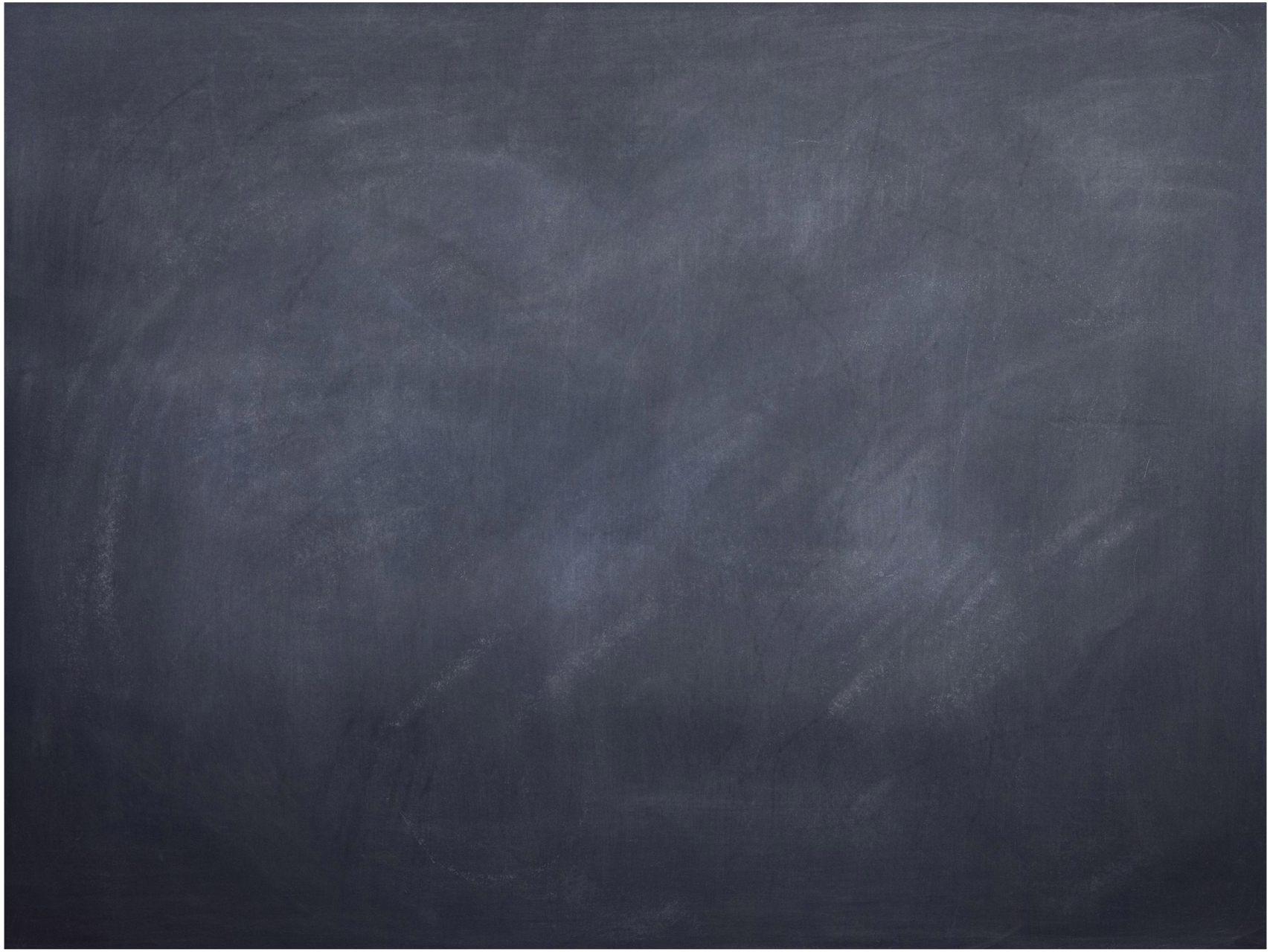
Let there be light!

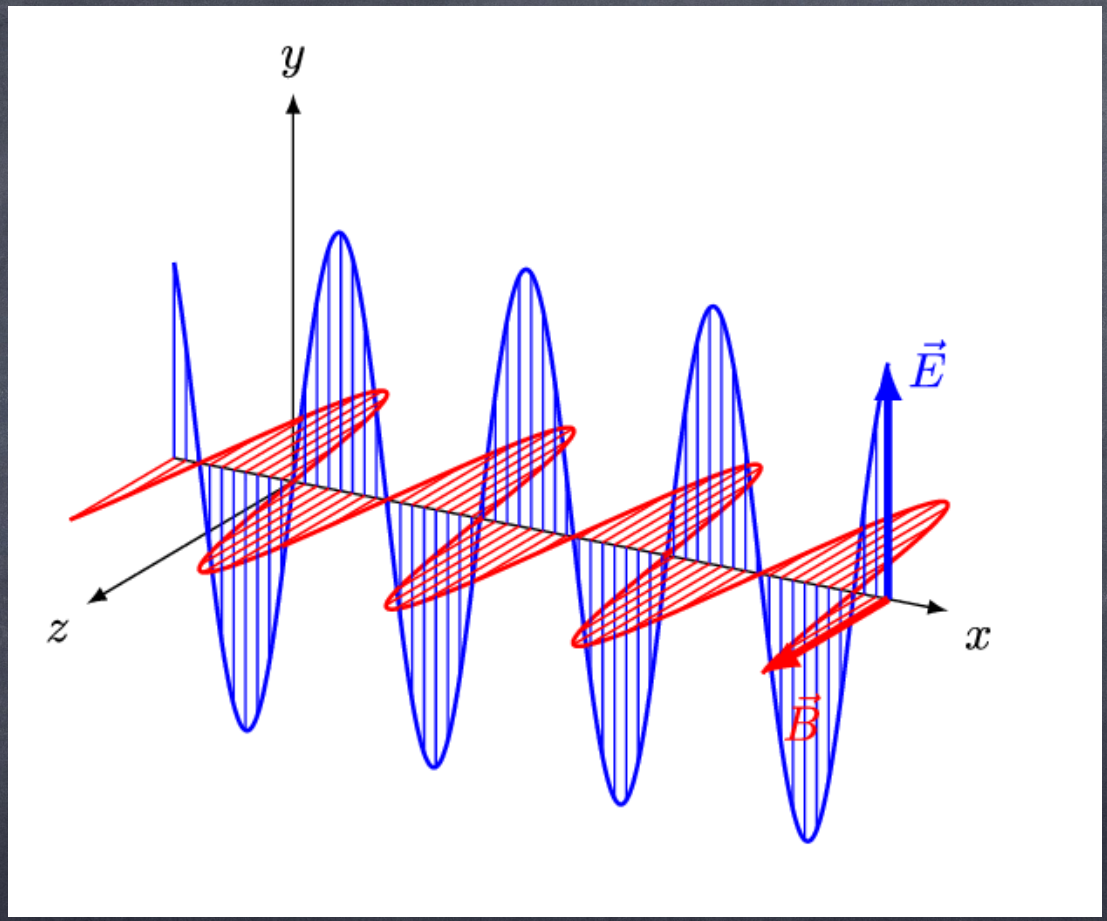
PHY117 HS2024

Today:
Electromagnetic waves
Creating light theoretically & experimentally
Speed of light
Refraction

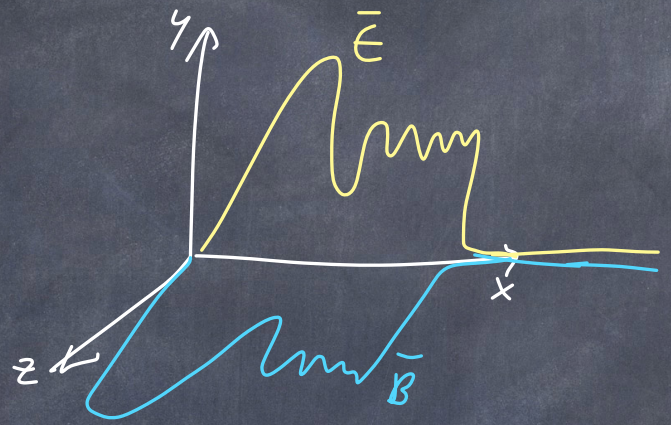
Week 13, Lecture 1
Dec. 10th, 2024
Prof. Ben Kilminster

