

ANTIMATTER RESEARCH

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ANTIMATTER RESEARCH



CURRICULUM & CLASSROOM CONNECTIONS

The potential topics to introduce antimatter:

- astrophysics/star evolution & Big Bang
- conservation laws (conservation of lepton number, conservation of momentum)
- future energy sources
- medical imaging (PET-scan)

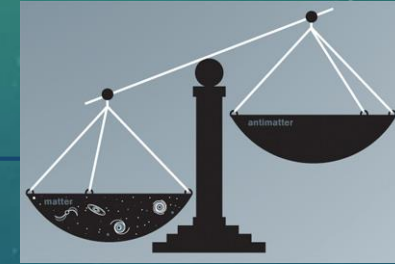
We have no curricula that includes the topic antimatter separately but indirectly through the different applications of it.

- Except for Colombia the Big bang theory and Positron Emission Tomography (PET scans) are taught in the four other countries**

KEY IDEAS FOR SUCCESSFUL INSTRUCTION



The big questions



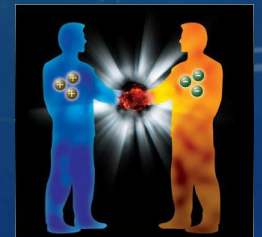
Applications

Production and detection



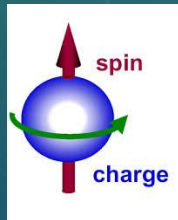
Annihilation and storage

Defining antimatter



Principles of particle physics

Familiar Scenarios



Potential student conceptions & challenges



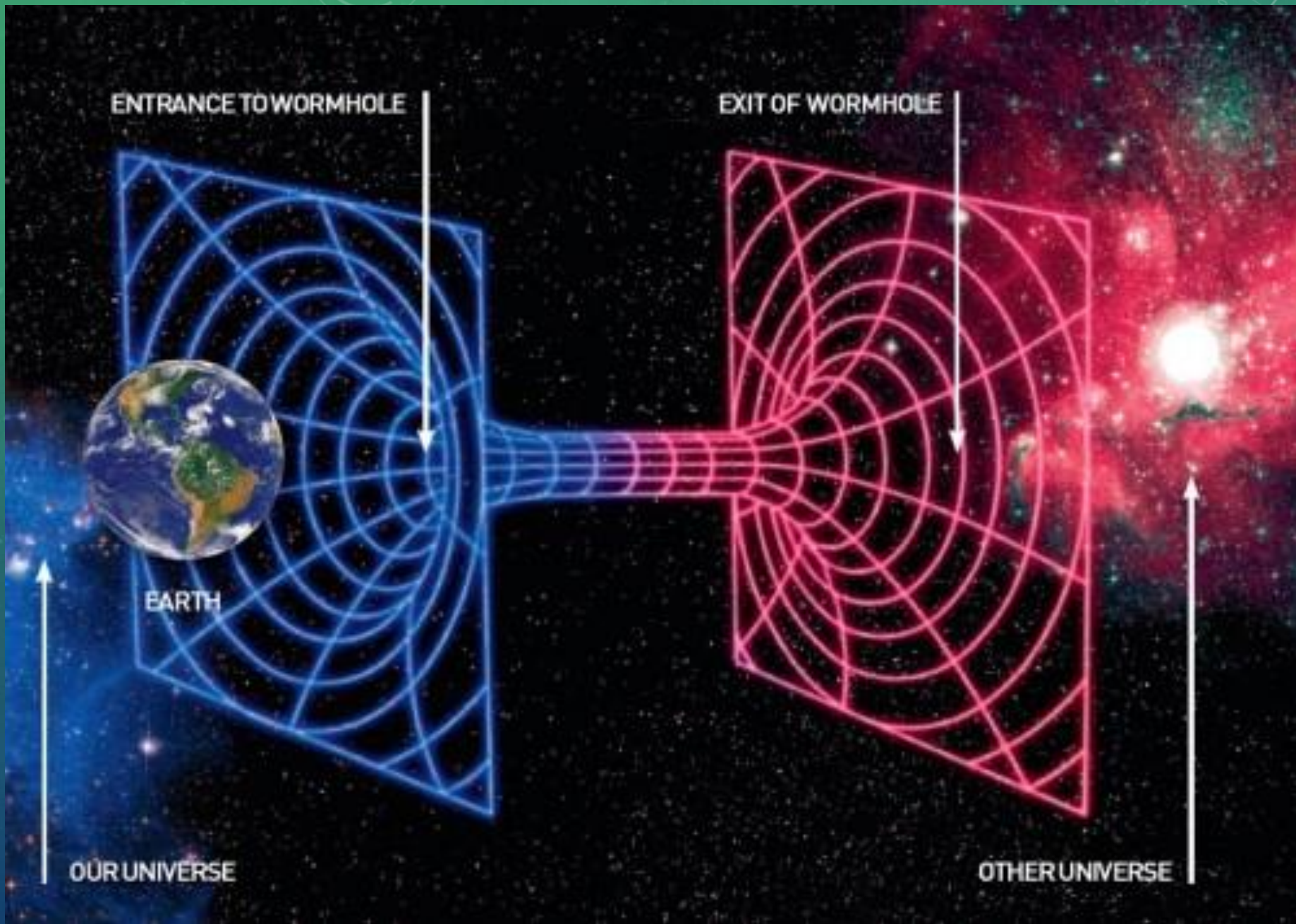
The Future of Renewable Energy



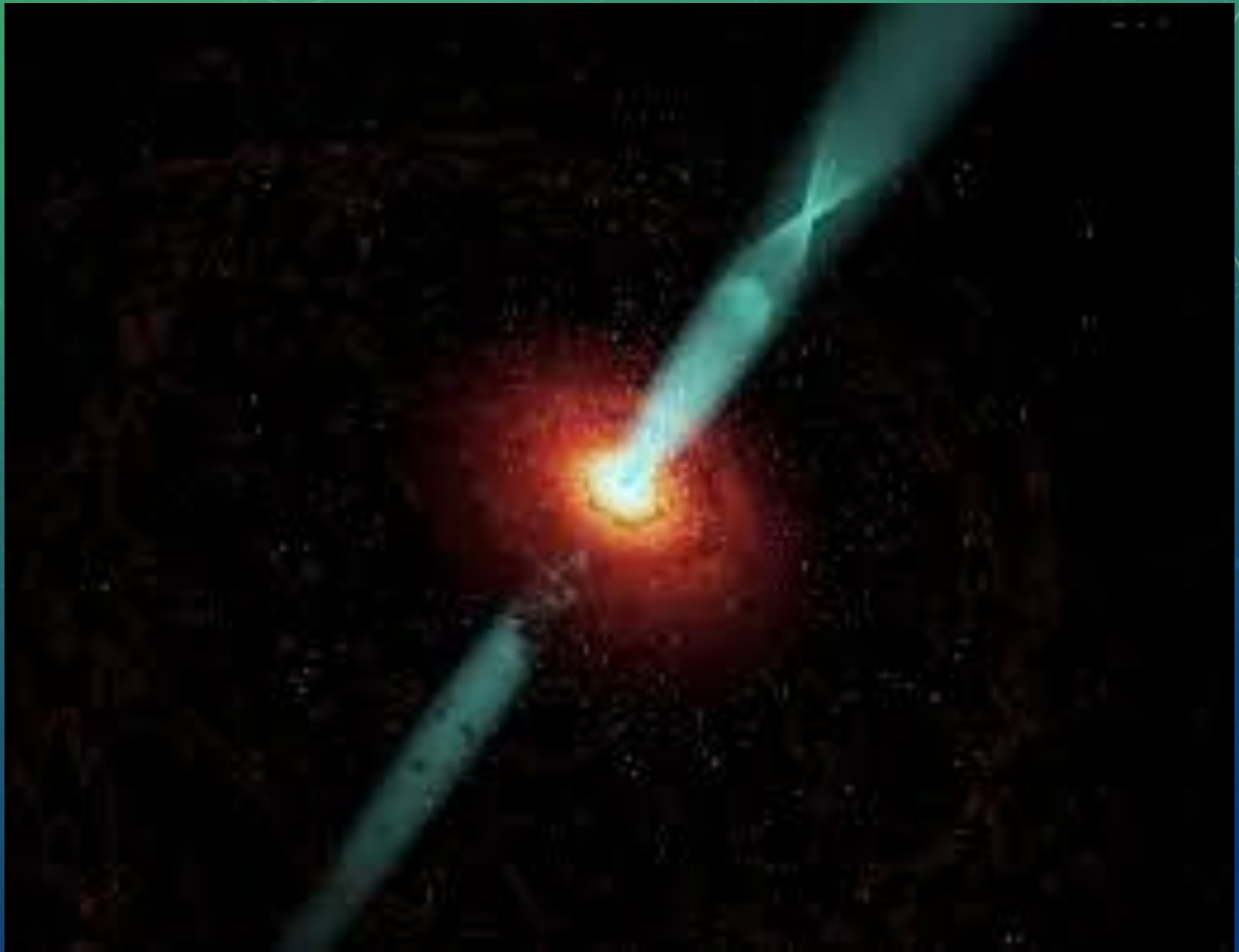
CONTAINING ANTIMATTER

*The antimatter trap from
"Angels & Demons"*











If something falls, you will be hit

Pray for it to be made of antimatter, or shift a little bit

EVIDENT MISCONCEPTIONS --> CHALLENGES

- It propels the Enterprise
- It's the future source of energy
- It can kill the pope
- Parallel universes are made of it
- Isn't it the same as Dark Matter?
- It's a Black Hole!
- It falls up!

HELPFUL MATERIAL AND RESOURCES

- KNOW YOUR STUFF! → Frank Close, **AntiMatter** & maybe a bit of tensor calculation
- Rolf Landua's video's and Lessons
- TES card game



The best is...

CERN Anti-matter Teaching Module Rolf Landua

1. Getting students ideas that science fiction and documentaries provided.
<https://www.youtube.com/watch?v=T7rQKWjm95Q>



2. Particles that conform the visible matter and their antiparticles.

What is the difference?

...an ANTIMATTER twin.



electron



neutrino



up quark



down quark



positron



anti-neutrino



anti-up quark



anti-down quark

It is traditional to use a little bar in the symbol for an antimatter particle to distinguish it from the symbol for its matter twin (the exception is the positron, where we use a '+' instead of the '-' of the electron).

