$$\vec{F} = m\vec{a}$$

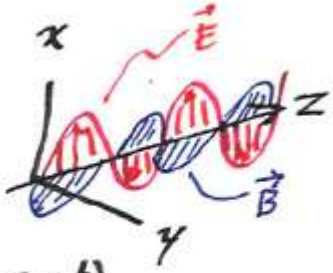
$$K.E. = \frac{1}{2} m v^2$$

$$\vec{E} = \frac{kQ}{r^2}\hat{r}\,; \quad \vec{B} = \frac{\mu_0 I}{2\pi R}\hat{\phi}$$

$$a_B = \frac{4\pi\varepsilon_0 (h/2\pi)^2}{me^2}$$

$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}} \approx mc^2 + \frac{1}{2}mv^2$$

Maxwell:



$$\vec{E} = \hat{i} E_0 \cos(kz - \omega t)$$

$$\vec{B} = \hat{j} B_0 \cos(kz - \omega t)$$

$B_0 = E_0/c$ and $\omega = ck$

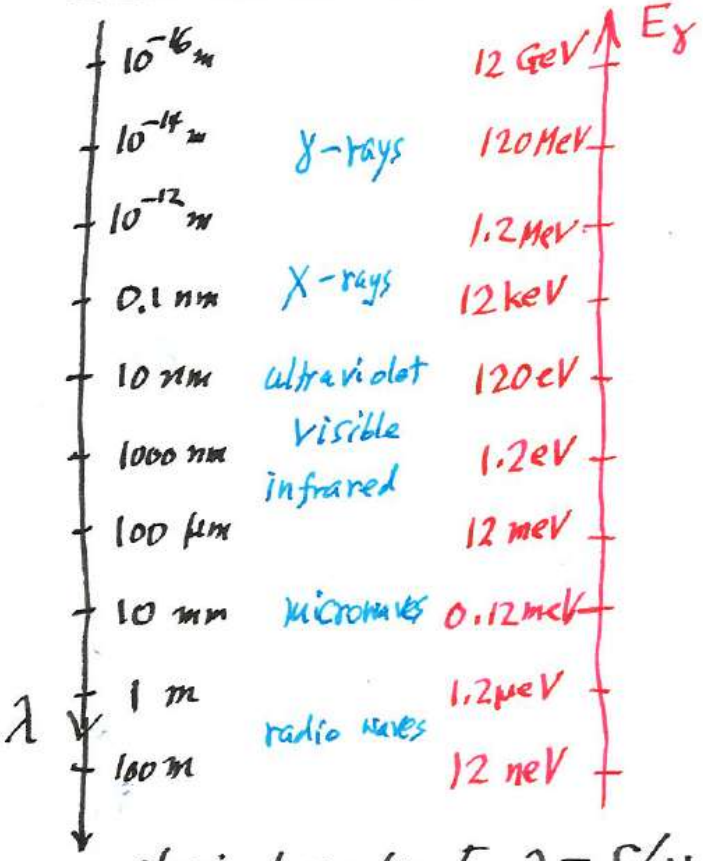
where $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

$$\frac{\delta z}{\delta t} = \frac{2\pi/k}{2\pi/\omega} = \frac{\omega}{k} = c$$

The speed of light in vacuum

Average energy density $= \frac{\epsilon_0}{2} E_0^2$.

