

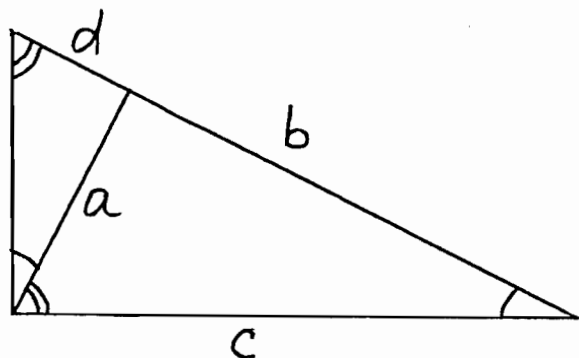
## ALBERT EINSTEIN

BORN: ULM, WÜRTTEMBERG, GERMANY MARCH 14, 1879  
 DIED: PRINCETON, NEW JERSEY APRIL 18, 1955

## CONTRIBUTIONS :

1. USED THE KINETIC THEORY TO PROVIDE AN EXPLANATION FOR BROWNIAN MOTION, WHICH IS THE IRREGULAR ZIG-ZAG MOTION OF POLLEN GRAINS SUSPENDED IN WATER.
2. THEORETICAL EXPLANATION OF THE PHOTOELECTRIC EFFECT IN WHICH HIGH ENERGY LIGHT IMPINGING ON A METAL PRODUCES AN ELECTRIC CURRENT. EINSTEIN HYPOTHESED THAT LIGHT CAME IN PACKETS CALLED PHOTONS. (1921 NOBEL PRIZE)
3. THE THEORY OF SPECIAL RELATIVITY TO EXPLAIN SPACE-TIME AND MASS FOR INERTIAL REFERENCE FRAMES, THAT IS, THOSE MOVING AT CONSTANT VELOCITY.
4. THEORY OF GENERAL RELATIVITY TO EXPLAIN GRAVITATION AND THE EFFECTS OF ACCELERATION FOR NON-INERTIAL REFERENCE FRAMES.

## EINSTEIN'S PROOF OF PYTHAGORAS' THEOREM:



ALL THREE TRIANGLES ARE SIMILAR.