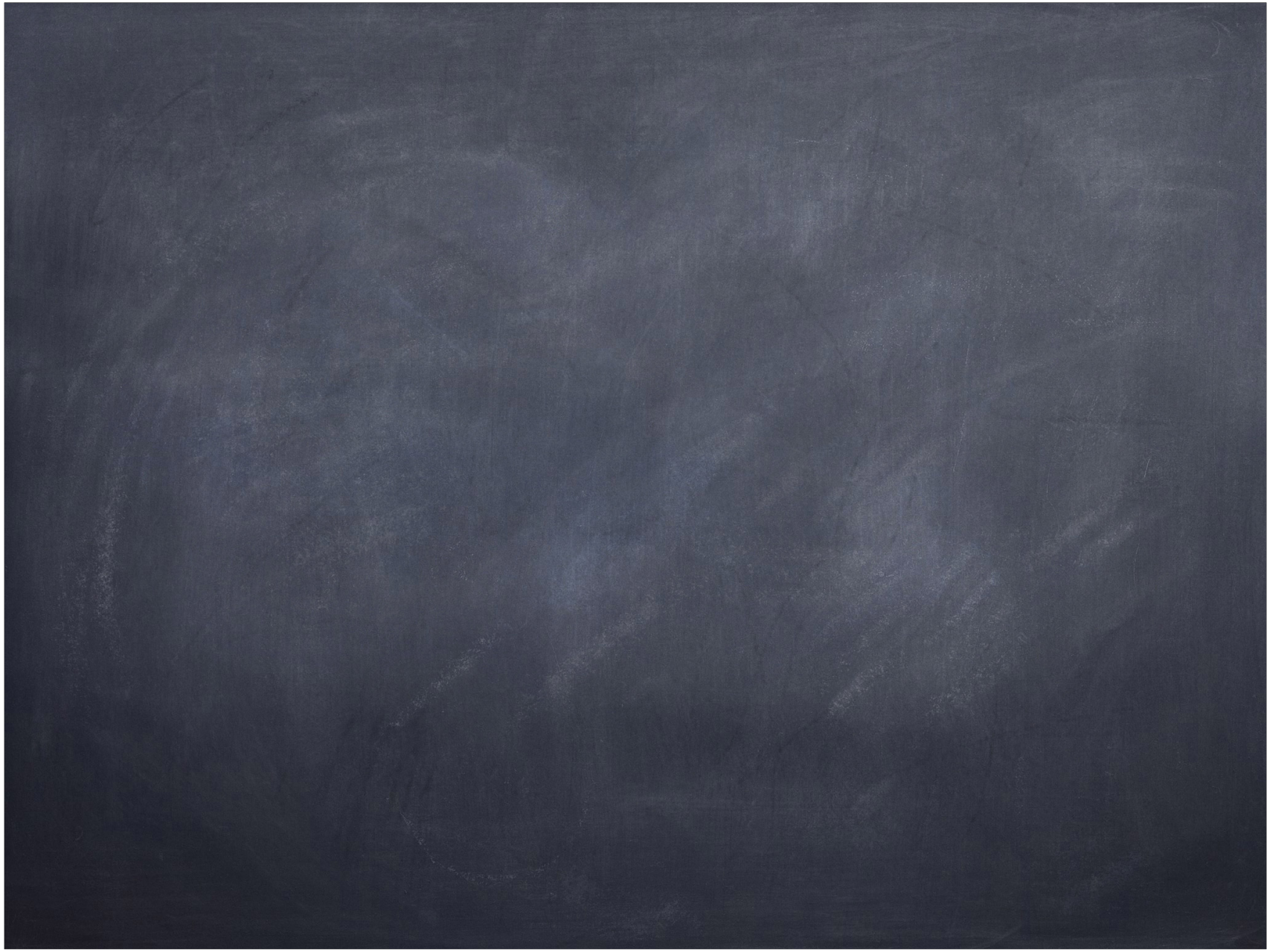


	MAXWELL'S EQUATIONS IN INTEGRAL FORM	
LHS	$X = E$	$X = B$
$\oint X.dA$	Gauss's Law (1813) $\oint E.dA = \frac{Q_{inside}}{\varepsilon_o}$ The Electric field through a closed area is equal to the total charge inside of the area divided by ε_o.	Gauss's Law for Magnetism (1813) $\oint B.dA = 0$ The Magnetic field through a closed surface is zero (as many field lines going out as going in). It means that magnetic monopoles do not exist.
$\oint X.dl$	Faraday's Law (1831) $\oint E.dl = -\int \frac{\partial B}{\partial t}.dA$ The Electric field around a closed loop is just equal to the minus of the rate of change of Magnetic field through the loop.	Maxwell - Ampere's Law (1861) $\oint B.dl = \mu_o I + \mu_o \epsilon_o \int \frac{\partial E}{\partial t}.dA$ The Magnetic field around a closed loop is equal to rate of change of Electric field through the loop times $\mu_o \epsilon_o$ plus the Electric current in the loop times μ_o.

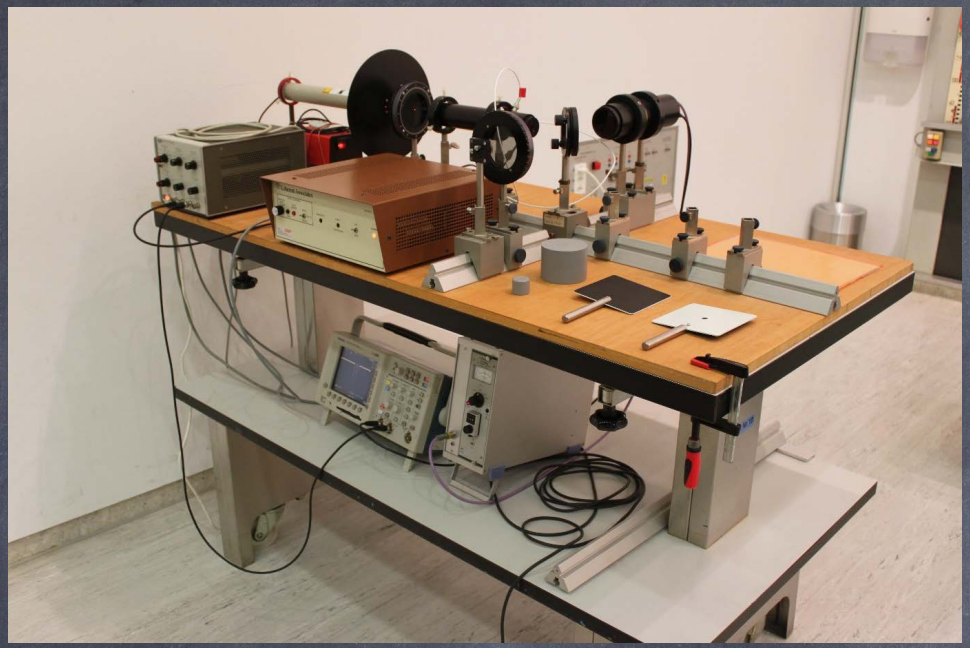

y
z
x
$\vec{E}$
$\vec{B}$

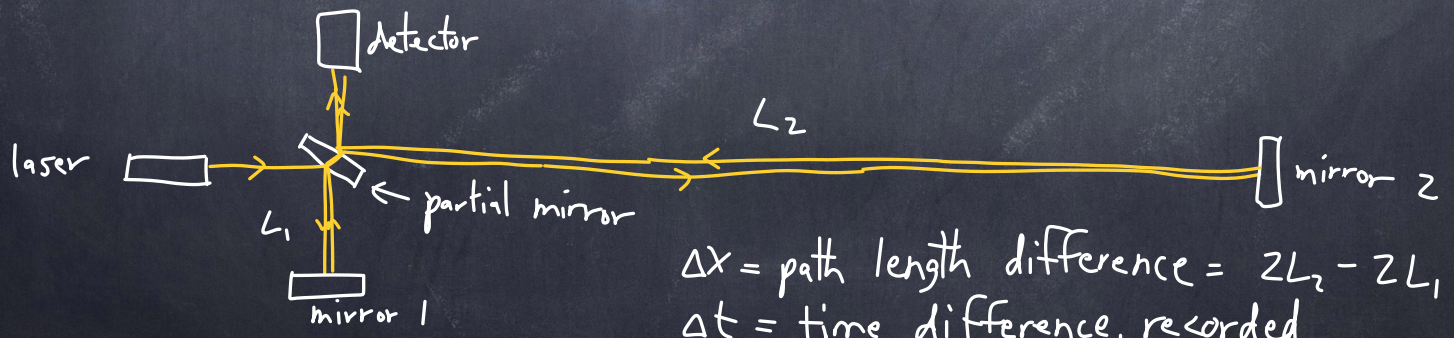
The shape does not need to be sinusoidal. It can be a weird pulse:





Speed of light measurement

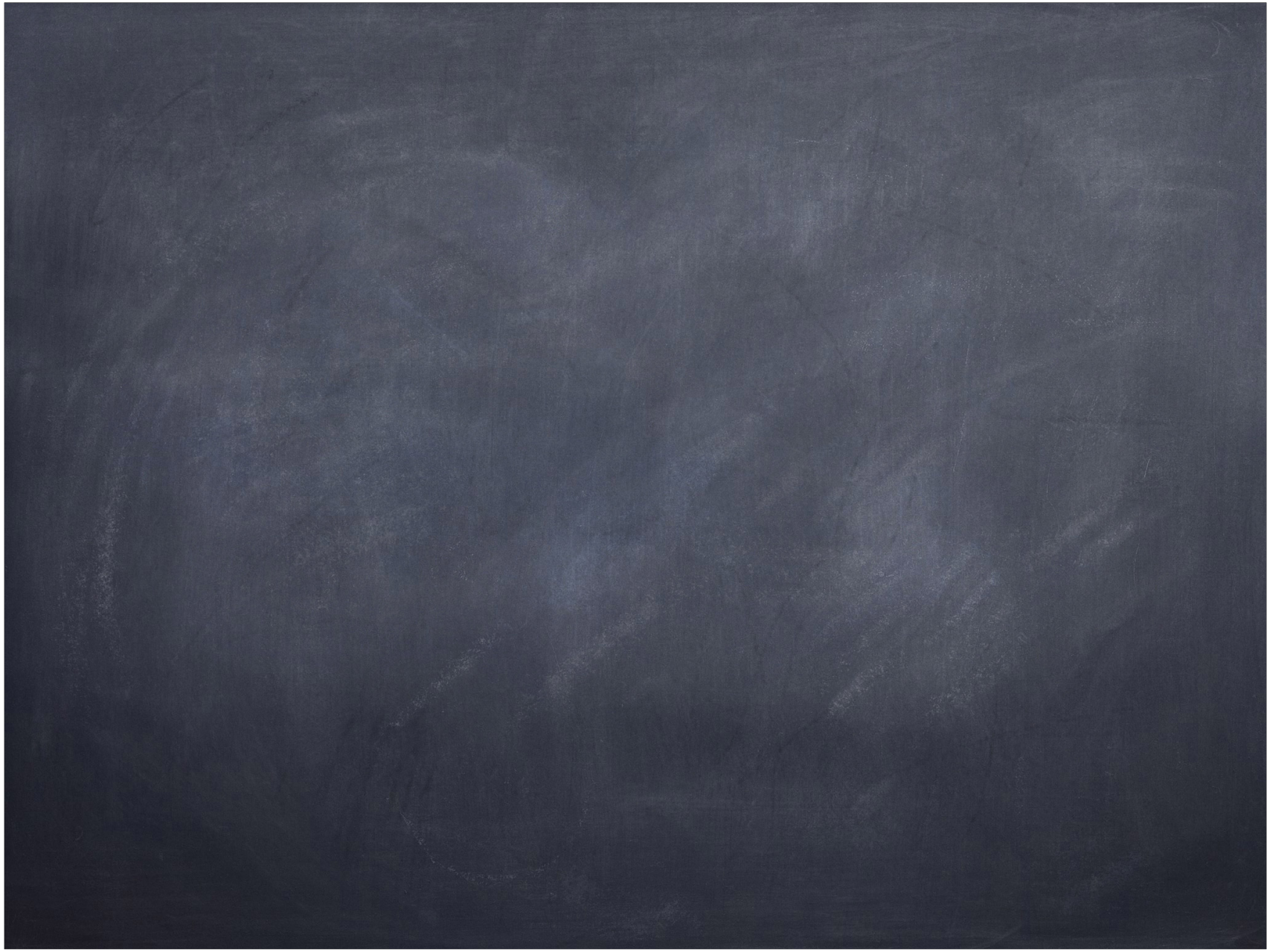


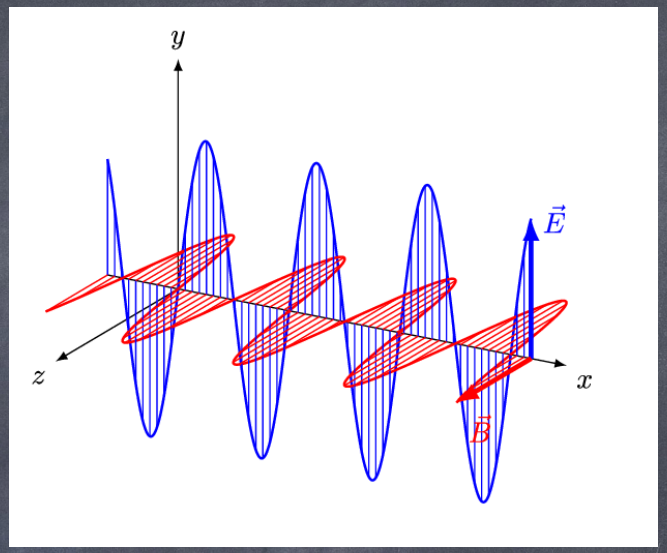


Δx = path length difference = $2L_2 - 2L_1$

Δt = time difference recorded on oscilloscope

$$c = \frac{\Delta x}{\Delta t} =$$




y
z
x
$\vec{E}$
$\vec{B}$

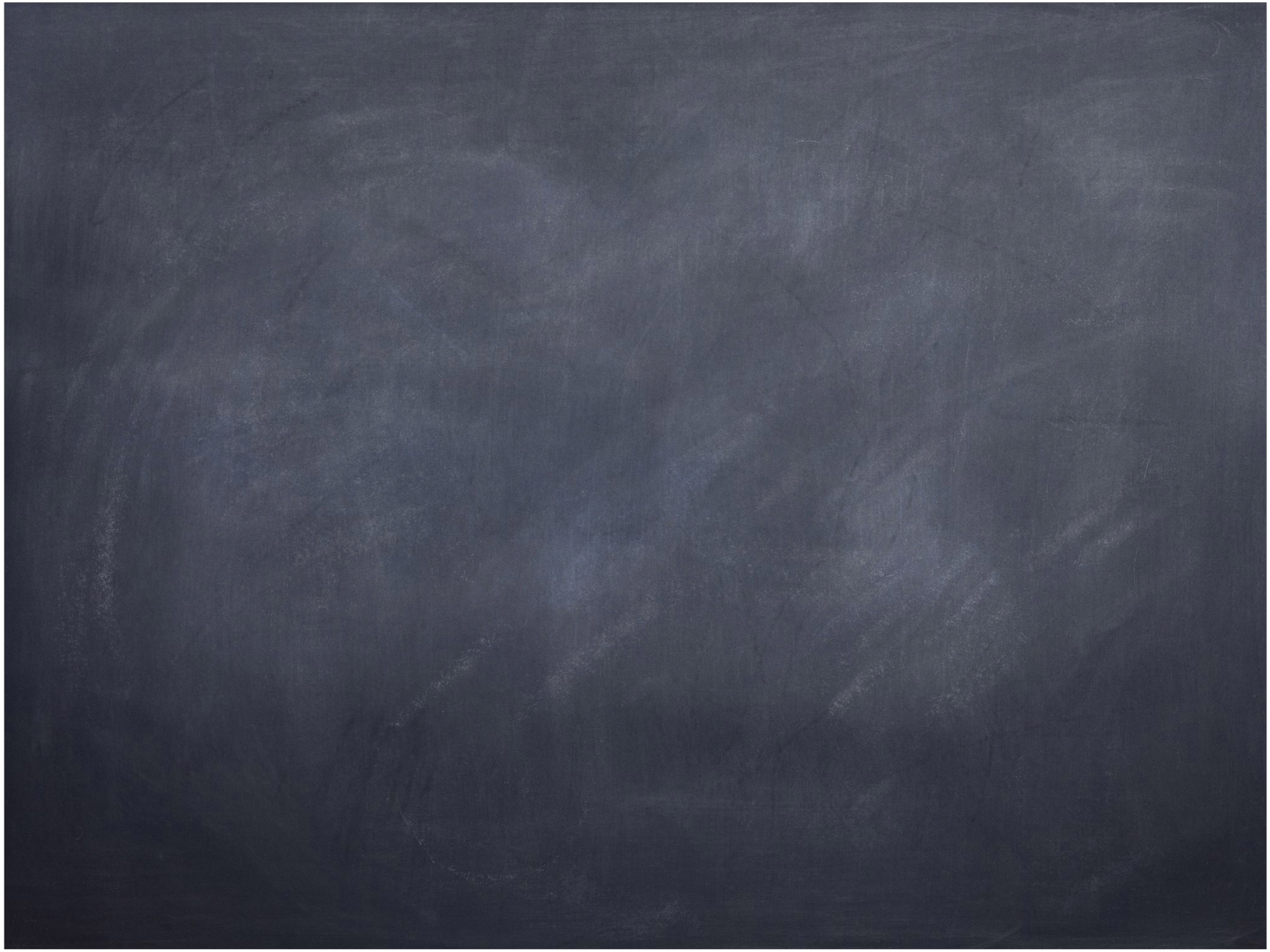


Table 13.1: Rough classification of electromagnetic spectrum and its applications.

Class	Wavelength λ	Frequency f	Application
Radio waves	$> 1\,\mathrm{m}$	$< 300\,\mathrm{MHz}$	Radio & TV broadcast, telecomunications maritime navigation
Microwaves	$1\,\mathrm{mm} - 1\,\mathrm{m}$	$300\,\mathrm{MHz} - 300\,\mathrm{GHz}$	Microwave oven, radar, mobile phones, 4G, Wi-Fi, satellite communications, GPS, cosmic microwave background
Infrared	$750\,\mathrm{nm} - 1\,\mathrm{mm}$	$300\,\mathrm{GHz} - 400\,\mathrm{THz}$	Thermal imaging, TV remote control, night vision, bio imaging, optical fibers