The electromagnetic spectrum



classical wavelength $\lambda = c/\nu$

photon energy $E_\gamma = h\nu$

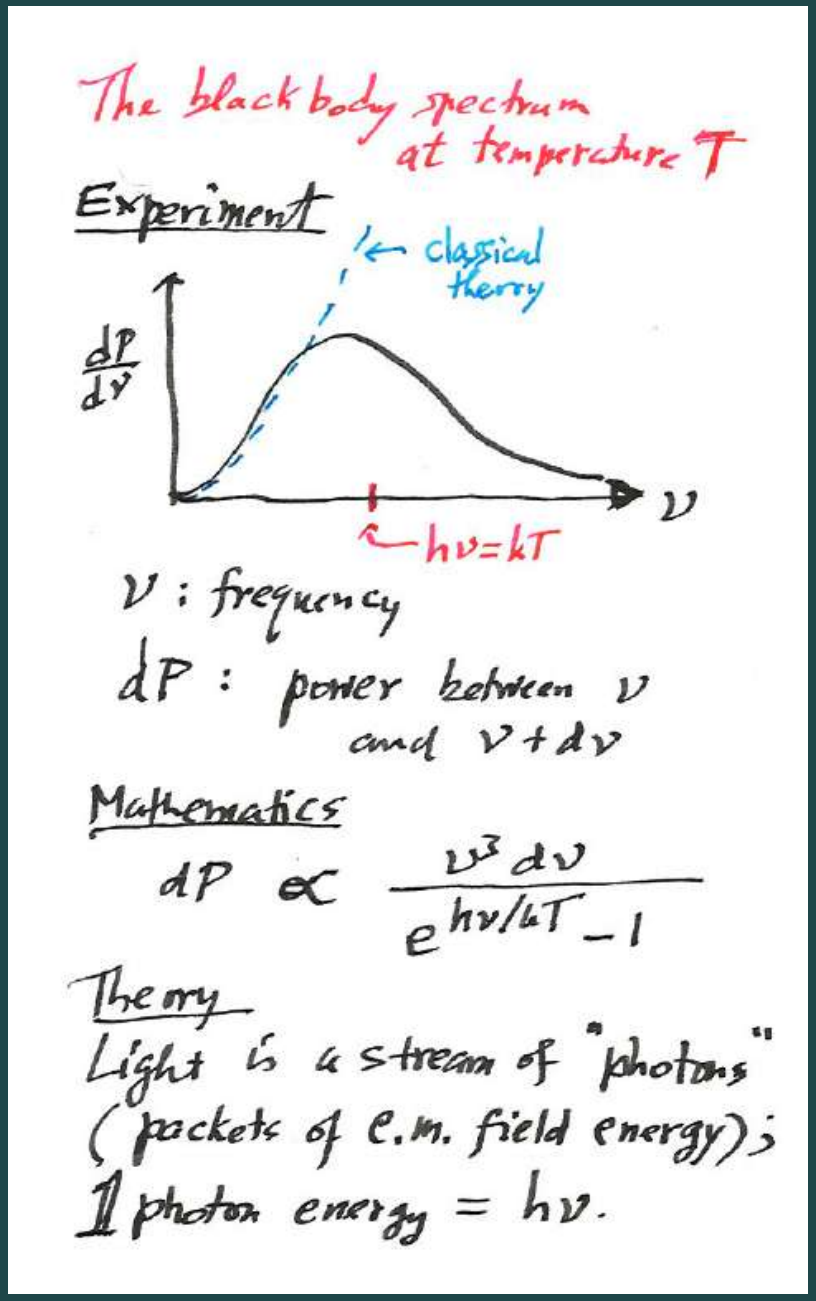
(ν = frequency)

frequency ν

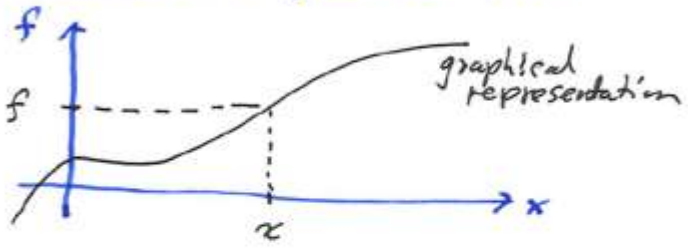
wavelength $\lambda = c/\nu$

single photon $E = h\nu$

A beam of light is a stream of photons.