$$\begin{cases} \frac{c}{d+b} = \frac{b}{c} \\ bd + b^2 = c^2 \end{cases}$$

$$\begin{cases} \frac{d}{a} = \frac{a}{b} \\ bd = a^2 \end{cases}$$

$$\therefore a^2 + b^2 = c^2$$

TIME DILATION  $K = \sqrt{1 - v^2/c^2}$   $C = 3 \times 10^8 \text{ m/s}$

1. SARAH IS ZOOMING AT  $.8c$  IN HER WHITE BMW. AS SHE CRUISES BY, WE BOTH SET OUR CLOCKS AT EXACTLY 2 P.M.
  - A) FIND  $K$ .
  - B) FIVE HOURS LATER, WHAT DOES OUR CLOCK READ TO US?
  - C) AT THAT TIME, WHAT DOES HER CLOCK READ TO US?
  - D) FIND HER SPEED IN  $\text{m/s}$ . ( $.6, 7 \text{ PM}, 5 \text{ PM}, 2.4 \times 10^8 \text{ m/s}$ )
2. HUGH AND JENNIFER ARE BOTH EIGHTEEN YEARS OLD WHEN JENNIFER ZOOMS AWAY AT  $.9c$  TO PROXIMA CENTAURI, WHICH IS  $4.3 \times 10^{16} \text{ m}$  FROM EARTH.
  - A) TO HUGH, HOW LONG WILL IT TAKE JENNIFER TO REACH HER DESTINATION? HOW OLD IS HUGH NOW? (5 YRS, 23)
  - B) TO JENNIFER, HOW LONG DID THE TRIP TAKE? HOW OLD IS SHE NOW? (2.2 YEARS; 20 YEARS, 73 DAYS OLD)
3. WHEN VIEWED AT REST, MUONS LIVE FOR  $2 \mu\text{SEC}$ . CREATED IN THE UPPER ATMOSPHERE, THEY ZOOM TOWARD EARTH AT  $.998c$ .
  - A) FIND  $K$ .
  - B) AS VIEWED BY A STATIONARY PHYSICIST ON EARTH, HOW LONG DO THE MOVING MUONS LIVE?
  - C) AS VIEWED BY THE PHYSICIST, HOW FAR DO THE MUONS TRAVEL? ( $.0632, 31.64 \mu\text{SEC}, 9473 \text{ m}$ )
4. CHARLOTTE LEAVES HOME AT 6:55 A.M. WHEN SHE ARRIVES AT T.P.H.S., THE SCHOOL CLOCK READS 7:20 A.M. HER CLOCK READS ONLY 7:15 A.M. JUST ON TIME! FIND THE SPEED WITH WHICH SHE ZOOMED TO SCHOOL. ( $.6c, 1.8 \times 10^8 \text{ m/s}$ )
5. STATIONARY, MR. HARVIE WATCHES JANE JOG BY IN THE TORREY PINES 5K EVENT. JANE'S CLOCK IS RUNNING ONLY ONE-THIRD AS FAST AS MR. HARVIE'S. FIND:
  - A) JANE'S SPEED. ( $.9428c, 2.828 \times 10^8 \text{ m/s}$ )
  - B) TO MR. H., HOW LONG DOES IT TAKE FOR HER TO RUN THE EVENT. (17.7  $\mu\text{SEC}$ )
  - C) TO JANE, HOW LONG DOES THE RACE TAKE? (5.9  $\mu\text{S}$ )
6. FIND THE DISTANCE WHICH LIGHT CAN TRAVEL IN ONE YEAR. ( $9.467 \times 10^{15} \text{ m} = 5.88 \times 10^{12} \text{ miles}$ )

## LENGTH CONTRACTION

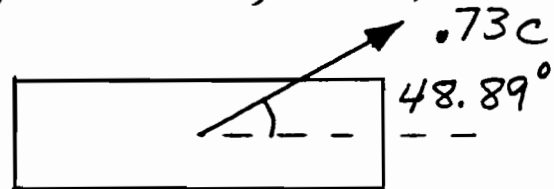
1. ATTIRED IN REEBOK, BRIA RUNS AT  $.52678c$  WHILE HOLDING A  $4\text{ m}$  VAULTING POLE STRAIGHT OUT IN FRONT OF HER. FIND THE LENGTH OF THE POLE AS VIEWED BY: A) BRIA B) A STATIONARY MR. H. ( $4, 3.4\text{ m}$ )

2. REX FLINGS A JAVELIN AT  $.7599c$ . AS IT ZOOMS THROUGH THE AIR, REX MEASURES THE LENGTH OF THE SPEAR TO BE  $1.235\text{ m}$  LONG. FIND THE LENGTH OF THE JAVELIN WHEN IT IS STATIONARY. ( $1.9\text{ m}$ )

3. AT REST, A QUADRALATERAL IS A SQUARE WHOSE SIDE ARE  $15\text{ m}$ . THE FIGURE NOW RACES HORIZONTALLY THROUGH THE ROOM AT  $.8284c$ . AS VIEWED BY A STATIONARY OBSERVER, FIND ITS: A) HEIGHT B) LENGTH C) AREA ( $15, 8.4\text{ m}, 126\text{ m}^2$ )

4. AT REST, A QUADRALATERAL IS A SQUARE. WHEN IT ZOOMS HORIZONTALLY THROUGH THE ROOM AT  $.9474c$ , ITS AREA IS  $4232\text{ m}^2$ . FIND ITS DIMENSIONS WHEN IT IS STATIONARY. ( $115\text{ m}, 115\text{ m}$ )

5. AT REST, A RECTANGLE IS  $12\text{ m}$  TALL AND  $22\text{ m}$  LONG. IT NOW ZOOMS BY AT  $.73c$  ON A DIAGONAL PATH.

