# Photonics: Fundamentals & Applications (Lect. 1, Monsoon 2020)

Instructor: Sayak Bhattacharya

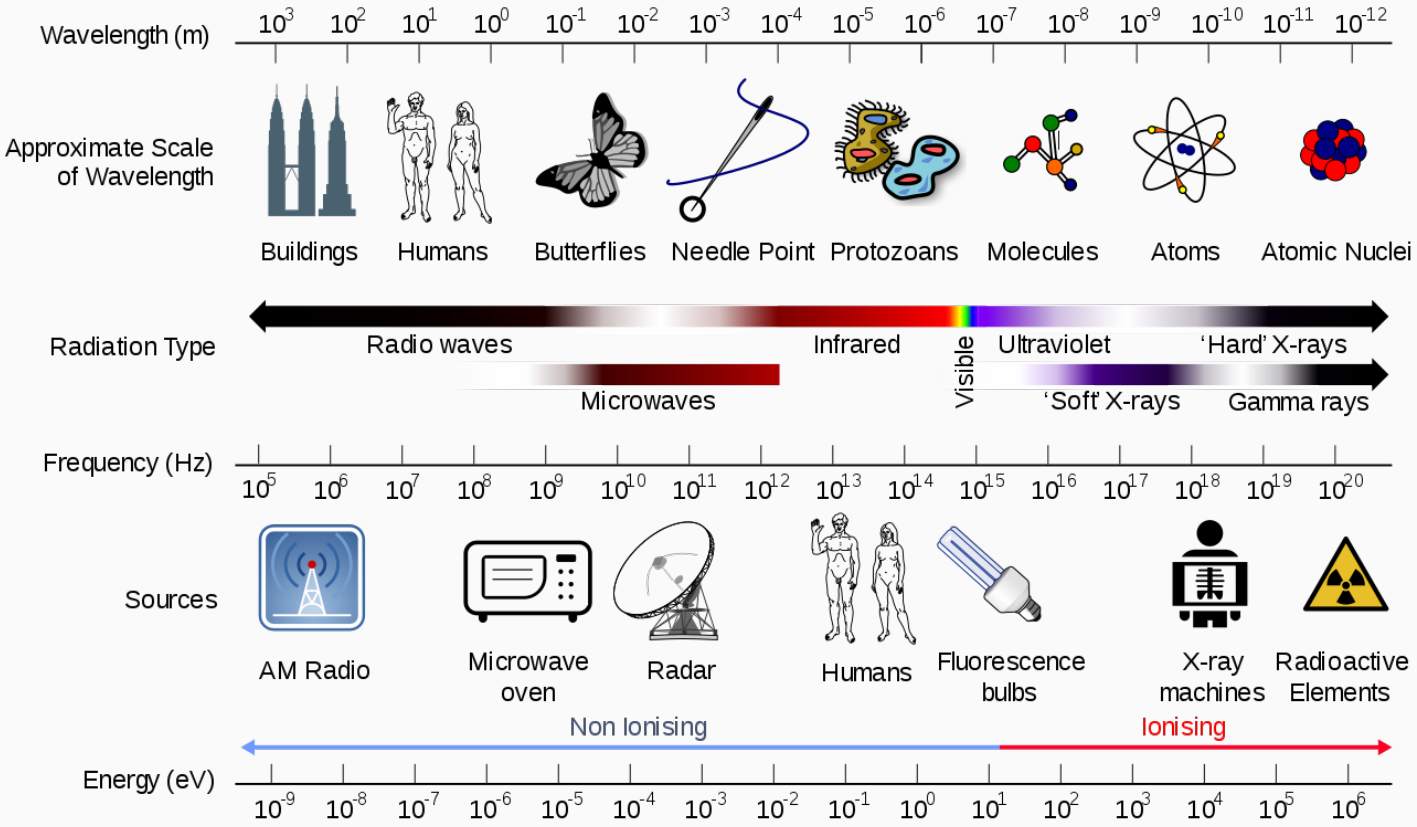
# Grading policy

- Assignments 15%
- Quiz 15%
- Mid-semester 20%
- Mini-project 15%
- End-semester 35%
- Relative grading.
- Penalty for late-submission of assignments: After the submission deadline is over, a penalty of 25% of the obtained marks 'll be imposed per day (so zero marks if submitted on 4th day after the deadline).
- Zero tolerance towards plagiarism and/or cheating in assignments/exams. Such cases 'll be dealt strictly.

# Course outline

- Review of Maxwell's equations, Electromagnetic boundary conditions, polarization of light-wave, TEM, TE and TM modes.
- Module 1: Optical components fundamentals: pulse propagation, ray-optics, mirror, beam-splitter, polarizer, interferometers, laser, photodiodes (We expect to reach this point after $6-7$ weeks from now)
- Module 2: Surface plasmon, localized surface plasmon resonance (LSPR) in metal nano-particles, applications to sensing.
- Module 3: Numerical tools for photonics and sensor design (Hands-on design starts!!)
- Module 4: Nanophotonics, Photonic crystals and applications to on-chip optical component design.