A continuous function $f(x)$



For any x there is a corresponding f.

Calculus deals with many concepts.
The two most important are ...

(i) the derivative ;
(ii) the integral.

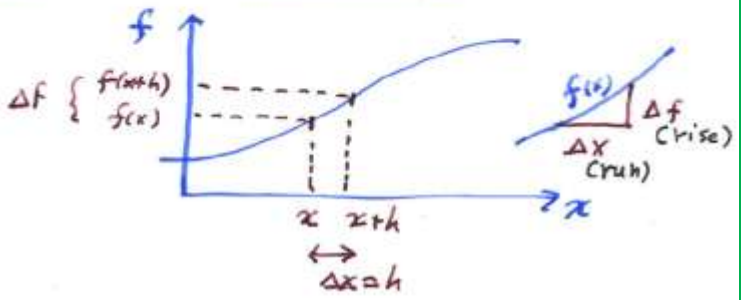
The derivative

Newton — Leibniz

Notation $f'(x)$ or $\frac{df}{dx}$

Definition $f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$

Graphical representation



$\frac{\Delta f}{\Delta x}$ = average rate of change of f over the interval Δx

$\frac{df}{dx} = \lim_{\Delta x \to 0} \frac{\Delta f}{\Delta x}$ = the instantaneous rate of change of f at variable value x.

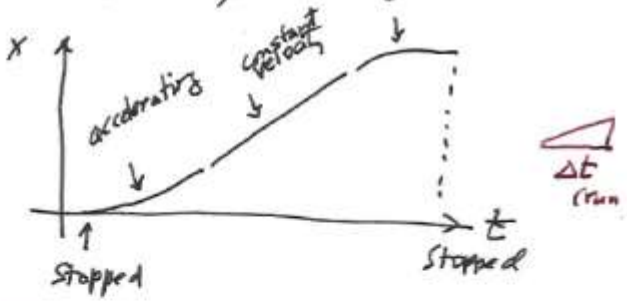
$f'(x)$ = instantaneous rate of change
= the slope of the curve at x
↳ slope of the tangent line

The derivative
Application to motion

Variable = t

Function = $x(t)$

Derivative = instantaneous velocity



$\frac{\Delta x}{\Delta t}$ = $\frac{\text{distance}}{\Delta t}$ = average velocity

$\frac{dx}{dt}$ = instantaneous velocity $v(t)$

Also, $\frac{dv}{dt}$ = acceleration $a(t)$

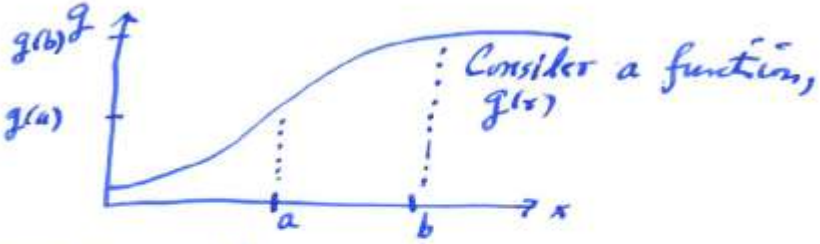
eqs. of m

$\frac{dx}{dt} = v$

$\frac{dv}{dt} = a =$

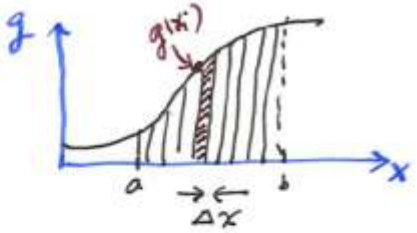
Newton's 2nd law

The Integral



Notation $\int_a^b g(x)\,dx$

Definition $\int_a^b g(x)\,dx = \lim_{\Delta x \to 0} \sum_{i=1}^{N} g(x_i)\,\Delta x$



$g(x_i)\,\Delta x \approx$ area of the strip.