Visible	$400\,\mathrm{nm} - 750\,\mathrm{nm}$	$400\,\mathrm{THz} - 750\,\mathrm{THz}$	Human vision, illumination, photography, microscopes, lasers
Ultraviolet	$10\,\mathrm{nm} - 400\,\mathrm{nm}$	$750\,\mathrm{THz} - 30\,\mathrm{PHz}$	Disinfection, dental curing, black lights, sun tanning, counterfeit detector
X rays	$0.01\,\mathrm{nm} - 10\,\mathrm{nm}$	$30\,\mathrm{PHz} - 30\,\mathrm{EHz}$	Crystallography, radiation therapy, medical imaging, security scans
Gamma rays	$< 0.01\,\mathrm{nm}$	$> 30\,\mathrm{EHz}$	Radioactive sources, cancer treatments, PET scans, cargo container screening

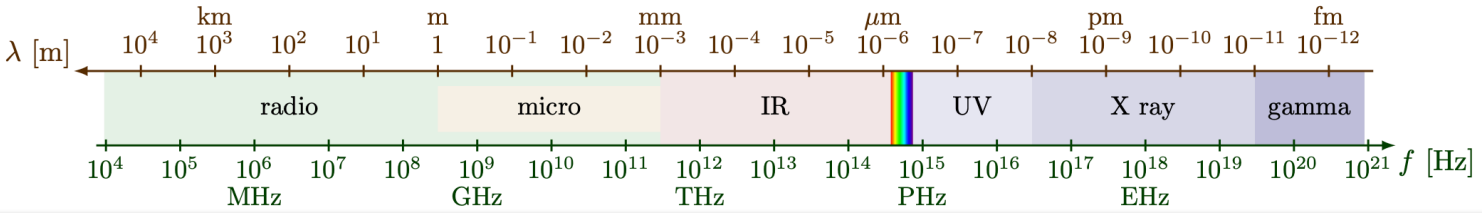
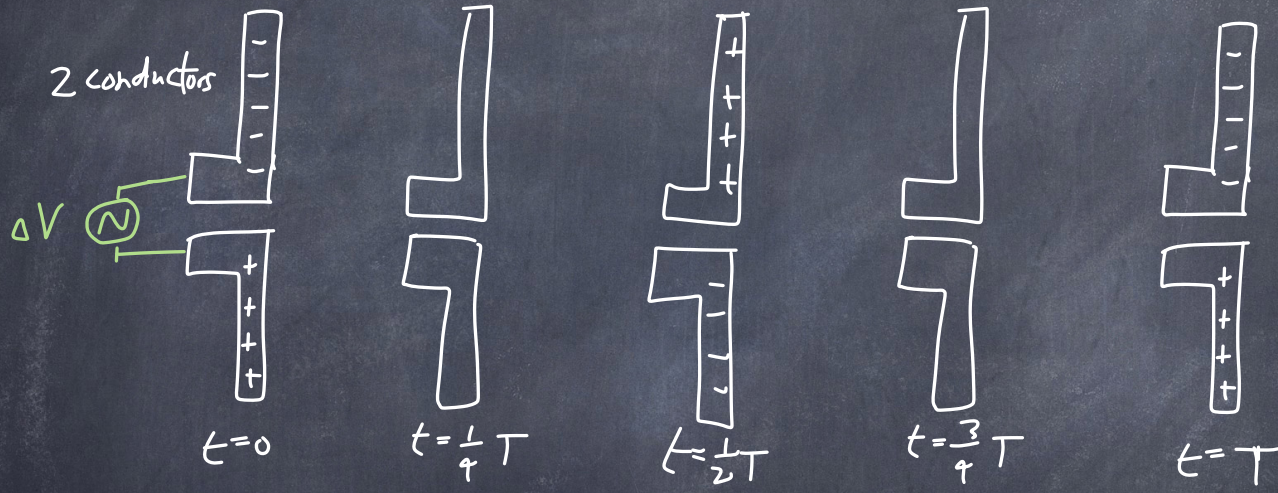
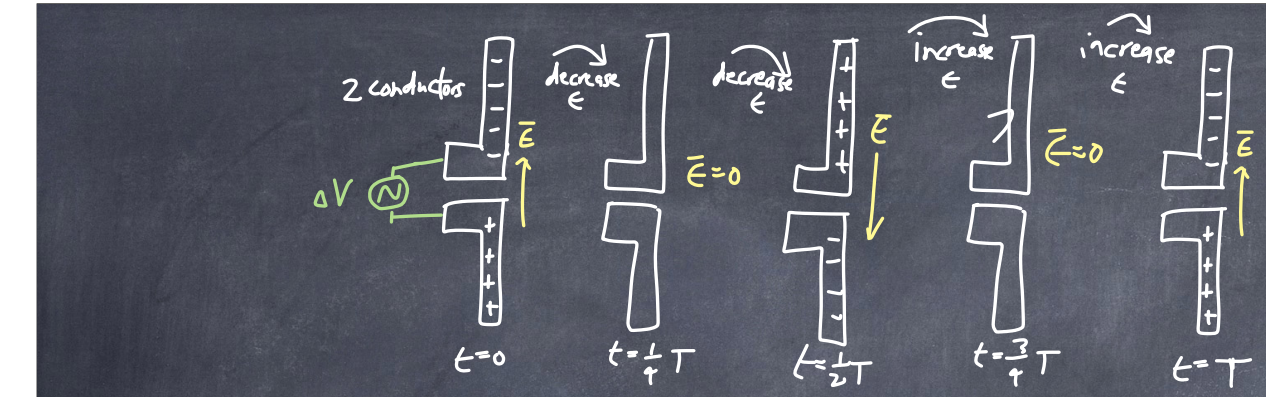


Figure 13.2: Electromagnetic spectrum with rough classification.

