Physics 104   Final Exam May 15, 2003

104ev4

Name_____ ID #_____

Section #_____ TA Name_____

Fill in your name, student ID # (not your social security #), and section # (under ABC of special codes) on the Scantron sheet. Fill in the letters given for the first 5 questions on the Scantron sheet. These letters determine which version of the test you took, and it is very important to get this right. Make sure your exam has questions 6—37.

1. A

2. E

3. C

4. D

5. B

6. Two point charges are separated by 10.0 cm and have charges of +2.00 and –2.00 μC, respectively. What is the electric field at a point midway between the two charges? ($k_e = 8.99 \times 10^9$ N·m²/C²)

   a. 28.8×10^6 N/C
   b. 14.4×10^6 N/C
   c. 7.19×10^6 N/C
   d. 3.10×10^6 N/C
   e. zero

7. Charge A and charge B are 3.00 m apart, and charge A is +2.00 C and charge B is +3.00 C. Charge C is located between them at a certain point and the force on charge C is zero. How far from charge A is charge C?

   a. 0.555 m
   b. 0.667 m
   c. 1.35 m
   d. 1.50 m
   e. 0.833 m

8. Four point charges are on the rim of a circle of radius 10 cm. The charges are (in 10^{-6} C) +0.50, +1.5, −1.0, −0.50. If the electrical potential at the circle's center due to the +0.5 charge alone is 4.5×10^4 V, what is the total potential at the center due to the four charges combined?

a. 18×10^4 V
b. 4.5×10^4 V
c. zero
d. -4.5×10^4 V
e. 0.50×10^4 V

IF THEY ARE ON A CIRCLE, THEY ARE ALL AT THE SAME DISTANCE r FROM THE CENTER

$V = \dfrac{k_e q}{r}$ *FOR EACH SO IF* $+0.5 \times 10^{-6} \to 4.5 \times 10^4 V$

THEN $1.5 \to 13.5 \times 10^4$ $-.5 \to -4.5 \times 10^4$,

$-1.0 \to -9 \times 10^4$ $13.5 - 9 + 4.5 - 4.5 = 4.5$

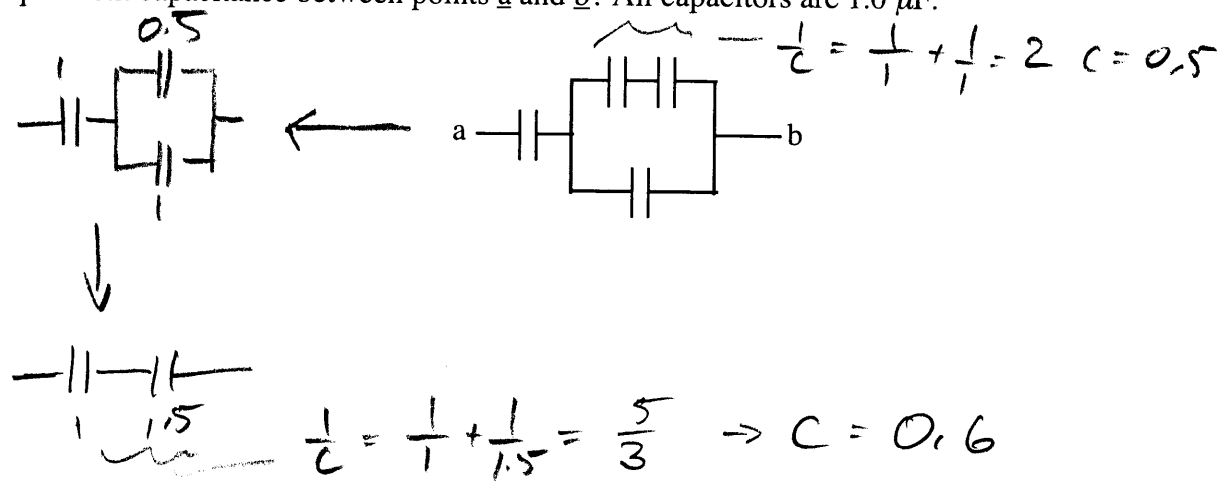9. Increasing the voltage across the two plates of a capacitor will produce what effect on the capacitor?

