المحاضرة الثانية

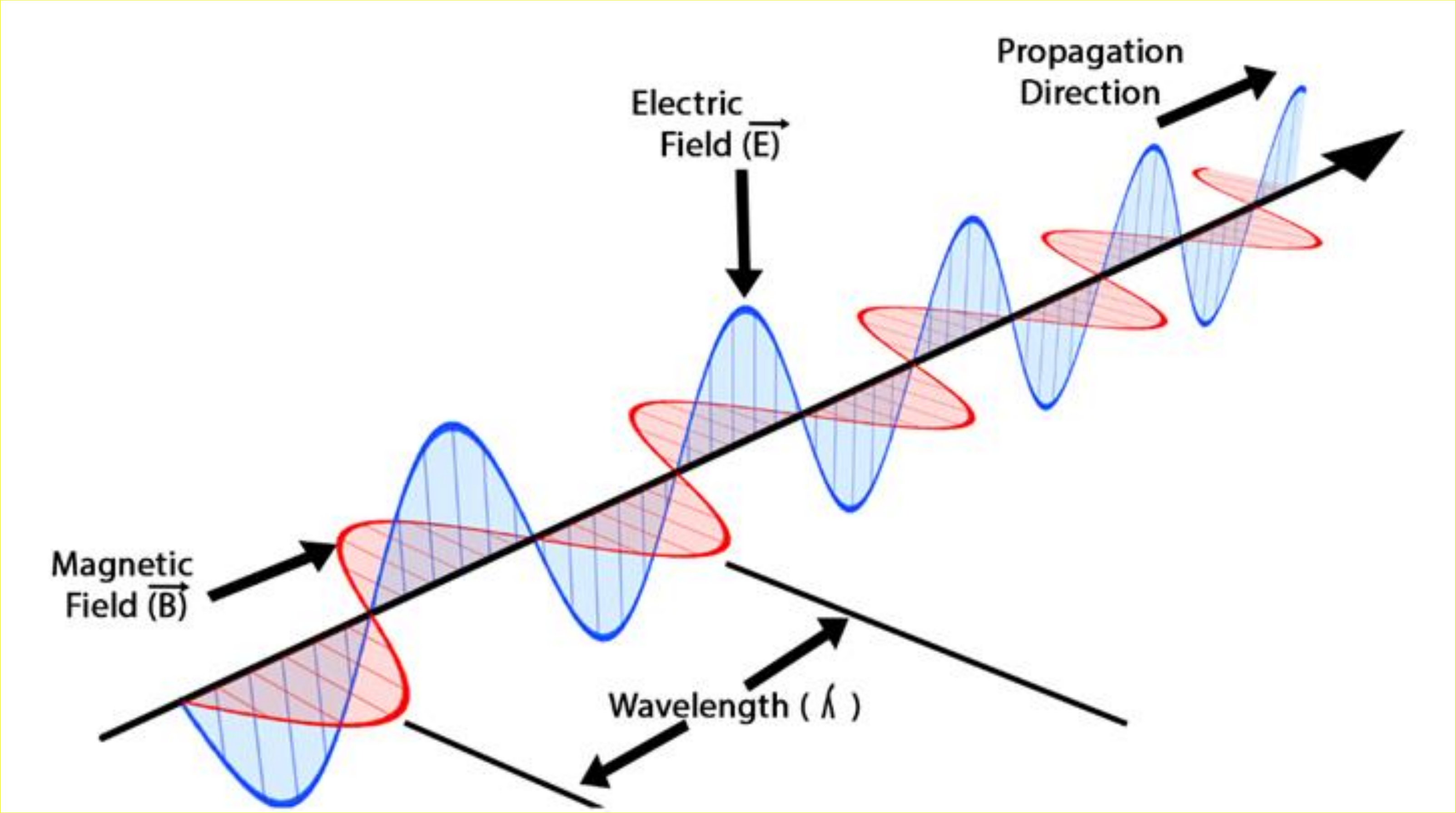
نظرية انتشار الضوء ومعادلات ماكسويل

Light spreading and Maxwell's equations

Nature of Light

- نظرية نيوين
- نظرية هيجنز
- نظرية ينج
- ماكسويل
- بلانك وأينشتين

❑ The electromagnetic wave theory



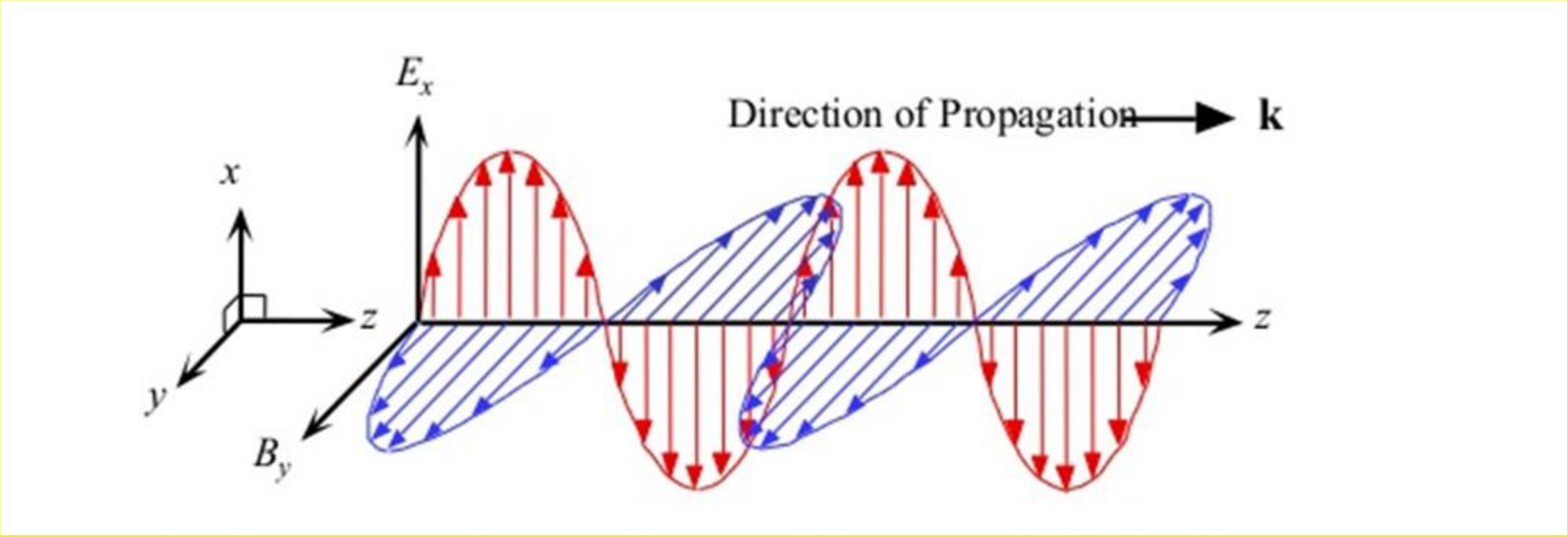
- **Maxwell proved that light must be a transverse wave and that E and B, for a plane wave in an isotropic medium with no free charges and no currents, are mutually perpendicular and lie in a plane normal to the direction of propagation, k**

- **K is the wave vector which gives the direction of the propagation of a light ray. As an example, if you use a laser pointer, k is parallel to the light beam.**

Maxwell's Equations

The phone in your pocket or the light in your bedroom. The electric cars on the road or the biggest machine in the world, the Large Hadron Collider. If you ask how they work, and keep asking 'why' questions like a toddler, you will always end up at Maxwell's equations.

- These equations describe how electric and magnetic fields propagate, interact, and how they are influenced by objects.
- Maxwell was one of the first to determine the speed of propagation of electromagnetic (EM) waves was the same as the speed of light - and hence to conclude that EM waves and visible light were really the same thing.
- Maxwell's Equations shows that separated charge (positive and negative) gives rise to an electric field and to magnetic field.