# Electromagnetic spectrum (Image source: wiki)



# Down memory lane: Corpuscular theory of light

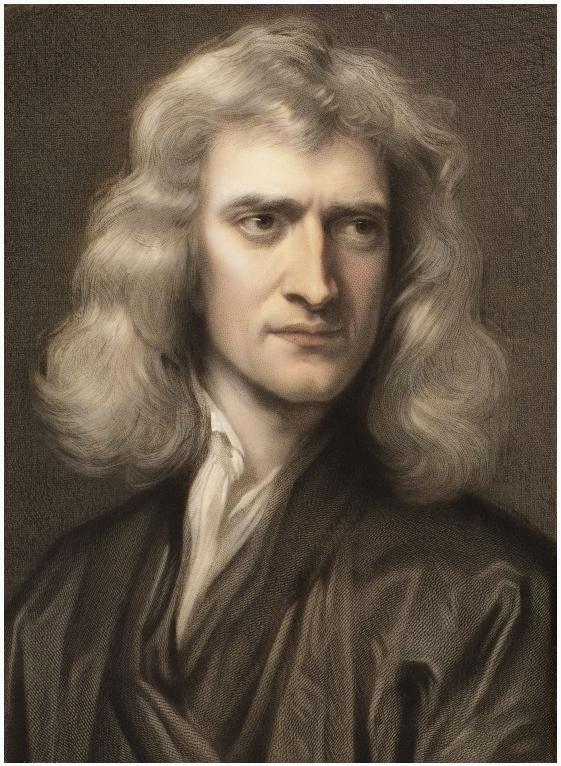


**Figure 1:** Isaac Newton (1643 – 1727)

# Huygen's principle

**Figure 2:** Christiaan Huygens (1629 – 1695)

# Double slit experiment

**Figure 3:** Thomas Young (1773 – 1829)

# Unified theory of electricity and magnetism

- 1785 : Charles-Augustin de Coulomb reports inverse square law for charges
- 1800 : Alessandro Volta invents battery
- 1820 : Hans Christian Ørsted shows deflection of compass needle brought in the proximity of a current carrying wire
- 1820 : Ampere shows two parallel current-carrying wire attracts/repel depending on the direction of the current
- 1831 : Michael Faraday discovers electromagnetic induction

# Unified theory of electricity and magnetism: Maxwell's equations

**Figure 4:** James Clerk Maxwell (1831 – 1879)

# Unified theory of electricity and magnetism: Maxwell's equations

$$\left.\begin{aligned}
&\mathrm{PX} \quad +(p+h)x+(k+l)y=\int \mathrm{A}dt-\int \mathrm{D}dt,\\
&\mathrm{Q(X-Z)}+(h+q)x+(m+n)y=\int \mathrm{D}dt-\int \mathrm{C}dt,\\
&\mathrm{RY} \quad +(k+m)x+(r+o)y=\int \mathrm{A}dt-\int \mathrm{E}dt,\\
&\mathrm{S(Y+Z)}+(l+n)x+(o+s)y=\int \mathrm{E}dt-\int \mathrm{C}dt,\\
&\mathrm{GZ}=\int \mathrm{D}td-\int \mathrm{E}dt.
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

Solving these equations for Z, we find

$$\left.\begin{aligned}
&\mathrm{Z}\left\{\tfrac{1}{\mathrm{P}}+\tfrac{1}{\mathrm{Q}}+\tfrac{1}{\mathrm{R}}+\tfrac{1}{\mathrm{S}}+\mathrm{B}\left(\tfrac{1}{\mathrm{P}}+\tfrac{1}{\mathrm{R}}\right)\left(\tfrac{1}{\mathrm{Q}}+\tfrac{1}{\mathrm{S}}\right)+\mathrm{G}\left(\tfrac{1}{\mathrm{P}}+\tfrac{1}{\mathrm{Q}}\right)\left(\tfrac{1}{\mathrm{R}}+\tfrac{1}{\mathrm{S}}\right)+\tfrac{\mathrm{BG}}{\mathrm{PQRS}}(\mathrm{P+Q+R+S})\right\}\\
&\quad =-\mathrm{F}\tfrac{1}{\mathrm{PS}}\left\{\tfrac{p}{\mathrm{P}}-\tfrac{q}{\mathrm{Q}}-\tfrac{r}{\mathrm{R}}+\tfrac{s}{\mathrm{S}}+h\left(\tfrac{1}{\mathrm{P}}-\tfrac{1}{\mathrm{Q}}\right)+k\left(\tfrac{1}{\mathrm{R}}-\tfrac{1}{\mathrm{P}}\right)+l\left(\tfrac{1}{\mathrm{R}}+\tfrac{1}{\mathrm{Q}}\right)-m\left(\tfrac{1}{\mathrm{P}}+\tfrac{1}{\mathrm{S}}\right)\right.\\
&\quad \left.+n\left(\tfrac{1}{\mathrm{Q}}-\tfrac{1}{\mathrm{S}}\right)+o\left(\tfrac{1}{\mathrm{S}}-\tfrac{1}{\mathrm{R}}\right)\right\}.
\end{aligned}\right\} \quad (25)$$