$Q = CV \qquad V\uparrow \to Q\uparrow$

a. decrease charge
b. increase capacitance
c. increase charge
d. decrease capacitance
e. decrease charge and decrease the capacitance

10. What is the equivalent capacitance between points a and b? All capacitors are 1.0 μF.

a. 4.0 μF
b. 1 7 μF
c. 2.2 μF
d. 0.25 μF
e. 0.60 μF

$\dfrac{1}{C} = \dfrac{1}{1} + \dfrac{1}{1} = 2 \quad C = 0.5$

$\dfrac{1}{C} = \dfrac{1}{1} + \dfrac{1}{1.5} = \dfrac{5}{3} \to C = 0.6$

11. Number 10 copper wire (radius = 1.3 mm) is commonly used for electrical installations in homes. What is the voltage drop in 40 m of #10 copper wire if it carries a current of 10 A? (The resistivity of copper is 1.7×10^{-8} Ω·m.)

a. 0.77 V
b. 0.50 V
c. 0.13 V
d. 1.3 V
e. 1.0 V

$R = \rho \dfrac{L}{A} = \dfrac{1.7 \times 10^{-8} \times 40}{\pi (1.3 \times 10^{-3})^2} = 1.28 \times 10^{-1} \ \Omega$

$V = IR = 10 \times 1.3 \times 10^{-1} = 1.3 \ V$

12. A flashlight bulb operating at a voltage of 4.5 V has a resistance of 8.0 Ω. How many electrons pass through the bulb filament per second ($e = 1.6 \times 10^{-19}$ C)?

a. 3.7×10^{16}
b. 1.8×10^{21}
c. 9.4×10^{17}
d. 2.1×10^{22}
e. 3.5×10^{18}
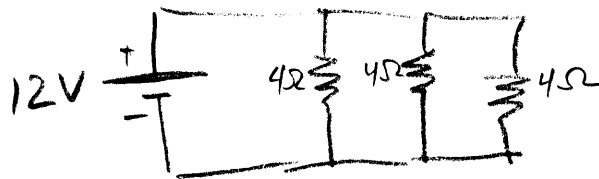
$$I = \frac{V}{R} = \frac{4.5}{8} = .5625 \text{ A}$$

$$1 A = 1 \text{ Cou.}/sec = \frac{1}{1.6 \times 10^{-19} \text{ cou}/e} = 6.24 \times 10^{18} \, e/sec$$

$$.5625 \times 6.24 \times 10^{18} = 3.5 \times 10^{18}/s$$

13. Three 4.0-Ω resistors are connected in parallel to a 12.0-V battery. What is the current in any ONE of the resistors (not the total current)?
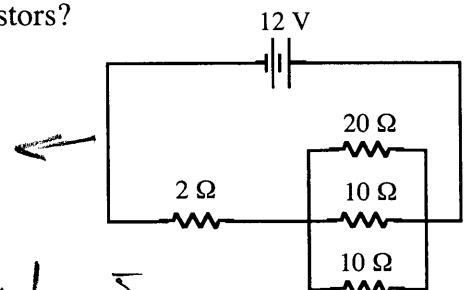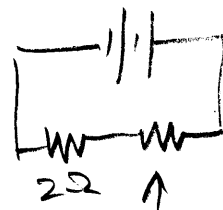
a. 3.0 A
b. 16 A
c. 9.0 A
d. 1.0 A
e. 21 A

12V, 4Ω, 4Ω, 4Ω

ALL 3 HAVE 12 V ACROSS THEM SO FOR ALL 3

$$I = V/R = 12/4 = 3A$$

14. How much power is being dissipated by one of the 10-Ω resistors?

a. 24 W
b. 9.6 W
c. 16 W
d. 6.4 W
e. 3.2 W

2Ω

12 V
20 Ω
2 Ω
10 Ω
10 Ω

$$\frac{1}{R} = \frac{1}{20} + \frac{1}{10} + \frac{1}{10} = \frac{5}{20}$$

$$R = 4\Omega \qquad 12 \text{ VOLTS}, \text{ TOTAL } 6\Omega$$

$$I = V/R = 12/6 = 2A$$

$$V(\text{ACROSS } 4\Omega) = 2A \times 4\Omega = 8V$$

$$P_{10\Omega} = \frac{V^2}{R} = \frac{64}{10} = 6.4 W$$

15. Two long parallel wires 20 cm apart carry currents of 5.0 A and 8.0 A in the same direction. Is there any point between the two wires where the magnetic field is zero?

   a. yes, midway between the wires
   b. yes, 12 cm from the 5-A wire
   c. yes, 3 cm from the 5-A wire
   (d) yes, 7.7 cm from the 5-A wire
   e. no

THE FIELD GOES AROUND BOTH WIRES IN THE SAME DIRECTION (RIGHT HAND RULE). IN BETWEEN, IT TENDS TO CANCEL ;