Maxwell's Equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

Maxwell's equations

Electric field: $\mathbf{E}$ Magnetic field: $\mathbf{B}$

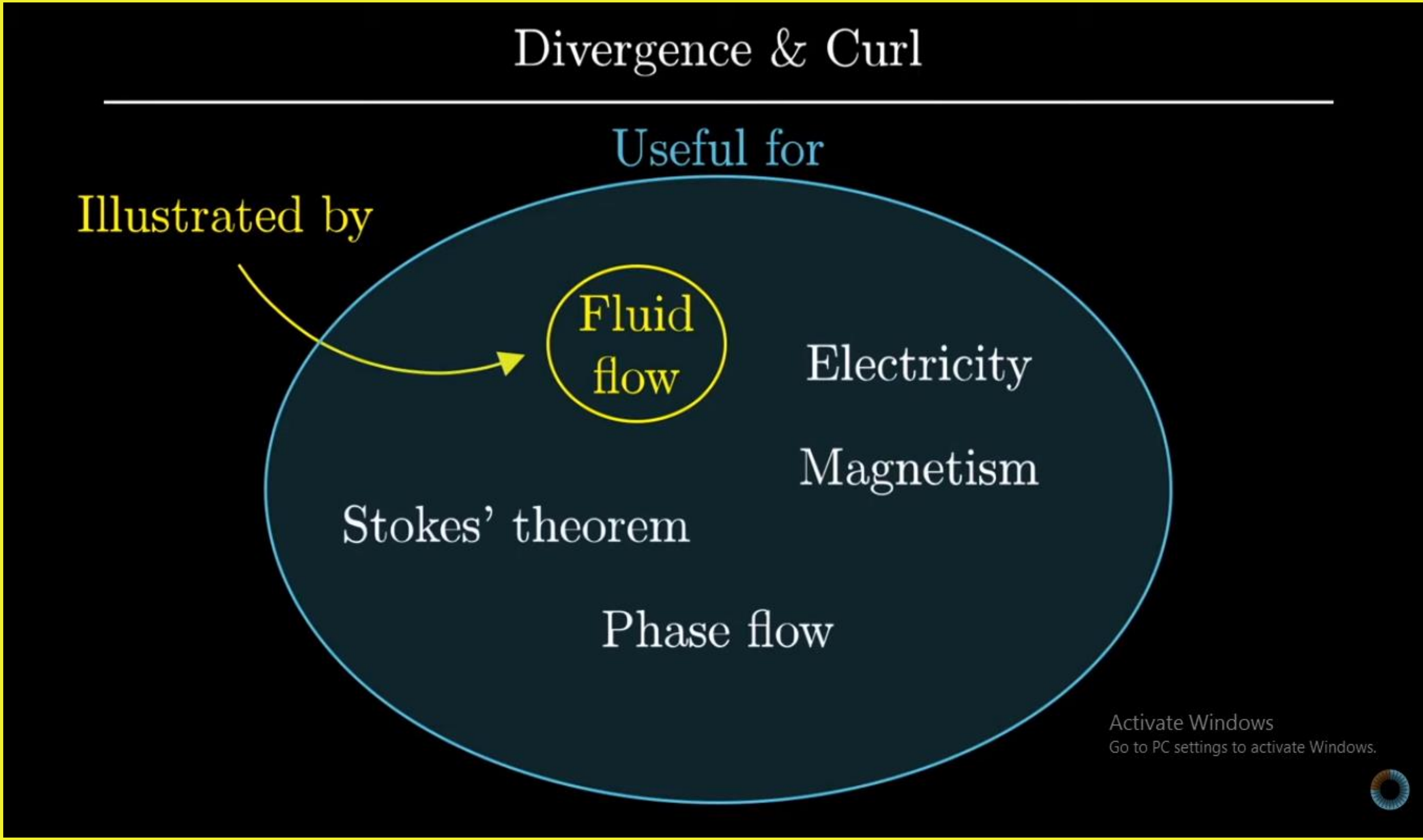
$$\operatorname{div} \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\operatorname{div} \mathbf{B} = 0$$

$$\operatorname{curl} \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\operatorname{curl} \mathbf{B} = \mu_0 \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$$