Atoms models

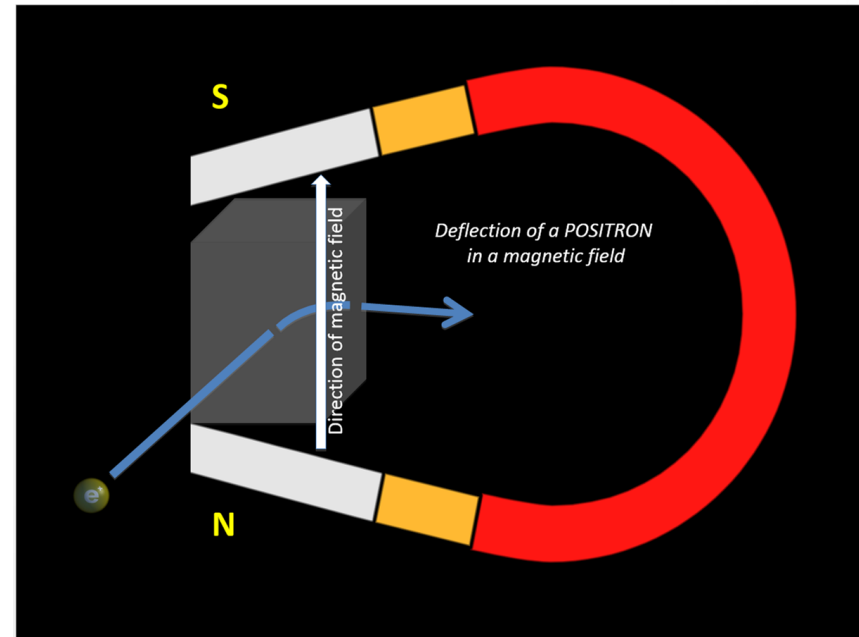
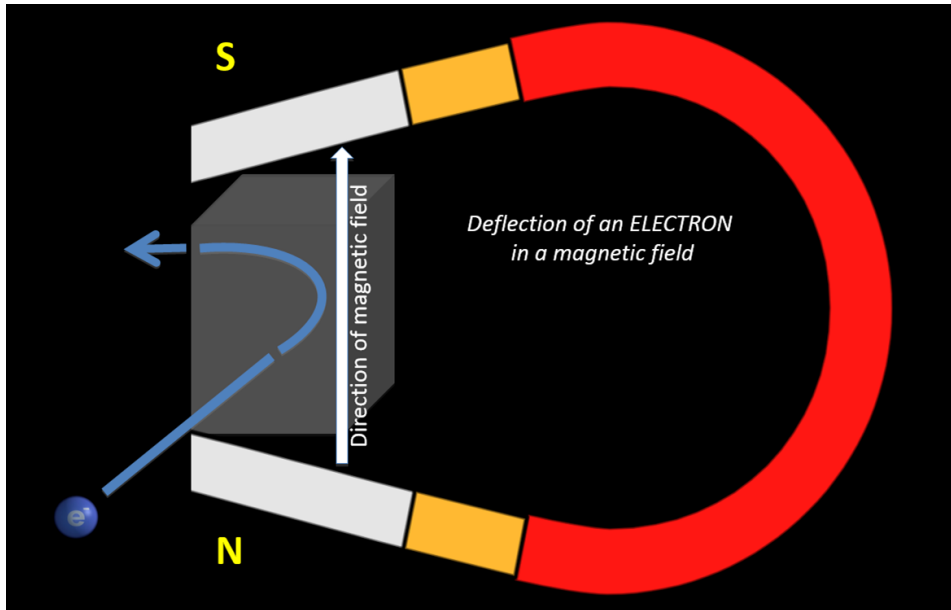
Mass

Charge

No entire charge



3. Detection



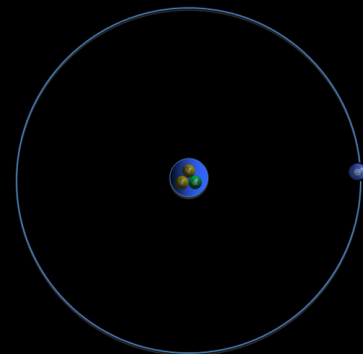
Lorentz Force

Cosmic Rays

AMS Experiment

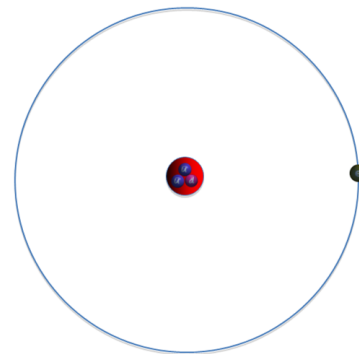
4. Antimatter

Let us picture a **hydrogen atom** as an **electron** orbiting its nucleus, a **proton**. BUT REMEMBER—this is NOT an accurate depiction! (For one thing, in the proper scale, our electron would have to be drawn about 1 kilometer away from the proton).



Hydrogen (H)

Let us now picture an **antihydrogen atom** as a **positron** orbiting its nucleus, an **antiproton**. (The same warnings apply!)