WE WANT A PLACE A DISTANCE r FROM THE 5 A WIRE SO THAT $B = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 5}{2\pi r} = \frac{\mu_0 8}{2\pi(20-r)}$; $\begin{cases} 8r = 100 - 5r \\ r = 7.7 \end{cases}$

16. A 100-m-long wire carrying a current of 4.0 A will be accompanied by a magnetic field of what strength at a distance of 0.050 m from the wire? (magnetic permeability in empty space $\mu_0 = 4\pi \times 10^{-7}$ T·m/A)

   a. 4.0×10^{-5} T
   b. 2.0×10^{-5} T
   c. 6.0×10^{-5} T
   d. zero
   (e) 1.6×10^{-5} T

$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 4.0}{2\pi \times .05}$

$B = \frac{8 \times 10^{-7}}{5 \times 10^{-2}} = 1.6 \times 10^{-5} T$

17. A planar loop consisting of four turns of wire, each of which encloses 200 cm², is oriented perpendicularly to a magnetic field that increases uniformly in magnitude from 10 mT to 25 mT in a time of 5.0 ms. What is the resulting induced current in the coil if the resistance of the coil is 5.0 Ω?

   a. 60 mA
   b. 12 mA
   c. 0.24 mA
   (d) 48 mA
   e. 30 mA

$\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -4\frac{(A\Delta B)}{5\times10^{-3} s} = -4\frac{(200\times10^{-4}\times15\times10^{-3})}{5\times10^{-3}}$

$(\Delta B = 25 mT - 10 mT = 15 mT = 15\times10^{-3}T)$

$|\varepsilon| = 4(2\times10^{-2}\times3) = 24\times10^{-2} = 0.24 V$

$I = \frac{V}{R} = \frac{0.24}{5} = 4.8\times10^{-2}A = 48 mA$

18. According to Lenz's law the direction of an induced current in a conductor will be that which tends to produce which of the following effects?

   a. enhance the effect which produces it
   (b) oppose the effect which produces it
   c. produce a greater heating effect
   d. produce the greatest voltage
   e. sometimes enhance and sometimes oppose the effect

19. A series *RLC* circuit in a radio is in resonance with AM 600 kHz. If the radio station is changed to AM 1200 kHz, by what factor must the capacitance be multiplied to again achieve resonance? (The *L* and the *R* remain unchanged).

a. 4
b. 2
c. 1/2
d. 1/4
e. 1/8

$$f = \frac{1}{2\pi\sqrt{LC}}$$ So TO DOUBLE f YOU MUST

REDUCE C BY $\frac{1}{4}$ $\left\{ \frac{1}{\sqrt{1/4}} = 2 \right\}$

20. A resistor and capacitor are connected in series with an applied AC voltage source. Separate voltmeter readings across the resistor and capacitor give values of 50 V and 75 V (rms), respectively. What is the effective (rms) voltage of the source?

a. 25 V
b. 90 V
c. 63 V
d. 150 V
e. 125 V

THE VOLTAGE ON THE CAPACITOR LEADS THE CURRENT BY 90°, ON THE RESISTOR IT IS IN PHASE WITH THE CURRENT.
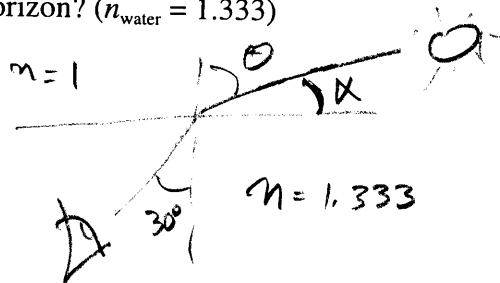
$$V_T = \sqrt{V_c^2 + V_R^2} = \sqrt{50^2 + 75^2}$$

$$V_T = 90 V.$$
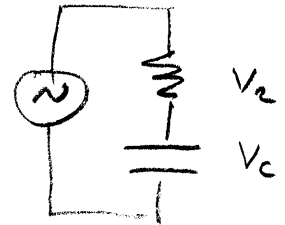
21. What is the wavelength of 100-MHz FM radio electromagnetic waves?

a. 0.3 cm
b. 3 m
c. 9 km
d. 10 m
e. 3 cm

$$f\lambda = c \quad So \quad \lambda = c/f = \frac{3\times 10^8}{10^8} = 3 \text{ m}$$