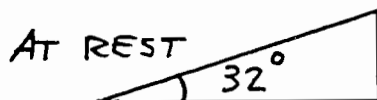


AS SEEN BY A STATIONARY OBSERVER, FIND:

A)  $V_x, K_x, X$  B)  $V_y, K_y, Y$  C) AREA  
( $.48c, .877, 19.3\text{ m}, .55c, .835, 10\text{ m}, 193\text{ m}^2$ )

6. AT REST, AN ANGLE HAS A MEASURE OF  $45^\circ$ . FLEEING A PROTRACTOR, IT ZOOMS HORIZONTALLY THROUGH THE ROOM AT  $.6871c$ . AS SEEN BY A STATIONARY OBSERVER, FIND THE MEASURE OF THE ANGLE. ( $54^\circ$ )

7. A RIGHT TRIANGLE AT REST HAS AN ANGLE OF  $32^\circ$ . ZOOMING HORIZONTALLY THROUGH THE ROOM, THE ANGLE INCREASES TO  $48^\circ$ . FIND ITS SPEED. ( $.8268c$ )



## RELATIVISTIC MASS INCREASE

1. RECLINED ON THE COUCH, MR. HARVIE'S MASS IS 80 KG. TIME TO GO! MR. H DONS HIS NIKE AND JOGS DOWN THE SHORE AT  $.51c$ . FIND HIS MASS AS SEEN BY A STATIONARY OBSERVER. (93 KG)
2. A WOOLLY MAMMOTH TROTS BY AT  $.6c$ . AS HE ZOOMS BY, A CRO-MAGNON HUNTER THINKS, "THAT'S 7000KG OF BIG MACS." BUT NO! THE FURRY BEAST STOPS TO CATCH ITS BREATH — LUNCH IS SUDDENLY LESS MASSIVE, FIND THE PACHYDERM'S REST MASS. (5600 KG).
3. WEARING HER ADIDAS, PAIGE RACES AROUND THE T.P.H.S. TRACK. A STATIONARY SPECTATOR OBSERVES THAT HER MASS IS 2.3 TIMES HER MASS AT REST. FIND HER SPEED. ( $.9c$ ,  $2.7 \times 10^8$  m/s)

## SUMMARY

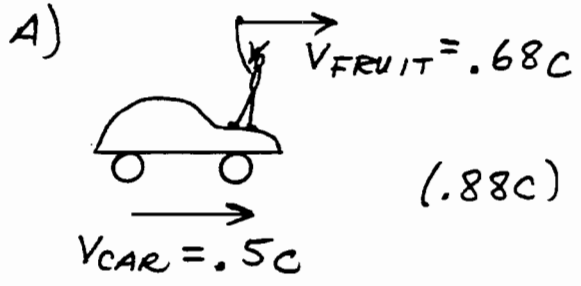
THE STANFORD LINEAR ACCELERATOR, SLAC, SHOTS ELECTRONS, WHOSE REST MASS IS  $9.11 \times 10^{-31}$  KG, AT  $.9999c$  ALONG A PATH WHOSE LENGTH IS 3200 M.

- A) FIND  $K$ .
- B) AS SEEN BY A STATIONARY PHYSICIST, FIND:
  1. THE LENGTH OF THE ACCELERATOR.
  2. THE TIME FOR THE TRIP.
  3. THE ELECTRON'S MASS
- C) AS SEEN BY THE SCREAMING ELECTRON AS IT ZOOMS ALONG IN THE ACCELERATOR, FIND:
  1. THE LENGTH OF THE ACCELERATOR.
  2. THE TIME FOR THE TRIP.
  3. THE ELECTRON'S MASS.