**Figure 5:** James Clerk Maxwell, A Dynamical Theory of the Electromagnetic Field, Royal Society Publishing (1865)

# Oliver Heaviside: condensed form of Maxwell's equations (1885)

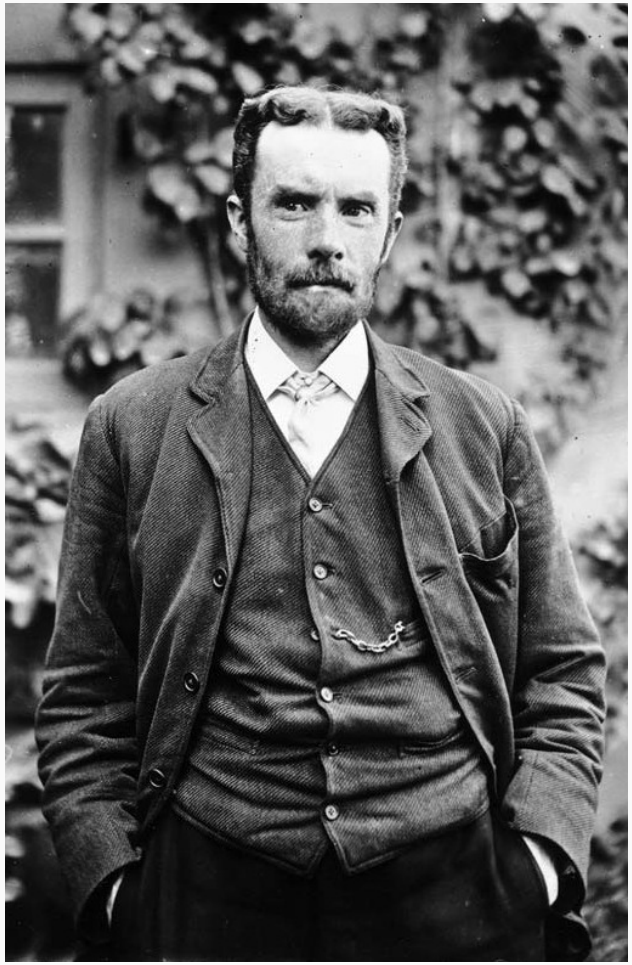


**Figure 6:** Oliver Heaviside (1850–1925)

# Oliver Heaviside: condensed form of Maxwell's equations (1885)

- $\vec{\nabla}.\vec{E} = \frac{\rho}{\varepsilon_0}$
- $\vec{\nabla}.\vec{B} = 0$
- $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$
- $\vec{\nabla} \times \vec{B} = \mu_0 \left( \vec{J} + \frac{\partial \vec{D}}{\partial t} \right)$

# Photoelectric effect: photon

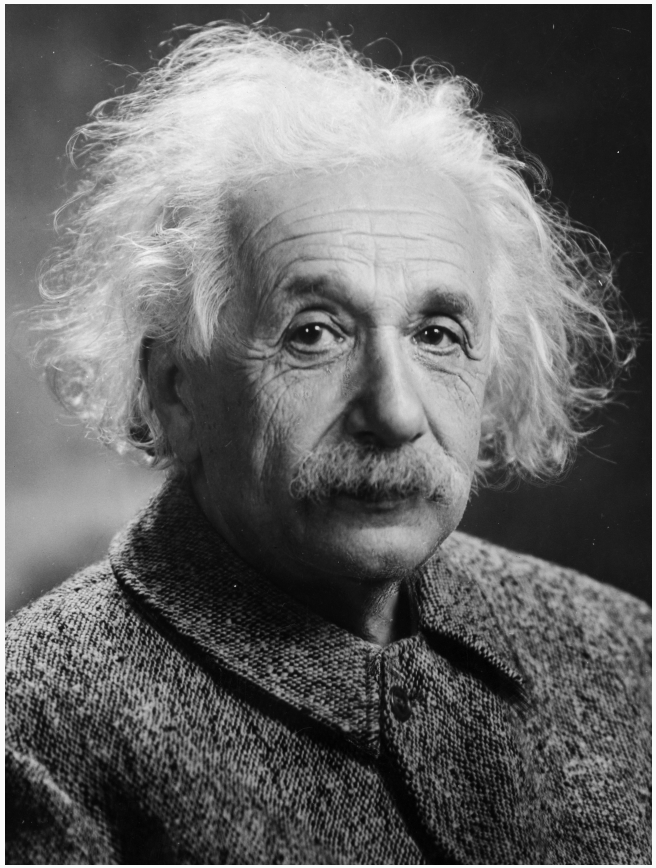


**Figure 7:** Albert Einstein (1879 – 1955)

# Quantum optics

**Figure 8:** E.C. George Sudarshan (1931 – 2018)