwave broadcast	C	G, H	4–8 GHz
VHF	30–300 MHz	FM. TV	X	I, J	8–12 GHz
UHF	300–3000 MHz	TV LAN, cellular, GPS	Ku	J	12–18 GHz
SHF	3–30 GHz	Radar, GSO satellites, data	K	J	18–26 GHz
EHF	30–300 GHz	Radar, automotive, data	Ka	K	26–40 GHz

Review

SUMMARY

LO 1: Explain the evolution of antennas

- ***Antennas*** are electronic eyes and ears of the world and are essential for aircraft, ships, space vehicles, cellular phones and all types of wireless devices.
- First radio antennas were built by a German professor, Heinrich Hertz, in 1886.
- Marconi's invention at the beginning of twentieth century made him the Wizard of Wireless.

LO 2: Define the units and dimensions

- A ***dimension*** defines a physical characteristic of an object.