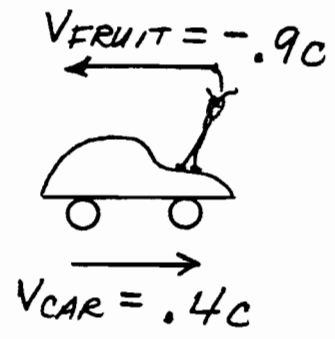
(.01414; 3200 m, 10.668  $\mu$ SEC,  $6.44 \times 10^{-29}$  KG;  
45.25m, .1509  $\mu$ SEC,  $9.11 \times 10^{-31}$  KG)

ADDITION OF VELOCITIES 
$$V_{TOTAL} = \frac{V_1 + V_2}{1 + (V_1 V_2 / c^2)}$$

1. AS SEEN BY A STATIONARY OBSERVER, FIND THE SPEED OF THE TOMATO.

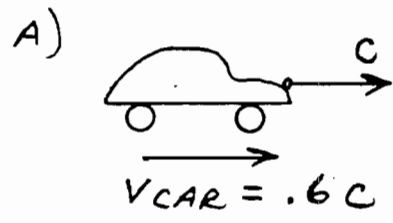


(.88c) (-.78c)

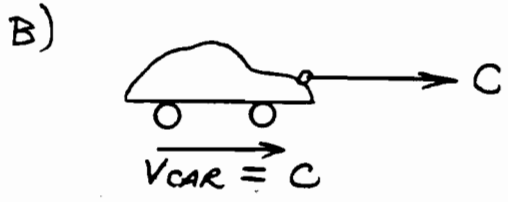


2. JON IS DRIVING HIS JEEP CHEROKEE AT .8c PAST MR. HARVIE, WHO IS STATIONARY. JON NOW THROWS A MCINTOSH APPLE FORWARD, WHOSE SPEED IS .9c AS SEEN BY MR. H. FIND THE SPEED OF THE SCOTTISH APPLE AS SEEN BY JON. (.357c)

3. THE DRIVER TURNS ON THE HEAD LAMPS AND SEES THE LIGHT TRAVEL FORWARD AT SPEED C. FIND THE SPEED OF THE LIGHT AS SEEN BY A STATIONARY OBSERVER.



(c) (c)



4. AUSTIN DRIVES HIS METALLIC GREEN PORSCHE AT 100 MPH. HE NOW SHOOTS AN ARROW FORWARD AT 400 MPH RELATIVE TO HIMSELF. FIND THE SPEED OF THE ARROW AS SEEN BY A STATIONARY OBSERVER. LEAVE THE SPEEDS IN MPH AND USE  $6.7 \times 10^8$  MPH FOR THE SPEED OF LIGHT. (500 MPH)