Anti-Hydrogen (\bar{H})

H	He																
Li	Be	B	C	N	O	F	Ne										
Na	Mg	Al	Si	P	S	Cl	Ar										
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq	Uur	Uus	Uut	Uuq	Uur
Lanthanide series		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb		
Actinide series		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No		



H	He																
Li	Be	B	C	N	O	F	Ne										
Na	Mg	Al	Si	P	S	Cl	Ar										
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uuq	Uur	Uus	Uut	Uuq	Uur
Lanthanide series		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb		
Actinide series		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No		

5. Operation: Annihilate!



Law Conservation Of Energy

$$E = mc^2$$



THE PHOTON
(the symbol for the photon is γ)

$$9.11 \times 10^{-31} \text{ kg} + 9.11 \times 10^{-31} \text{ kg}$$



electron

+



positron



$$0.82 \times 10^{-13} \text{ J}$$



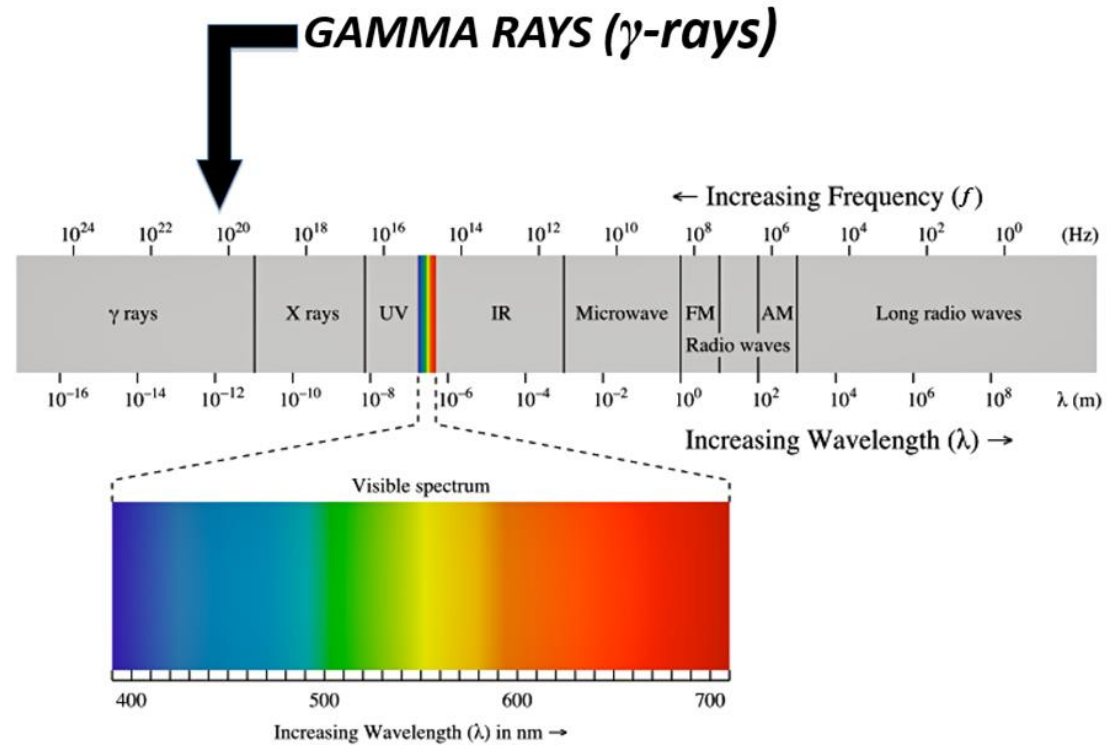
$$0.82 \times 10^{-13} \text{ J}$$

$$E = hf^*$$

Wave motion

6. Applications

Frequencies of 10^{20} Hz (or wavelengths of 10^{-12} m) are characteristic of



BEST PRACTICE EXAMPLE

- Project “Antimatter falls up?”
- Animation “If matter falls down, does antimatter fall up?” from Chloé Malbrunot
- Antimatter Factory

BEST PRACTICE EXAMPLE

- **Students attend a university lecture;**
- **Design an experiment**
- **Make animations**
- **Apply for Beamline-for-schools**

THANK YOU!