$\nabla \cdot$ $\nabla \times$

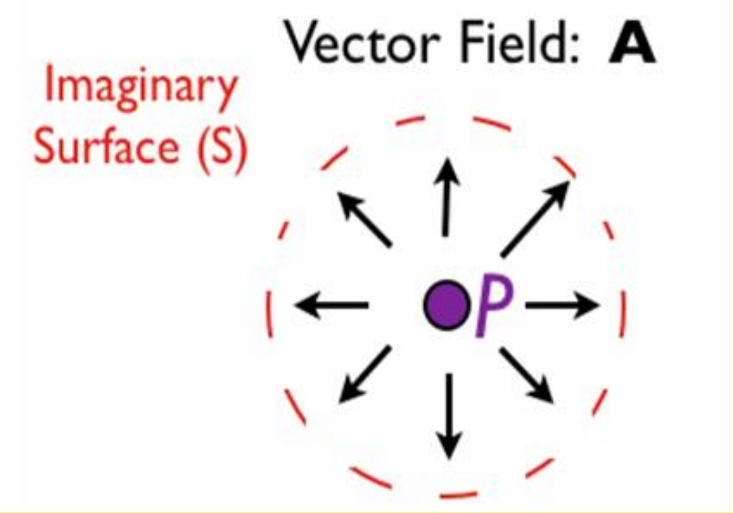


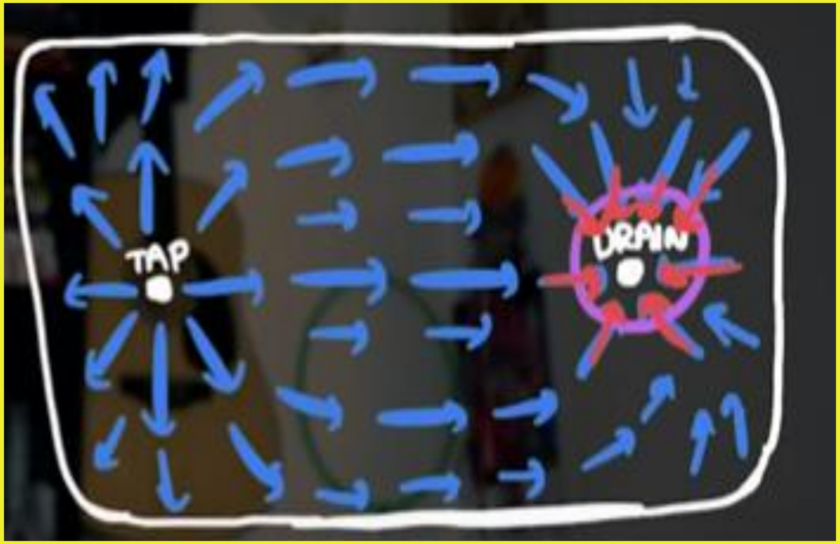
The Divergence Operator

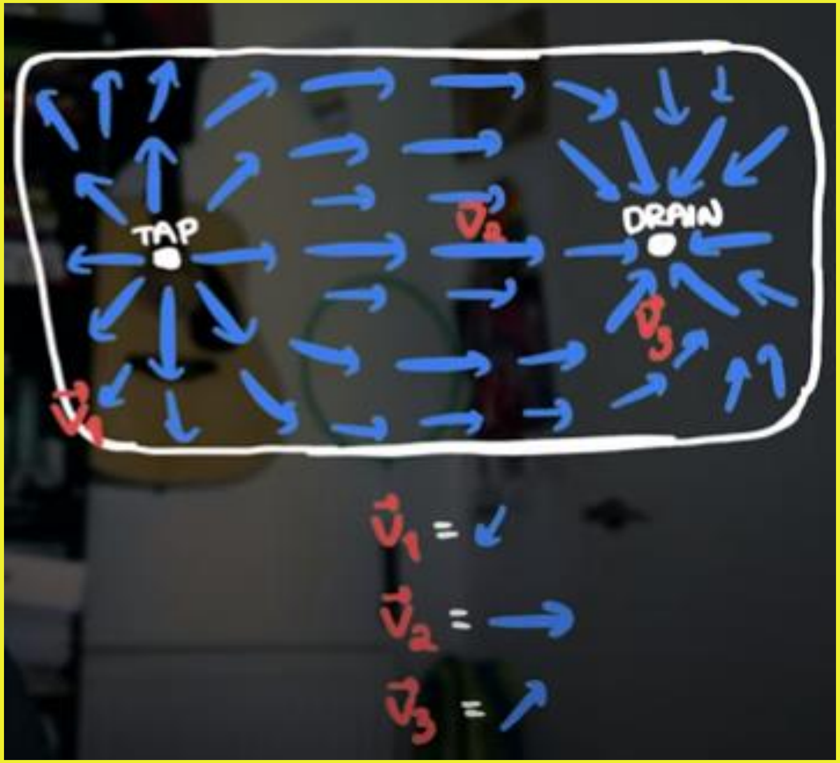
$$\nabla \cdot$$

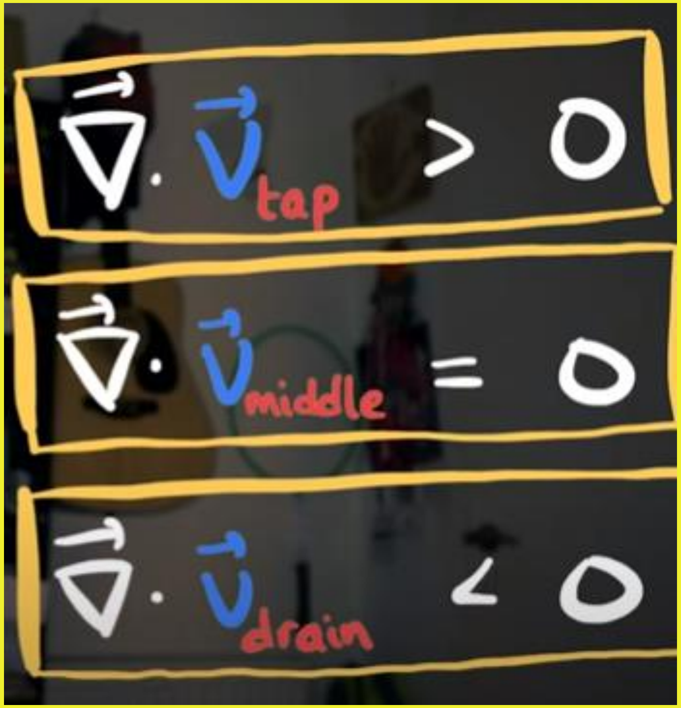
- Divergence at a point (x,y,z) is the measure of the vector flow out of a surface surrounding that point and flow in a surface surrounding that point.

- Imagine we have a vector field (given by the vector function A) as shown in Figure, and we want to know what the divergence is at the point P:




