



NOTE TO THE TEACHER: THIS LESSON AND ITS COMPANION LESSON "ENERGY'S SPAWN" DEAL WITH THE TRANSFORMATION OF MATTER TO ENERGY (AND ENERGY TO MATTER) USING THE FORMULA



IT IS RECOMMENDED THAT YOU GO THROUGH "CONSERVATION OF ENERGY-REVISTED" IN THE BACKGROUND MATERIALS WITH YOUR STUDENTS BEFORE EMBARKING UPON THESE TWO LESSONS:



4 PARTICLES...











4 PARTICLES...



4 PARTICLES...







BUT FOR NOW, WE WILL INTRODUCE YOU TO JUST ONE MORE...



BUT FOR NOW, WE WILL INTRODUCE YOU TO JUST ONE MORE...



THE PHOTON

(the symbol for the photon is γ)

WE SHALL DISPENSE WITH THE ARMS AND LEGS FROM HERE ON, AND JUST REPRESENT IT LIKE THIS:



The photon can be considered as a tiny packet of ENERGY. For example, LIGHT is a stream of photons.

THE ENERGY OF A SINGLE PHOTON

IS GIVEN BY THE FOLLOWING

SIMPLE LITTLE FORMULA:

E = hf *

WE WILL COME BACK TO THIS FORMULA LATER, BUT FIRST ...

*You will find a short tutorial on this formula in WOh No!! Formulas!Win the Background Materials:



PREVIOUSLY, WE SAW WAYS IN WHICH MATTER AND ANTIMATTER ARE SIMILAR AND WAYS IN WHICH THEY DIFFER.

INTERESTING THOUGH THAT MAY BE, IT DOESN[®]T REALLY EXPLAIN WHY THERE IS SO MUCH OF A FUSS ABOUT ANTIMATTER.

TO GET AN IDEA OF WHAT WE ARE TALKING ABOUT, HAVE A LOOK AT THE FOLLOWING CLIP...

From the film 'Angels & Demons" (2009)



To see the video, click on the picture



Who WROTE this stuff???



Ivm going to have a little chat with my agent 2

NOW, LET^vS TAKE A CLOSER LOOK AT SOME OF THAT RIVETING DIALOGUE²

(THE INTERESTING BITS ARE IN BLUE)

Vittoria Vetra:	That canister contains an extremely combustible substance called antimatter. We need to locate it immediately or evacuate Vatican City!
Cdr. Richter:	I ữ n quite familiar with incendiaries, Miss Vetra. I ữ n unaware of antimatter being used as such.
Vittoria Vetra:	Well, it \mathfrak{F} never been generated in sufficient quantities before. It \mathfrak{F} a way of studying the origins of the Universe
	H The antimatter is suspended there, in an airtight, nano-composite shell with electromagnets on each end. But if it were to fall out of suspension and come in contact with matter , say at the bottom of the canister, then the two opposing forces would annihilate one another, violently.
Cdr. Richter:	And what might cause it to fall out of suspension?
Vittoria Vetra:	The battery going dead. Which it will $ ilde{m U}$ just before midnight.
Cdr. Richter:	What kind of annihilation? How violent?
Vittoria Vetra:	A cataclysmic event. A blinding explosion equivalent to about five kilotons.
Robert Langdon:	Vatican City will be consumed by light.

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TRUE.

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TRUE.

ANTIMATTER + MATTER = ENERGY

LET'S LOOK AT THIS MORE CLOSELY FOR THE CASE OF AN ELECTRON AND A POSITRON:

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MATTER



electron

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MATTER + ANTIMATT ER



LET[®]S LOOK AT THIS MORE CLOSELY FOR THE CASE OF AN ELECTRON AND A POSITRON:





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THE ELECTRON (m_{e-}) AND THE POSITRON (m_{e+})