Graphical representation

$\int_a^b g(x)\,dx$ = The area between the curve and the x axis between a and b.

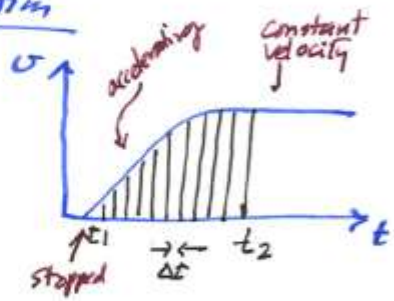
The integral

Application to Motion

Variable = t

Function = v(t)

Integral = x(t), distance



$$\int_{t_1}^{t_2} v(t)\,dt = \lim_{\Delta t \to 0} \sum_{i=1}^{N} v(t_i)\,\Delta t$$

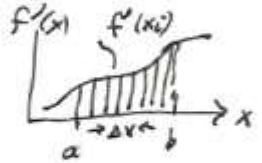
$v(t_i)\,\Delta t \approx$ distance traveled from t_i to $t_i + \Delta t$

$$= \lim_{\Delta t \to 0} \{ d_1 + d_2 + d_3 + \dots + d_N \} \quad (d_i)$$

$$= x(t_2) - x(t_1) \quad \text{(difference of coordinate)}$$

The fundamental theorem of calculus

Theorem $\int_a^b f'(x)\,dx = f(b) - f(a)$



Proof

$$\lim_{\Delta x \to 0} \sum_{i=1}^{N} \underbrace{f'(x_i)\,\Delta x}_{\approx f(x_i + \Delta x) - f(x_i)}$$

$$= \lim_{\Delta x \to 0} \left\{ \approx (f_2 - f_1) + (f_3 - f_2) + (f_4 - f_3) + \dots + (f_N - f_{N-1}) \right\}$$

$$= \lim_{\Delta x \to 0} \left\{ \approx f_N - f_1 \right\}$$

$$= f(b) - f(a) \qquad \text{Q.E.D.}$$

Application to motion

$$\int_{t_0}^{t} v(t')\,dt' = x(t) - x(t_0)$$

Sim. $$\int_{t_0}^{t} a(t')\,dt' = v(t) - v(t_0)$$

Another answer: Mathematics is an example of pure logic, which exists separately from human existence.

And God is a mathematician.

Eugene Wigner:

"The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. We should be grateful for it and hope that it will remain valid in future research ."(1960)

One answer: Mathematics is only a language that humans have developed to describe nature. It describes nature because that is the the purpose for which we developed it.

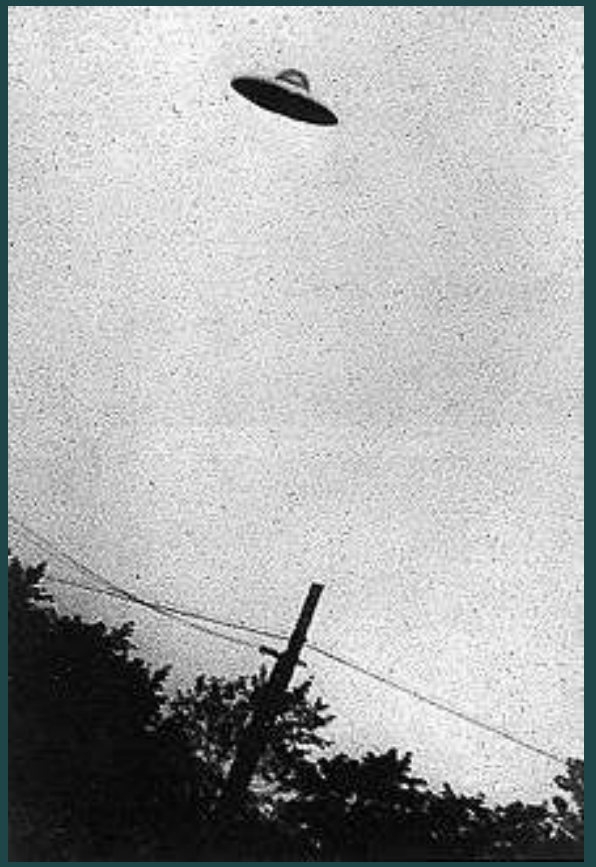
Galileo Galilei: "Philosophy is written in that great book which ever lies before our eyes — the universe — but we cannot understand it if we do not first learn the language in which it is written. This book is written in the language of mathematics." (1623)