TAP
DRAIN


TAP
DRAIN
$\vec{v}_2$
$\vec{v}_3$
$\vec{v}_1$
$\vec{v}_1 =$
$\vec{v}_2 =$
$\vec{v}_3 =$

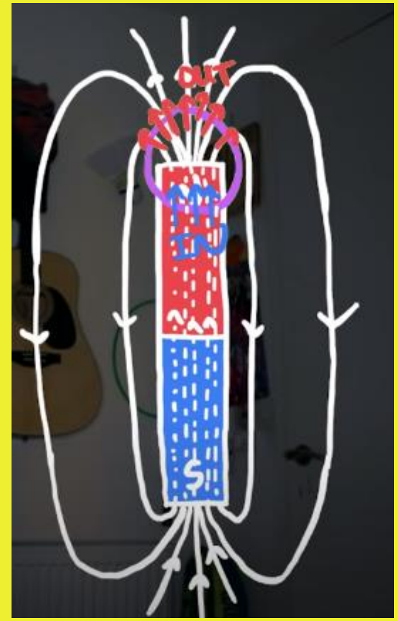

$\vec{\nabla} \cdot \vec{v}_{tap} > 0$
$\vec{\nabla} \cdot \vec{v}_{middle} = 0$
$\vec{\nabla} \cdot \vec{v}_{drain} < 0$

Magnetic field: NO sources or sinks since $\vec{\nabla}\cdot\vec{B}=0$, NOT $\vec{\nabla}\cdot\vec{B}>0$ x or $\vec{\nabla}\cdot\vec{B}<0$ x