AND THE FORMULA

$$E = mc^2$$

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Let $\tilde{\mathbf{v}}$ do a short calculation $\hat{\mathbf{Z}}$

he masses of an electron and a positron are the same: $m_{e^-} = m_{e^+} = 9.11 \sum 10^{-31} kg$ So the total mass of both particles is: -30 kg $m_{e^-} + m_{e^+} = m = 1.82 \sum 10$ and, $c = 3.00 \sum 10$ 8 m/s So. $E = mc^{2} = 1.82 \sum 10^{-30} \sum (3.00 \sum 10^{8})^{2}$ $E = 1.64 \sum 10 -13 J$











THE CALCULATION BECOMES MUCH SIMPLER IF, INSTEAD OF USING MASS UNITS (KILOGRAMS) AND JOULES, WE USE THE ENERGY UNITS MEGA ELECTRON VOLTS (MeV) FOR ALL OF THE PARTICLES Â

For information on the electron volt, see WUnits! Winth in the Background Materials:



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WE CAN EVEN FIND OUT IN WHAT FORM

THIS ENERGY IS BY USING

E = hf

TAKING E = hf and rearranging in terms of f gives:

$$f = \frac{0.82 \times 10^{-13}}{6.63 \times 10^{-34}} = 1.24 \times 10^{20} \text{Hz}$$

f

h

As an exercise, use $E = \frac{hc}{\lambda}$ to show that the wavelength 7 of the photon is $2.42 \sum 10$ -12

m

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GAMMA RAYS (y-rays)

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(Answer: 3.01×10⁻¹⁰ J)

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(Answer: γ-rays)

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5 KILOTONS OF WHAT ?

LET^vS ASSUME THAT THEY MEAN 5 KILOTONS OF TNT.

THIS LEADS TO AN INTERESTING LITTLE EXERCISE:

When 1 kiloton of TNT explodes, it gives roughly $4.2 \sum 10$ energy. So 5 kilotons would give $2.1 \sum 10$ 13 joules.

Using E = mc ², calculate the total mass (antimatter + matter) required to obtain 2.1 $\sum 10^{-13}$ joules of energy.

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If we assume that it is the annihilation of protons by antiprotons, how many antiprotons would be required? (Answer: $7.2 \sum 10$ ²² antiprotons) SO, IT SEEMS THAT WHEN ABOUT

0.12 GRAMS OF ANTIMATTER

ANNIHILATES

0.12 GRAMS OF MATTER,

THE RESULTING ENERGY IS EQUIVALENT TO

5,000,000 kg OF TNT!

PER UNIT MASS, WE GET AROUND 4 BILLION TIMES MORE ENERGY FROM THE ANNIHILATION OF MATTER WITH ANTIMATTER THAN WE GET FROM USING TNT.

AND WHY STOP AT THE ANNIHILATION OF ONLY TINY AMOUNTS OF MATTER AND ANTIMATTER?

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HOW ABOUT SOMETHING BIGGER?

LET'S INTRODUCE A MYSTERY CELEBRITY SOCIALITE * TO HER ANTI-SELF...

* Teachers should feel free to choose their own example, be it animate or inanimate.

Celebrity Socialite



Celebrity Socialite



anti-Celebrity Socialite



Of course, our anti-celebrity would not really look like this \hat{U} it \tilde{w} just used as an effect.

LATEST FIGURES SHOW THE MASS OF THE CELEBRITY TO BE 52 kg.

CALCULATE THE AMOUNT OF ENERGY PRODUCED UPON ANNIHILATION.

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(Answer: 9.4×10¹⁸ J)



THIS ANNIHILATION WOULD GIVE MORE ENERGY THAN 2000 MEGATONS OF TNT!



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OR, TO LOOK AT IN A LESS VIOLENT WAY:

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TOTAL WORLDWIDE ENERGY CONSUMPTION IN 2008 WAS APPROXIMATELY 5×10²⁰ J.

THIS ANNIHILATION WOULD PROVIDE NEARLY 2% OF ONE YEAR'S PLANETARY ENERGY NEEDS!





ANTIMATTER AS THE SOLUTION TO OUR ENERGY NEEDS?

IF ONLY IT WERE THAT SIMPLE...



ANTIMATTER AS THE SOLUTION TO OUR ENERGY NEEDS?

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(SEE THE LESSON "BOYS WITH TOYS" TO FIND OUT WHY IT IS NOT "THAT SIMPLE")