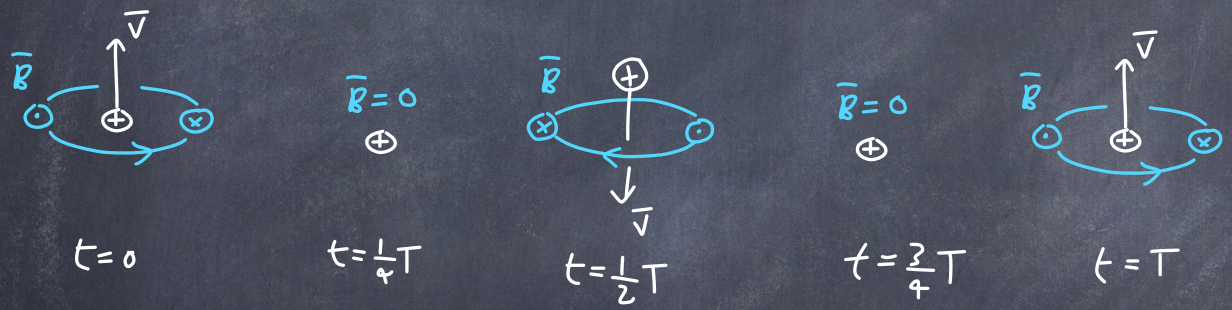
How to create light from moving an electric charge:

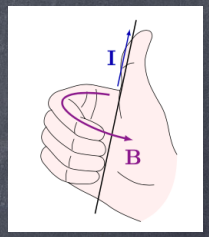
To make an EM wave, we can accelerate an electric charge.



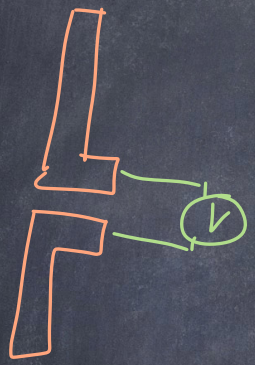


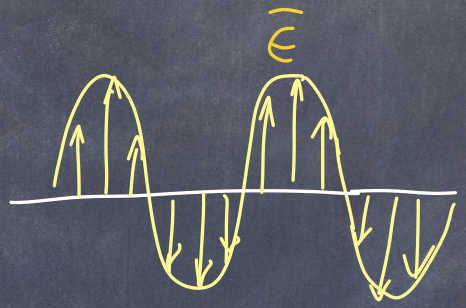
Moving electric charges generate magnetic fields.

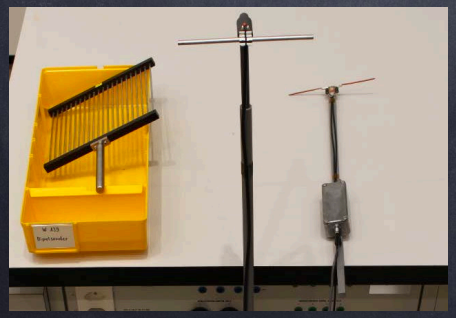




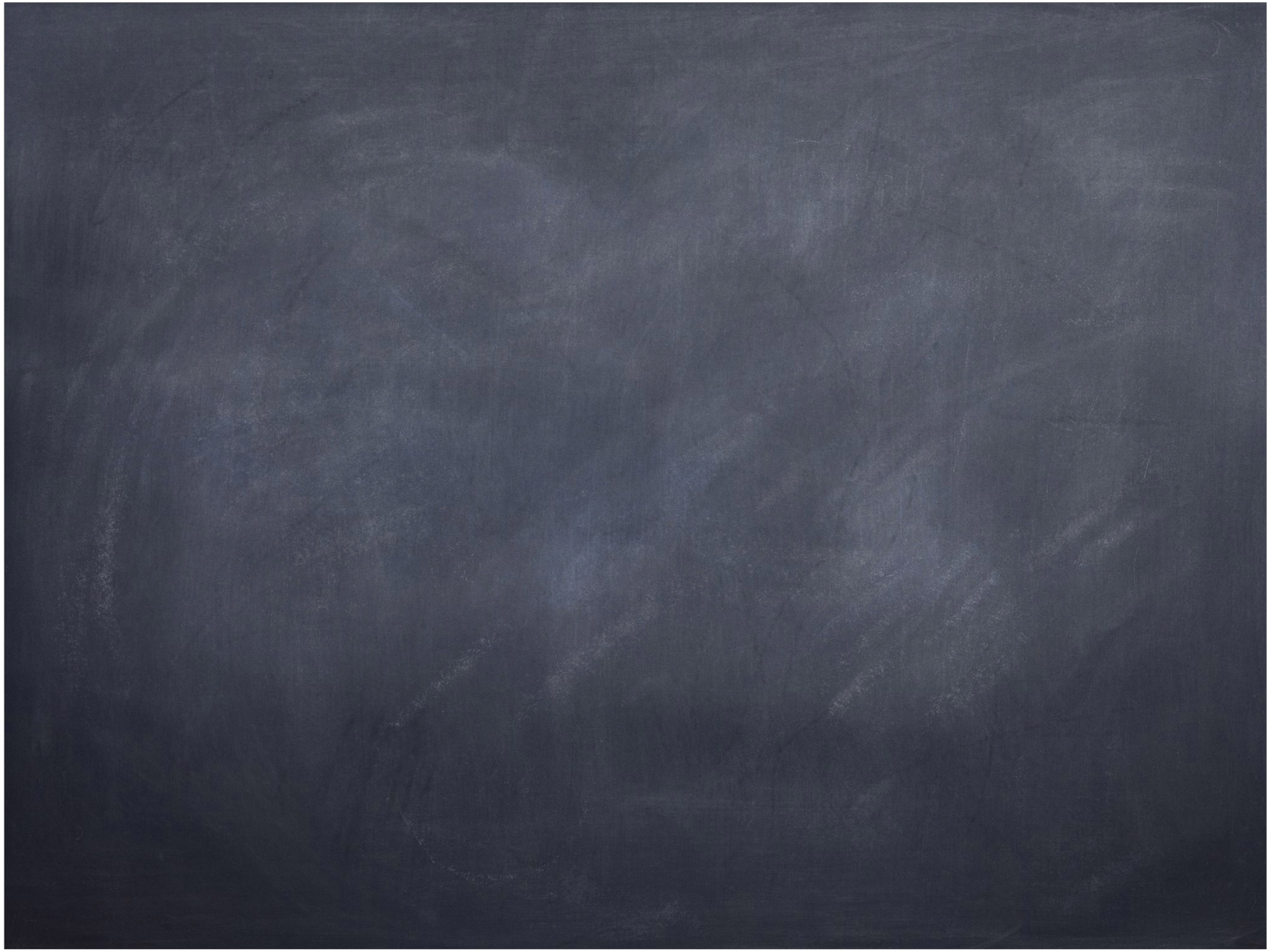
we have made an EM wave. Detecting an EM wave is the opposite of making one.