22. An underwater scuba diver sees the sun at an apparent angle of 30.0° from the vertical. How far is the sun above the horizon? ($n_{water} = 1.333$)

a. 22.0°
b. 41.8°
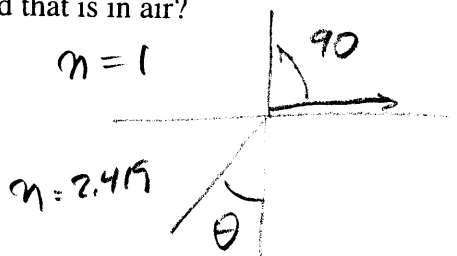c. 48.2°
d. 68.0°
e. 74.3°

$1 \sin\theta = 1.333 \sin 30°$

$\sin\theta = 1.333 \times \frac{1}{2}$

$\theta = 41.8°$

$\alpha = 90 - \theta = 48.2°$

23. Diamond has an index of refraction of 2.419. What is the critical angle for internal reflection inside a diamond that is in air?

a. 48.8°
b. 155°
c. 24.4°
d. 131°
e. 37.2°

$1 \sin 90 = 2.419 \sin\theta$

$\sin\theta = \frac{1}{2.419}$

$\theta = 24.4°$

24. A woman looking in a makeup mirror sees her face at twice its actual size and right-side up. If she is 28.0 cm from the mirror, what is its focal length?

a. 56.0 cm
b. 18.6 cm
c. 25.0 cm
d. 48.3 cm
e. 44.0 cm

RIGHT SIDE UP → VIRTUAL IMAGE, $q < 0$

$M = 2 = -q/p = -q/28$

$q = -2 \times 28 = -56$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{28} - \frac{1}{56} = \frac{1}{56}$

25. Sally places an object 6.0 cm from a thin convex lens along its axis. The lens has a focal length of 9.0 cm. What are the respective values of the image distance and magnification?

    a. 18 cm and 3.0
    b. –18 cm and 3.0
    c. 3.0 cm and –0.50
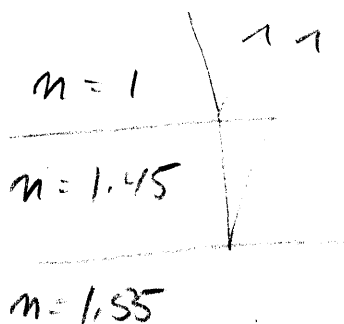   d. –18 cm and –3.0
    e. 18 cm and –0.5

$$p = 6 \quad f = 9$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \implies \frac{1}{6} + \frac{1}{q} = \frac{1}{9}$$

$$\frac{1}{q} = \frac{1}{9} - \frac{1}{6} = -\frac{1}{18} \quad q = -18$$

$$M = -\frac{q}{p} = -\frac{(-18)}{6} = +3$$

26. A silicon monoxide thin film ($n = 1.45$) of thickness 90.0 nm is applied to a camera lens made of glass ($n = 1.55$). This will result in a destructive interference for reflected light of what wavelength?

    a. 720 nm
    b. 558 nm
    c. 635 nm
    d. 450 nm
    e. 522 nm

$n = 1$

$n = 1.45$

$n = 1.55$

2 PHASE SHIFTS

$\implies$ DESTRUCTIVE IS

$$2t = \left(m + \frac{1}{2}\right)\left(\lambda/n\right)$$

$$2 \times 90\,nm = \left(m + \frac{1}{2}\right)\lambda/1.45$$

$$\lambda = \frac{180 \times 1.45}{m + \frac{1}{2}} = \frac{261}{m + \frac{1}{2}}$$

$$m = 0 \implies \lambda = 522\,nm$$

27. A Young's double-slit apparatus is set up. The source wavelength is 430 nm and the double-slit spacing is 0.040 mm. At what distance from the double slits should the screen be placed if the spacing between alternating bright fringes is to be 2.4 cm? (1 nm = 10^{-9} m)

    a. 1.6 m
    b. 2.4 m
    c. 2.2 m
    d. 2.9 m
    e. 1.8 m

$$y_{BRIGHT} = \frac{n\lambda}{d}L \quad ; \quad \text{From } n \text{ TO } n+1, \ \Delta y = 2.4\,cm$$

$$SO \quad 2.4\,cm = \frac{\lambda}{d}L \quad L = \frac{2.4 \times 10^{-2} \times .04 \times 10^{-3}}{430 \times 10^{-9}} \cdot 10^{11}$$

$$L = \frac{2.4 \times 4}{4.3} = 2.2\,m$$

28. A given individual is unable to see objects clearly when they are beyond 100 cm. What focal length lens should be used to correct this problem?