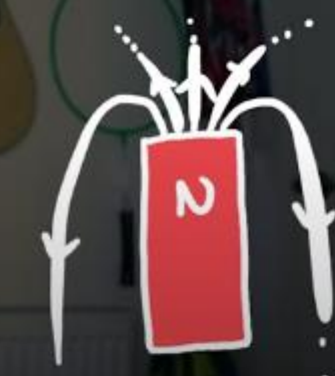
Electric field: CAN have

$\vec{\nabla}\cdot\vec{E}>0$

$\vec{\nabla}\cdot\vec{E}<0$



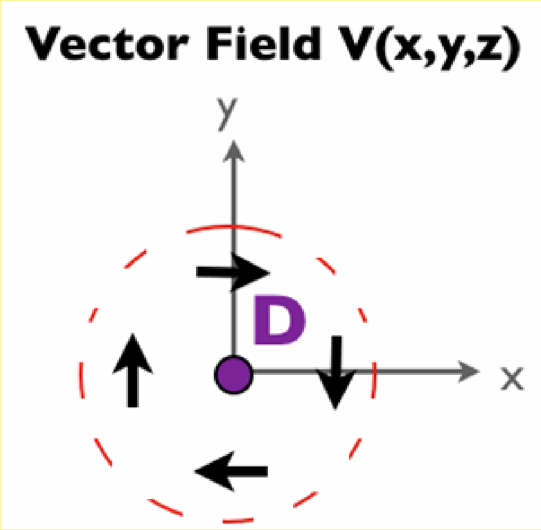
CANNOT HAVE

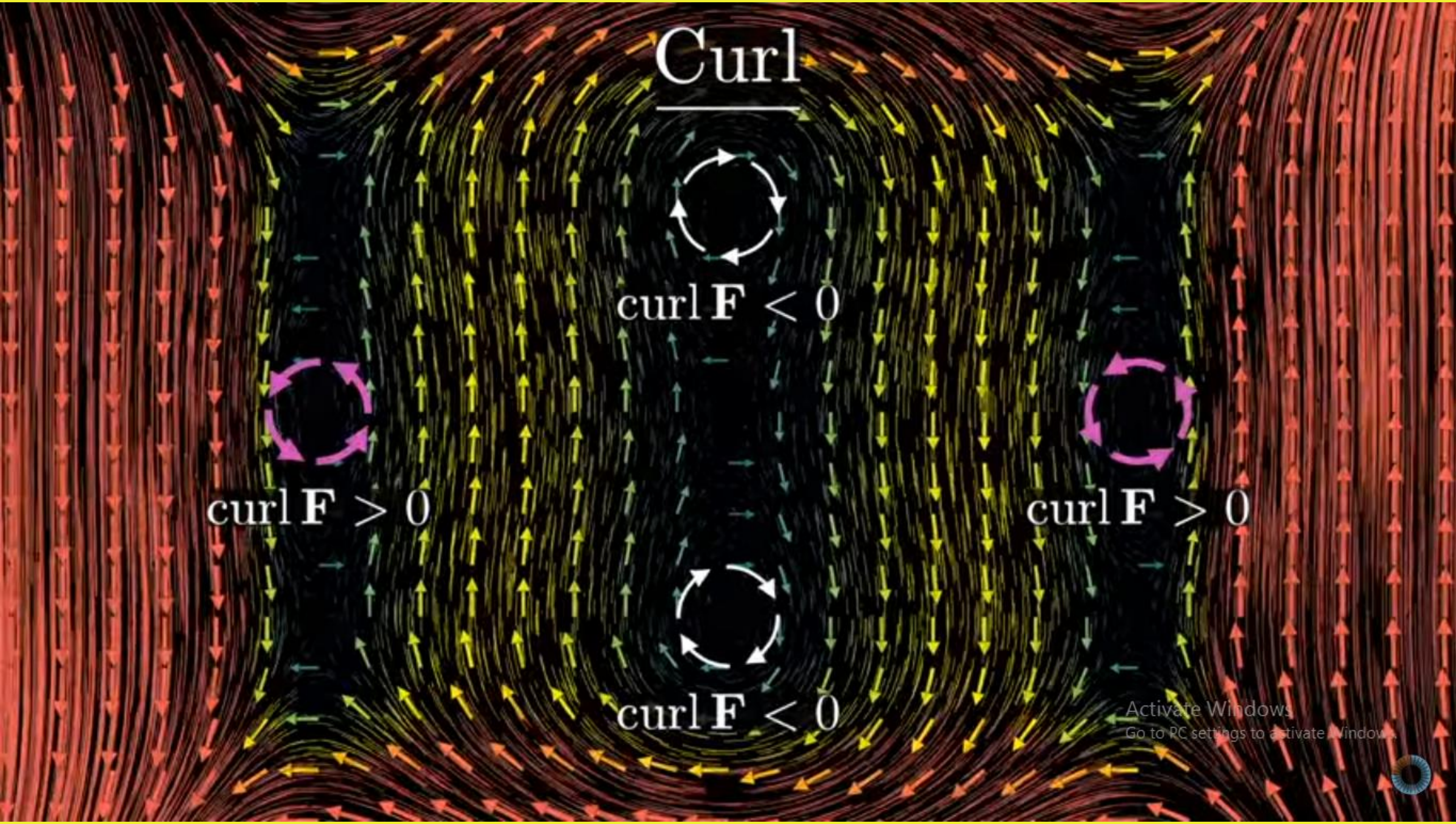


❑ The Curl Operator

$$\nabla \times$$

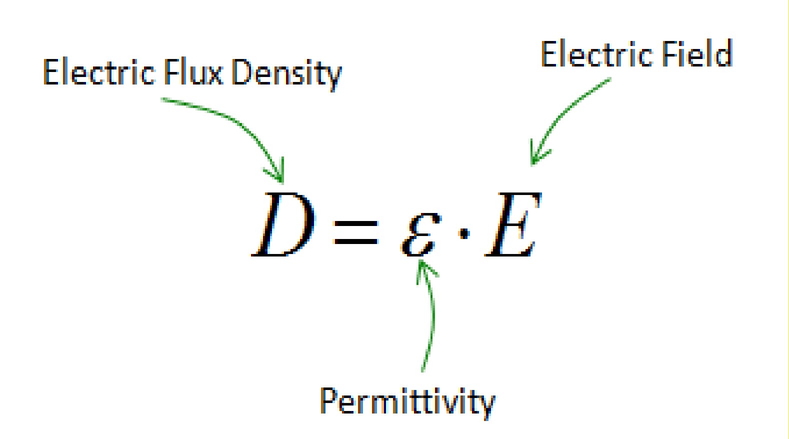
- The curl is a measure of the rotation of a vector field.
- In Figure, we have a vector function (V) and we want to know if the field is rotating at the point D (that is, we want to know if the curl is zero).




Curl
curl **F** < 0
curl **F** > 0
curl **F** > 0
curl **F** < 0

❑ Dielectric Constant – Permittivity (ε)

- In Electromagnetics, permittivity is one of the fundamental material parameters, which affects the propagation of Electric Fields. Permittivity is typically denoted by the symbol ε .



- The permittivity of a material relates the Electric Flux Density (D) to the Electric Field (E).

- Permittivity (ε) is a measure of the ability of a material to be polarized by an electric field.

❑ Dielectric Constant - Permeability (μ)