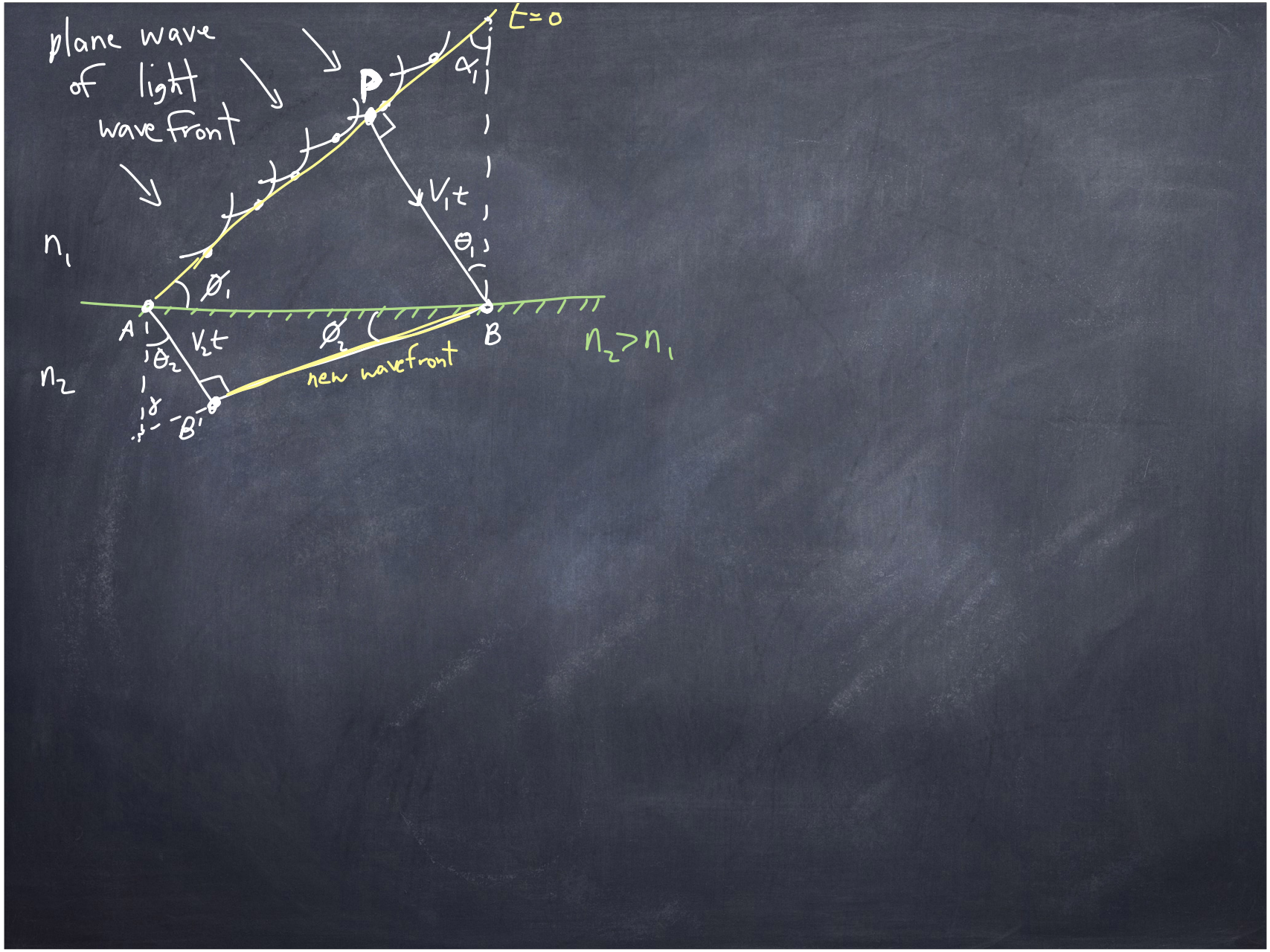


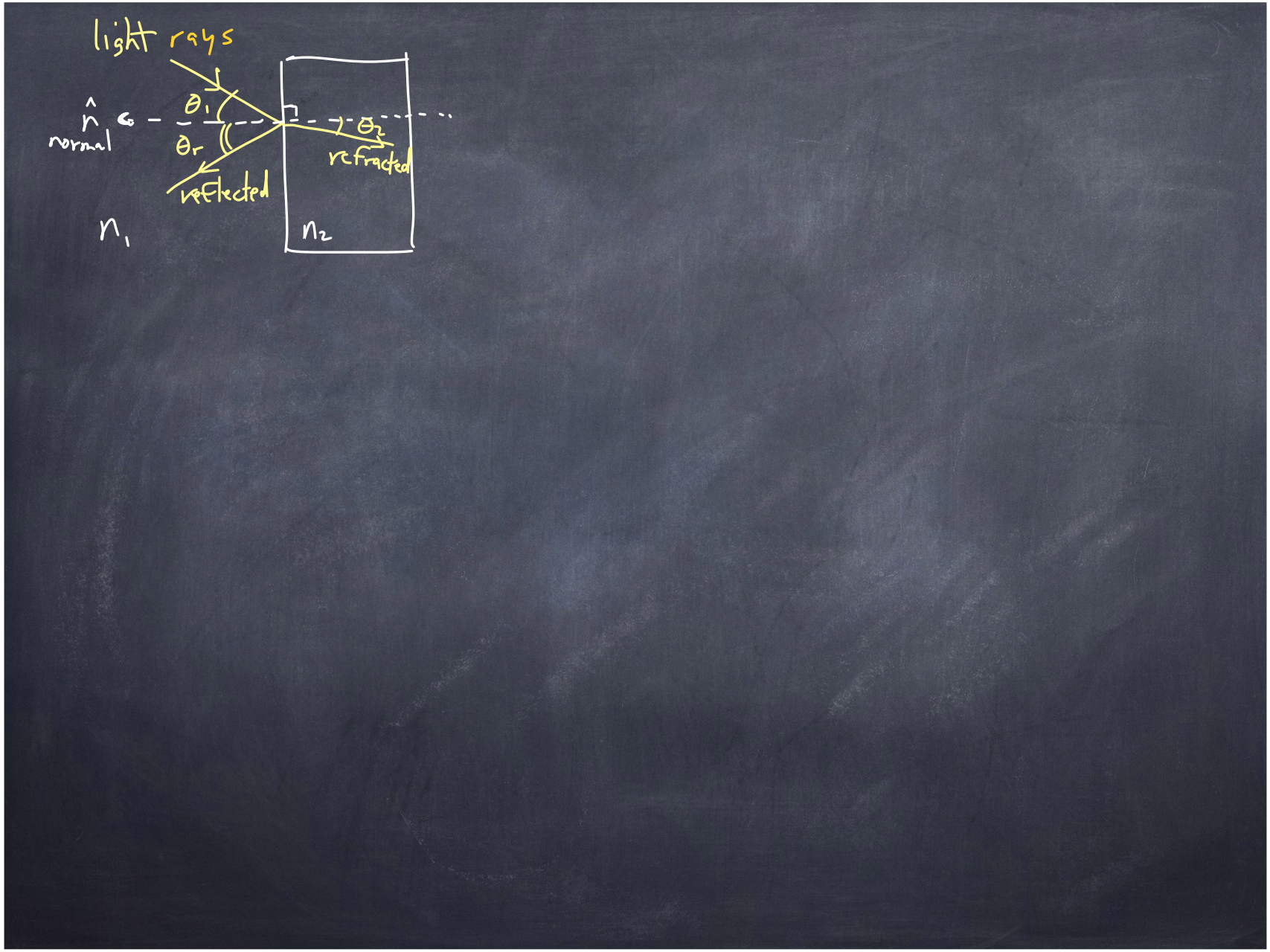


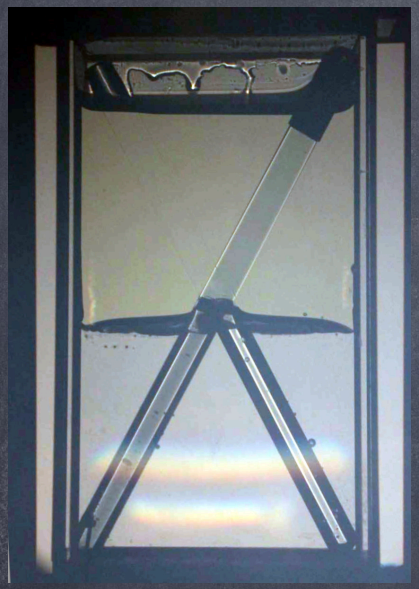



plane waves:
multiple sources
$\bar{\epsilon}$
$\bar{v}$
medium

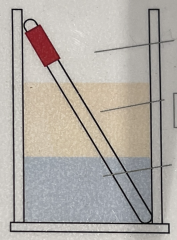



plane wave of light wavefront
t=0
P
a_1
V_1t
θ_1
n_1
ϕ_1
A
V_2t
ϕ_2
B
$n_2>n_1$
θ_2
new wavefront
B'