## ENERGY AND MASS CONVERSIONS

$$E = mc^2$$

$$\text{POWER} = \text{ENERGY} / \text{TIME}$$

1. AN ATOMIC BOMB CONTAINS 40 KG OF U-235. DURING A FISSION NUCLEAR REACTION, .089% OF THIS MASS IS DESTROYED AND CONVERTED TO ENERGY.
  - A) FIND THE AMOUNT OF MASS DESTROYED. (.0356 KG)
  - B) FIND THE ENERGY RELEASED. ( $3.2 \times 10^{15} \text{ J}$ )
2. AN UP QUARK, WHICH IS A CONSTITUENT OF PROTONS, HAS A MASS OF  $7 \times 10^{-30} \text{ KG}$ . FIND THE ENERGY NECESSARY TO CREATE AN UP QUARK. ( $6.3 \times 10^{-13} \text{ J}$ )
3. THE SUN'S RADIANT POWER IS  $3.92 \times 10^{26}$  WATTS.
  - A) FIND THE ENERGY EMITTED BY THE SUN EACH DAY.
  - B) FIND THE MASS DESTROYED EACH DAY.
  - C) THE SUN'S PRESENT MASS IS  $2 \times 10^{30} \text{ KG}$ . IN  $4.5 \times 10^9$  YEARS, THE SUN'S NUCLEAR REACTIONS WILL CEASE. FIND THE PERCENT OF THE SUN'S MASS WHICH WOULD HAVE BEEN DESTROYED DURING THAT INTERVAL OF TIME.  
( $3.387 \times 10^{31} \text{ J}$ ,  $3.763 \times 10^{14} \text{ KG}$ , .031%)
4. IN A CONVENTIONAL POWER PLANT, 480 TONS OF COAL ARE CONSUMED IN A CHEMICAL REACTION TO PRODUCE 900 MEGAWATT·HRS OF ELECTRICAL ENERGY.
  - A) CONVERT 900 MEGAWATT·HRS INTO JOULES. ( $3.24 \times 10^{12} \text{ J}$ )
  - B) SAN ONOFRE POWER STATION CONSUMES URANIUM-235 IN A NUCLEAR REACTION, RATHER THAN BURNING FOSSIL FUELS. THE STATION IS 22.5% EFFICIENT IN CONVERTING ITS NUCLEAR ENERGY INTO ELECTRICAL ENERGY. FIND THE MASS OF URANIUM WHICH MUST BE DESTROYED TO CREATE 900 MEGAWATT·HRS OF ELECTRICAL ENERGY. ( $1.6 \times 10^{-4} \text{ KG}$ )
  - C) DURING A FISSION NUCLEAR REACTION, .089% OF THE URANIUM IS DESTROYED. FIND THE MASS OF URANIUM FUEL NECESSARY TO MATCH THE OUTPUT OF THE COAL.  
(.18 KG)

# NUCLEAR PHYSICS

MASS OF PROTON =  $1.67265 \times 10^{-27}$  KG

NEUTRON =  $1.67495 \times 10^{-27}$  KG

FOR COMPARISON PURPOSES :

ELECTRON =  $9.11 \times 10^{-31}$  KG

1. A CARBON NUCLEUS,  ${}^{12}_6\text{C}$ , HAS A MASS OF  $19.92 \times 10^{-27}$  KG. a) HOW MANY PROTONS AND HOW MANY NEUTRONS ARE IN ITS NUCLEUS?

b) CALCULATE THE TOTAL MASS OF THAT MANY PROTONS AND THAT MANY NEUTRONS.

c) CALCULATE THE MASS DEFECT.

d) CALCULATE THE TOTAL BINDING ENERGY.

e) CALCULATE THE BINDING ENERGY PER NUCLEON.

2. A URANIUM ATOM WHICH UNDERGOES FISSION IN NUCLEAR REACTORS IS  ${}^{235}_{92}\text{U}$ . ITS MASS IS  $390.1792 \times 10^{-27}$  KG.

ANSWER QUESTIONS (a) - (e) AS IN QUESTION 1.

3. THE MOST STABLE ELEMENT IN THE UNIVERSE IS  ${}^{56}_{26}\text{Fe}$ , WHOSE MASS IS  $92.8519 \times 10^{-27}$  KG.

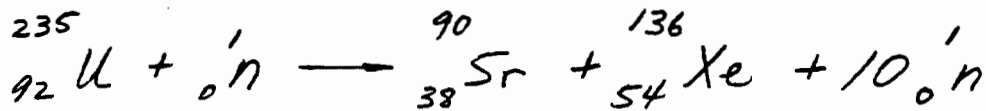
SAME QUESTIONS.