Similarly, materials can be classified by their permeability, which relates the Magnetic Flux Density (B) to the Magnetic Field (H) .

The permeability is most often denoted by the Greek symbol μ.

$$B = \mu H$$

where

- B is magnetic induction, or magnetic flux density
- μ is the permeability
- H is the magnetic field

- The speed of light in free space is related to the permittivity and permeability of a medium

$$c_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \cdot 10^8 \ \text{[m/s]} \quad \text{(free space)}$$

$$c = \frac{1}{\sqrt{\mu \varepsilon}}$$

$$\varepsilon = \varepsilon_r \varepsilon_0$$

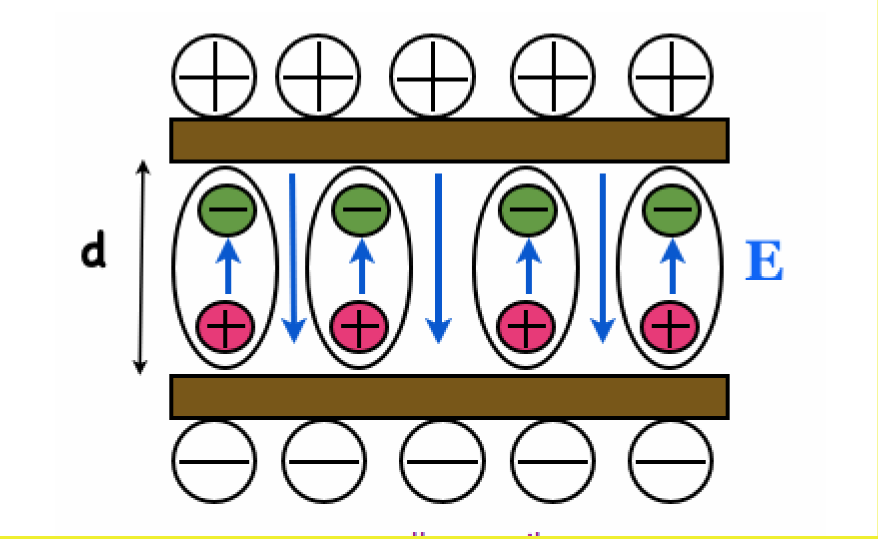


TABLE I. Common Values for the Dielectric Constant.

Material	ε_r
Vacuum	1.0
Air	1.0006
Teflon	2.1
Paper	3.85
FR-4	4.0
Silicon	11.7
Water (200 deg C)	34.5
Water (20 deg C)	80.1
Water (0 deg C)	88
Calcium Copper Titanate	250,000

Example :

If the relative permeability and relative permittivity of the medium is 1.0 and 2.25, respectively. Find the speed of the electromagnetic wave in this medium.

Lecture finish

Thank you