light rays
$\hat{n}$
normal
θ_1
θ_r
θ_2
reflected
refracted
n_1
n_2

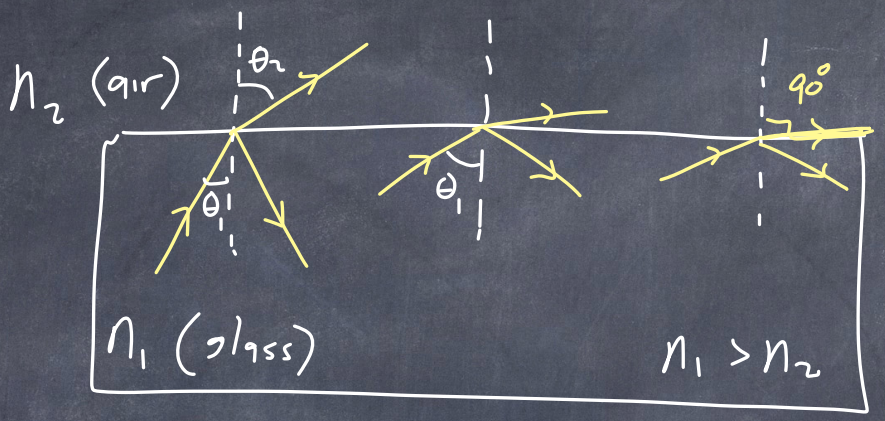


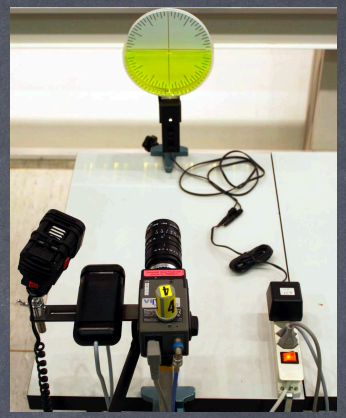
W 93



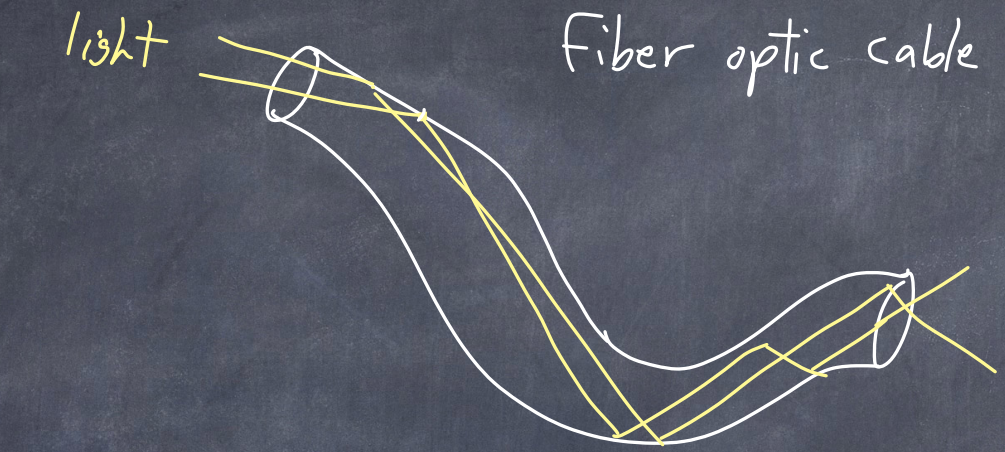
Farbe	Material	Brechungsindex
rot	Borsilikatglas (Pyrex)	1.473 *(587.6nm)*
blau	Weichglas (AR)	1.5 – 1.6
schwarz	Quarzglas	1.46
	Mandelöl	1.470 – 1.4715
	Wasser	1.33

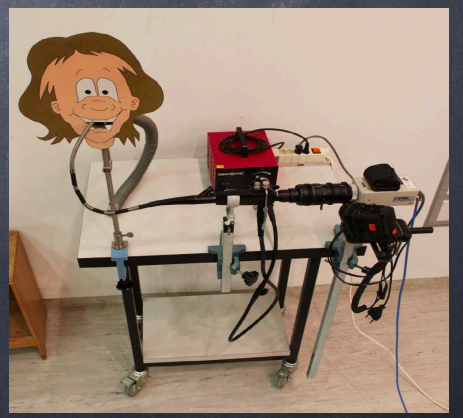
Reflection and refraction of light

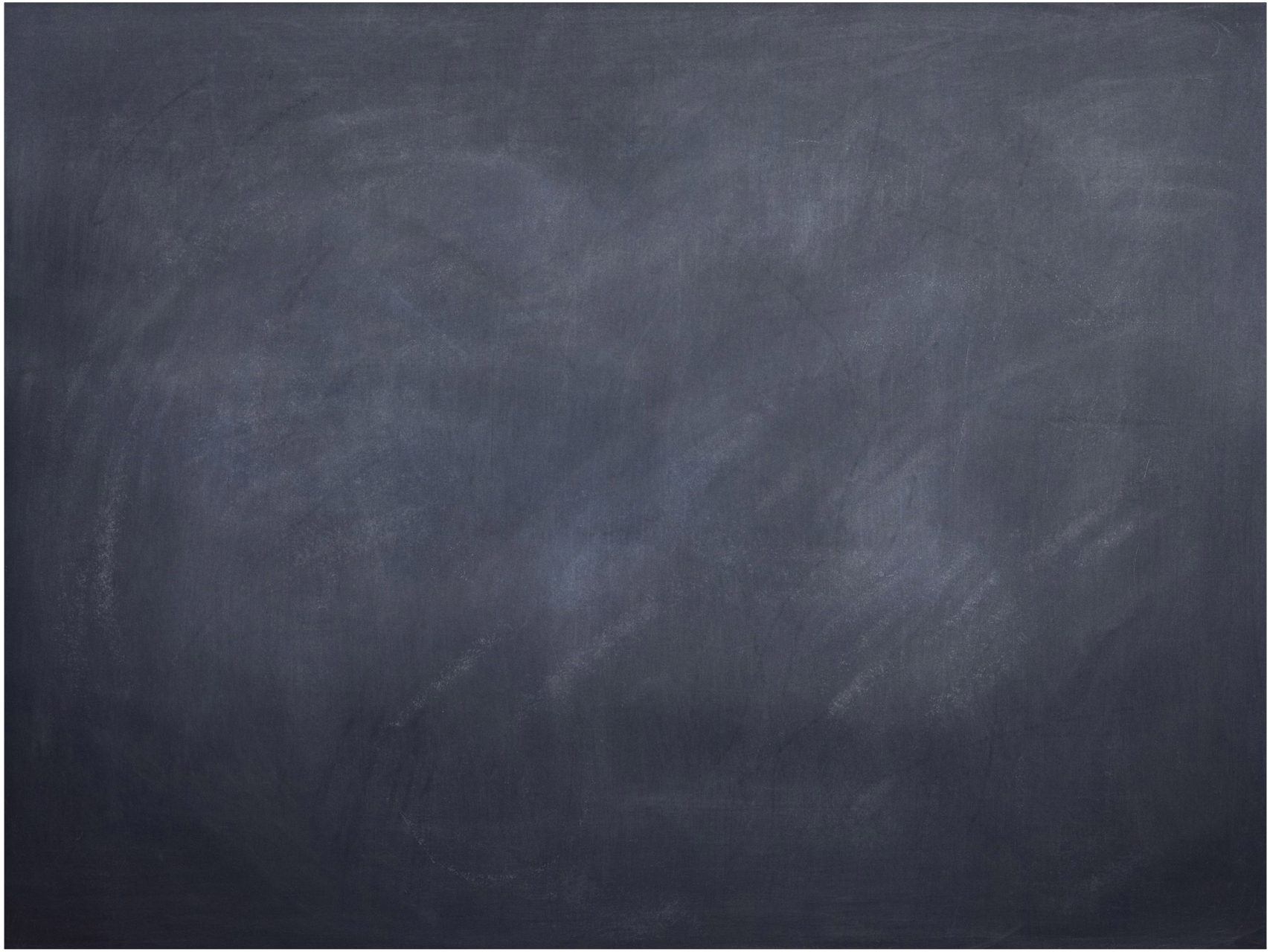




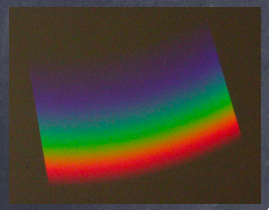
Above θ_c, we have total internal reflection