ANSWERS :

	${}^{12}_6\text{C}$	${}^{235}_{92}\text{U}$	${}^{56}_{26}\text{Fe}$	
a)	6, 6	92, 143	26, 30	
b)	20.0856	393.4016	93.7374	$\times 10^{-27}$ KG
c)	.1656	3.2224	.8855	$\times 10^{-27}$ KG
d)	1.4904	29.00	7.970	$\times 10^{-11}$ J
e)	1.242	1.234	1.423	$\times 10^{-12}$ J/N

## NUCLEAR POWER FROM FISSION AND FUSION

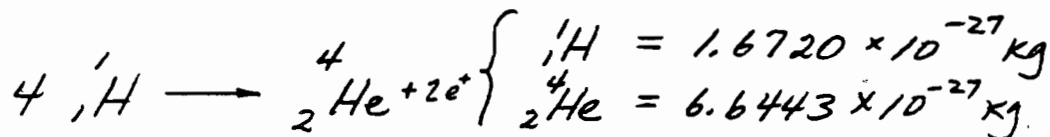
1. THE FISSION OF  ${}_{92}^{235}\text{U}$  CAN YIELD THE FOLLOWING:



$$\begin{aligned} \text{MASSES: } & {}_{92}^{235}\text{U} = 390.1729 \times 10^{-27} \text{ kg} \\ & {}_0^1\text{n} = 1.674384 \times 10^{-27} \text{ kg} \\ & {}_{38}^{90}\text{Sr} = 149.2461 \times 10^{-27} \text{ kg} \\ & {}_{54}^{136}\text{Xe} = 225.6060 \times 10^{-27} \text{ kg} \end{aligned}$$

- A) CALCULATE THE MASS WHICH DISAPPEARS. ( $.2513 \times 10^{-27} \text{ kg}$ )
- B) CALCULATE THE ENERGY RELEASED BY SPLITTING THIS ONE ATOM. ( $2.262 \times 10^{-11} \text{ J}$ )
- C) 1 kg OF  ${}_{92}^{235}\text{U}$  HAS  $2.56 \times 10^{24}$  ATOMS. HOW MUCH ENERGY IS RELEASED IF ALL OF THESE ATOMS UNDERGO FISSION? ( $5.791 \times 10^{13} \text{ J}$ )
- D) HOOVER DAM PRODUCES  $7 \times 10^8$  WATTS OF ELECTRICITY. IN HOW MANY HOURS WILL HOOVER DAM PRODUCE THESE  $5.8 \times 10^{13}$  JOULES OF ENERGY? (23 HRS)

2. IN THE FUSION OF HYDROGEN TO FORM HELIUM:



- A) CALCULATE THE MASS WHICH DISAPPEARS. ( $4.37 \times 10^{-29} \text{ kg}$ )
- B) CALCULATE THE ENERGY RELEASED IN THE PRODUCTION OF ONE HELIUM NUCLEUS. ( $3.93 \times 10^{-12} \text{ J}$ )
- C) 1 kg OF  ${}_1^1\text{H}$  HAS  $6.0 \times 10^{26}$  ATOMS. IF THEY ALL FUSE IN GROUPS OF FOUR, WHAT IS THE TOTAL ENERGY RELEASED? ( $5.90 \times 10^{14} \text{ J}$ )
- D) HOW MANY HOURS WOULD HOOVER DAM NEED TO WORK TO PRODUCE THIS MUCH ENERGY? (234 HRS)

## NUCLEAR PHYSICS IN RETROSPECT

1. ALEX VISITS A NEW UNIVERSE WHERE PROTONS HAVE A MASS OF 5 KG AND NEUTRONS HAVE A MASS OF 6 KG. HE DISCOVERS A NEW ELEMENT HERTZBERG WHICH CONTAINS 70 PROTONS AND 80 NEUTRONS. THE NUCLEUS OF HERTZBERG HAS A MASS OF 775 KG. FIND THE BINDING ENERGY PER NUCLEON. ( $3.3 \times 10^{16}$  J/NUCLEON)

2. JENSEN VISITS A NEW UNIVERSE AND DISCOVERS THE FOLLOWING REACTION:



A, B AND C ARE NEW ELEMENTS. N IS A NEUTRON.