Interstellar space travel

If this is possible, then where are all the UFO's?

No currently known propulsion method would make this possible.

Perhaps it is beyond the limits of science and technology.



The Unified Field Theory…

…which unifies all the fundamental interactions of high-energy physics, also including gravity.

Many theories have been invented, but none is proven with today's technology.

Is this idea beyond the limits of science and technology?

Aerial view of the Large Hadron Collider

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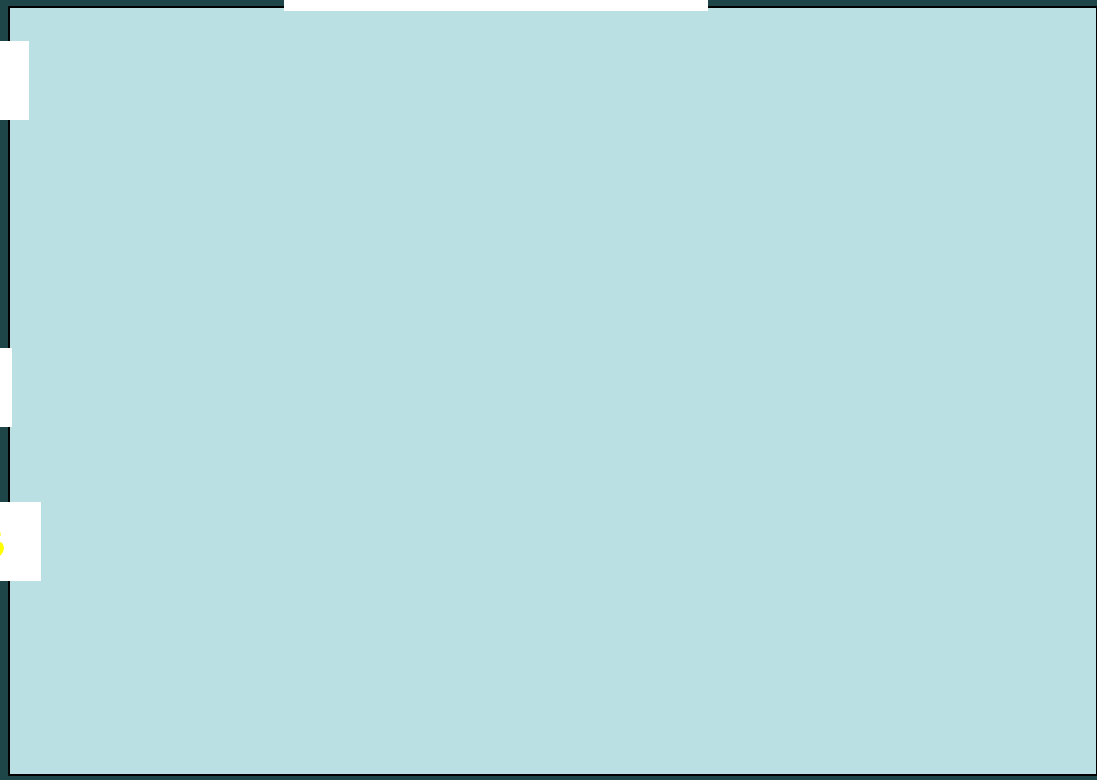
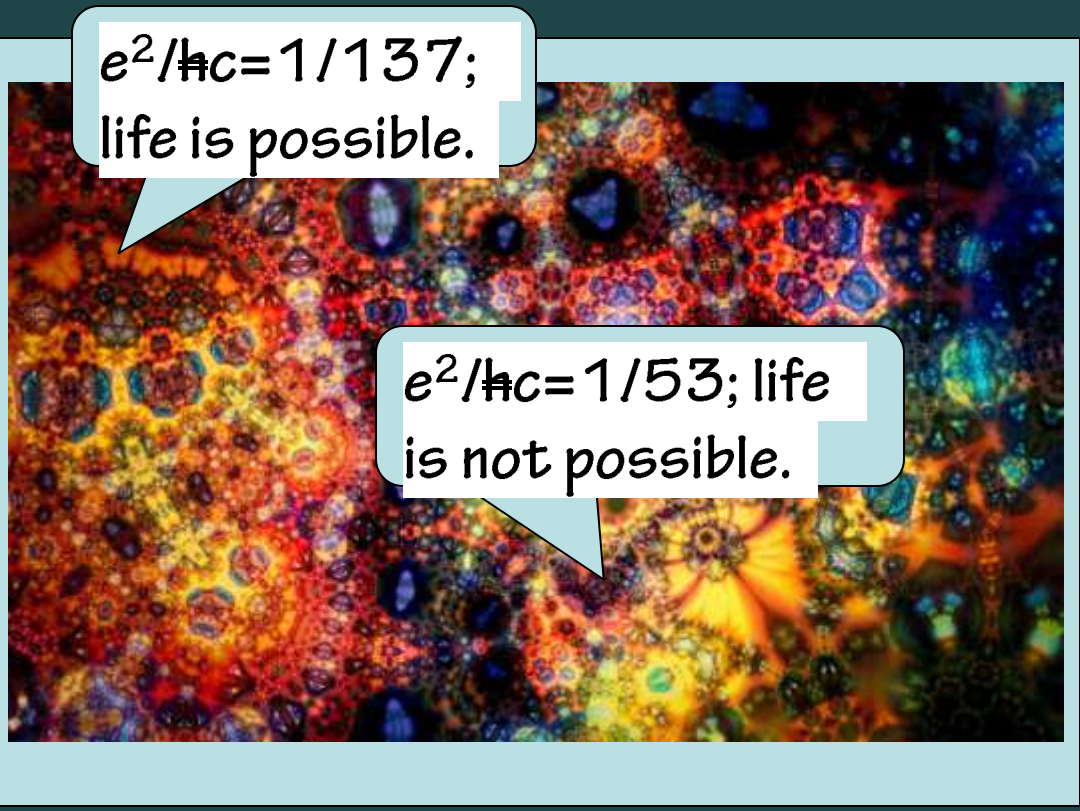


The Multiverse

According to this idea, the laws of physics are not universal, because there is not just one universe.

How could we know?

Is this idea beyond the limits of science?



Elementary		Prereq.	Credits
PHY 183 (or 193H)	PHYSICS I	MTH 132	4
PHY 184 (or 294H)	PHYSICS II	MTH 133	4
PHY 191	PHYSICS LAB 1	PHY 183	1
PHY 192	PHYSICS LAB 2	PHY 184	1
Intermediate			
PHY 215	MODERN PHYSICS	PHY 183	3
PHY 321 (+422†)	CLASSICAL MECHANICS	184 & M235	3
Advanced			
PHY 471 (+472†)	QUANTUM MECHANICS	PHY 215	3
PHY 481 (+482†)	ELECTRICITY AND MAGNETISM	MTH 234	3
PHY 410	THERMAL PHYSICS	PHY 471	3
PHY 431	OPTICS	PHY 215	3
PHY 440	ELECTRONICS	184 & 192	4
PHY 451	ADVANCED LAB	440 or 431	3
Capstone courses	(various)		6