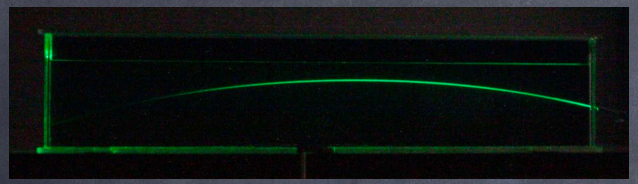


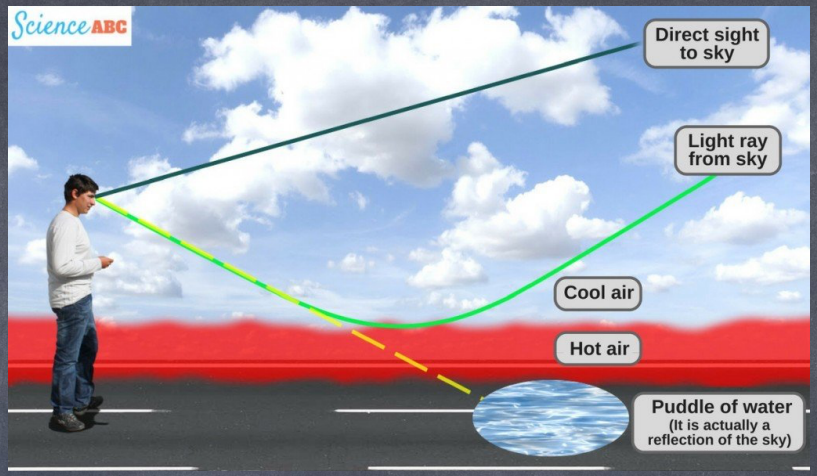


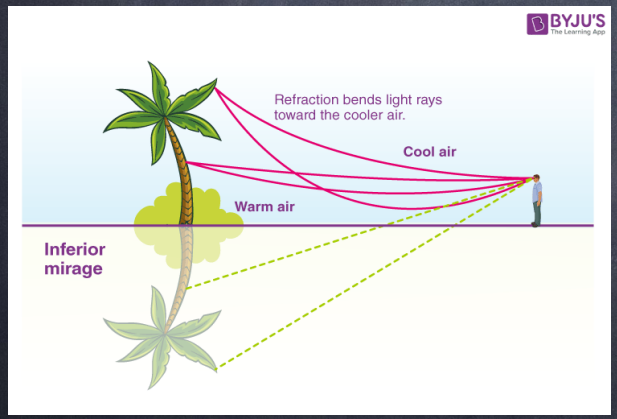


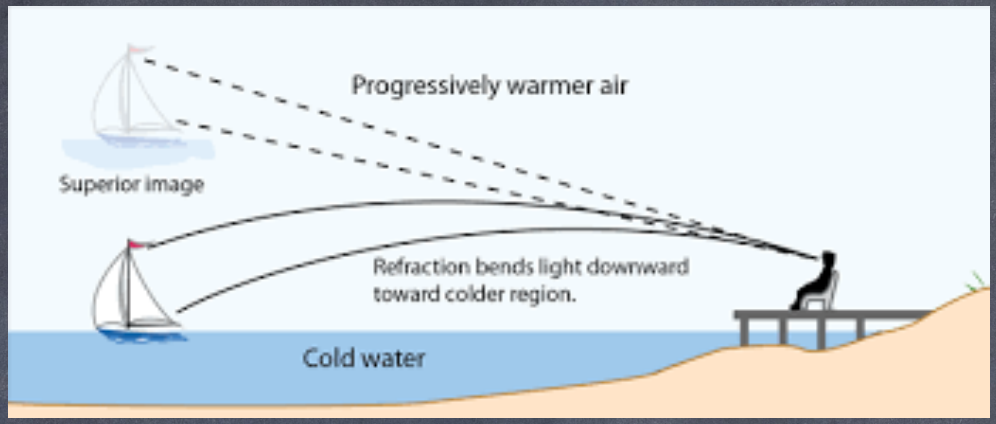
In addition) the index of refraction depends slightly on the wavelength of the light.





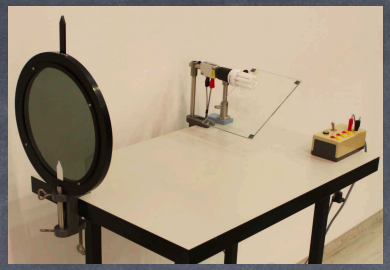

Science ABC
Direct sight to sky
Light ray from sky
Cool air
Hot air
Puddle of water
(It is actually a reflection of the sky)


BYJU'S
The Learning App
Refraction bends light rays toward the cooler air.
Cool air
Warm air
Inferior mirage



David Morris took the photographs from the hamlet of Gillan, near Falmouth

W51



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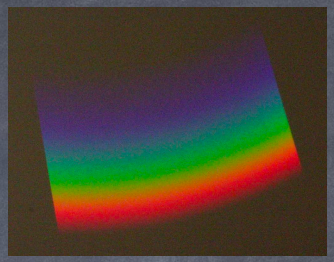

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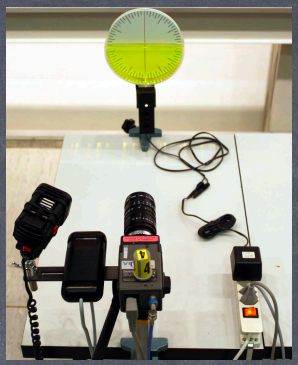

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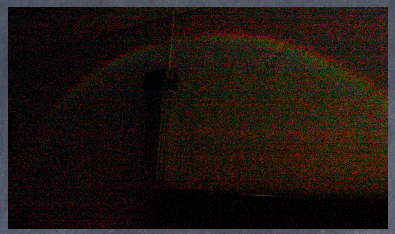

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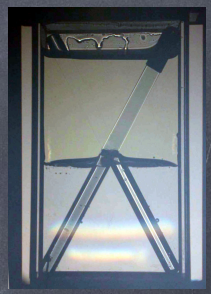

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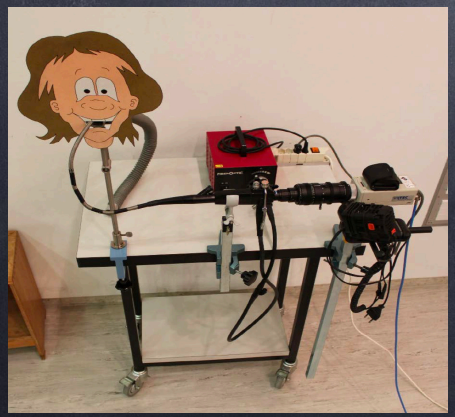

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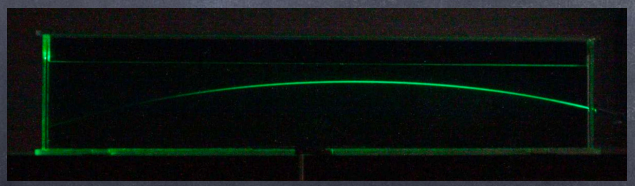

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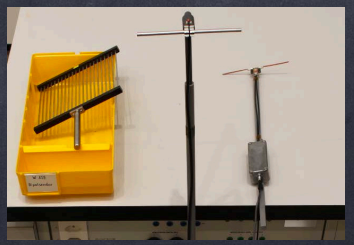

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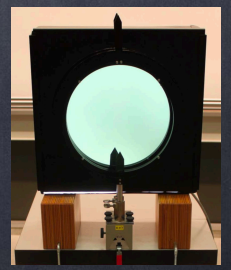

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