$$A = 280 \text{ KG}$$

$$B = 133 \text{ KG}$$

$$N = 2 \text{ KG}$$

$$C = 130 \text{ KG}$$

- LIST TWO REASONS WHICH ALLOW US TO CONCLUDE THAT THIS IS A NUCLEAR RATHER THAN A CHEMICAL REACTION.
- WHAT TYPE OF NUCLEAR REACTION IS THIS? FISSION OR FUSION? WHY?
- IS THIS A CHAIN REACTION? WHY OR WHY NOT?
- FIND THE ENERGY RELEASED. ( $6.3 \times 10^{17}$  J)

3. BERNETTE VISITS A NEW UNIVERSE AND DISCOVERS THE FOLLOWING REACTION.



X, Y AND Z ARE NEW ELEMENTS.  $\beta$  IS A POSITRON.

$$X = 80 \text{ KG}$$

$$Z = 150 \text{ KG}$$

$$Y = 90 \text{ KG}$$

$$\beta = 2 \text{ KG}$$

- LIST TWO REASONS ALLOWING US TO CONCLUDE THAT THIS IS A NUCLEAR RATHER THAN A CHEMICAL REACTION.
- WHAT TYPE OF NUCLEAR REACTION IS THIS? FISSION OR FUSION? WHY?
- FIND THE ENERGY RELEASED. ( $1.26 \times 10^{18}$  J)

## RADIOACTIVITY

1. WRITE BALANCED EQUATIONS FOR THE DECAY OF EACH OF THE FOLLOWING NUCLEI.

A.  $\beta^-$  DECAY OF STRONTIUM-90.

B.  $\beta^+$  DECAY OF COBALT-56.

C. ELECTRON CAPTURE BY POTASSIUM-40.

D.  $\alpha$  DECAY OF URANIUM-238.

2. OXYGEN-15 HAS A HALF-LIFE OF 124 SECONDS.

WHAT FRACTION WOULD REMAIN AFTER 620 SECONDS?

3. NEUTRONS HAVE A HALF-LIFE OF 11.7 MINUTES AS IT UNDERGOES  $\beta^-$  DECAY.

A. WHAT FRACTION WOULD BE LEFT AFTER 70.2 MINUTES?

B. AFTER HOW MANY MINUTES WOULD THE ORIGINAL SAMPLE DECAY TO ONE-EIGHTH OF ITS INITIAL VALUE?

4. BARIUM-140 UNDERGOES  $\beta^-$  DECAY. AFTER 76.8 DAYS, ONLY ONE-SIXTY-FOURTH OF THE ORIGINAL SAMPLE REMAINS. FIND THE HALF-LIFE OF BARIUM.

5. CARBON-14 HAS A HALF-LIFE OF 5730 YEARS.

FIRE RINGS IN FRENCH CAVES CONTAIN CHARCOAL WHOSE CARBON-14 HAS DECAYED TO ONE PERCENT OF ITS INITIAL VALUE. FIND THE AGE OF THE FIRE RING.

6. IODINE-131 UNDERGOES  $\beta^-$  DECAY. AFTER 22 DAYS, A SAMPLE HAS DECAYED SO THAT ONLY 14.86% REMAINS.

FIND THE HALF-LIFE OF IODINE-131.

ANSWERS:  ${}_{38}^{90}\text{Sr} \rightarrow {}_{39}^{90}\text{Y} + {}_{-1}^0\text{e}$ ,  ${}_{27}^{56}\text{Co} \rightarrow {}_{26}^{56}\text{Fe} + {}_{+1}^0\text{e}$ ,  ${}_{19}^{40}\text{K} + {}_{-1}^0\text{e} \rightarrow {}_{18}^{40}\text{Ar}$

${}_{92}^{238}\text{U} \rightarrow {}_{2}^4\text{He} + {}_{90}^{234}\text{Th}$ ,  $\frac{1}{32} = 3.125\%$ ,  $\frac{1}{64} = 1.56\%$ , 35.1, 12.8, 38070,