a. −33.3 cm
b. −20 cm
c. 75 cm
d. −100 cm
e. −200 cm

FAR POINT IS 100 cm, WE WANT AN OBJECT AT ∞ TO MAKE A VIRTUAL IMAGE AT 100 cm

SO p = ∞ AND q = −100

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \implies \frac{1}{\infty} + \frac{1}{-100} = \frac{1}{f} \implies f = -100$$

29. To produce a photograph, a camera uses a...

a. converging lens to form a real image ←
b. converging lens to form an imaginary image
c. diverging lens to form a real image
d. diverging lens to form an imaginary image
e. flat lens to keep dust out

OBJECT *FILM*
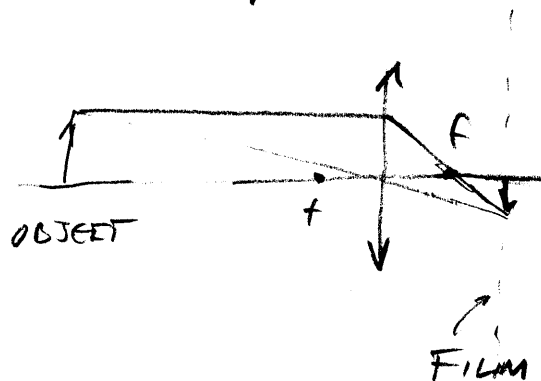
30. A spaceship of mass 10^6 kg is to be accelerated to 0.80 c. How much energy does this require?

a. 2.5×10^{23} J
b. 1.5×10^{23} J
c. 7.2×10^{22} J
d. 9.0×10^{22} J
e. 6.0×10^{22} J

$$E = \gamma m c^2 \qquad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - 0.8^2}} = \frac{1}{0.6}$$

$$E = 1.667 \times m c^2$$

$$KE = E - mc^2 = 0.667 \, mc^2$$

$$0.667 \times 10^6 \times \left(3 \times 10^8\right)^2 = 6 \times 10^{22} \text{ J}$$

31. If astronauts could travel at v = 0.95 c, we on Earth would say it takes (4.2/0.95) = 4.4 years to reach Alpha Centauri, 4.2 lightyears away. The astronauts disagree. How much time passes on the astronaut's clocks?

a. 1.9 years
b. 1.4 years
c. 2.4 years
d. 3.0 years
e. 1.0 years

ASTRONAUTS' TIME IS SHORTER BY $\frac{1}{\gamma}$

(THEIR CLOCKS RUN SLOWER)

$$\gamma = \frac{1}{\sqrt{1 - 0.95^2}} = 3.2$$

$$\frac{4.4}{3.2} = 1.4 \text{ YEARS}$$

32. A sodium vapor lamp has a power output of 300 W. If 590 nm is the average wavelength of the source, about how many photons are emitted per second? ($h = 6.63 \times 10^{-34}$ J·s, $c = 3.00 \times 10^8$ m/s, and 1 nm = 10^{-9} m)

a. 10^{17}
b. 10^{23}
c. 10^{25}
d. 10^{21}
e. 10^{29}

$PHOTON \quad E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{590 \times 10^{-9}} = 3.37 \times 10^{-19} J$

$300. W = 300 J/s \Rightarrow \frac{300}{3.37 \times 10^{-19}} PHOTONS/s$

$= 8.9 \times 10^{20} /s$

33. Light of wavelength 480 nm is incident on a metallic surface with a resultant photoelectric stopping potential of 0.55 V. What is the work function of the metal? ($h = 6.63 \times 10^{-34}$ J·s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, and 1 nm = 10^{-9} m)

a. 3.19 eV
b. 2.59 eV
c. 0.55 eV
d. 2.04 eV
e. 1.03 eV

$KE = 0.55 eV = \frac{hc}{\lambda} - \phi$

$\frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{480 \times 10^{-9} \times 1.6 \times 10^{-19}} eV = 2.58 eV$

$\phi = 2.58 - 0.55 = 2.03 eV$

34. The Lyman series of hydrogen corresponds to electron transitions from higher levels to $n = 1$. What is the longest wavelength in that series?

a. 91.4 nm
b. 100 mn
c. 273 nm
d. 456 nm
e. 122 nm

$LONGEST \lambda \Rightarrow LOWEST E \Rightarrow TRANSITION$
$FROM NEAREST (n=2) LEVEL$

$\Delta E = -13.6 eV \left(\frac{1}{2^2} - \frac{1}{1^2} \right) = \frac{3}{4} \times 13.6 eV = 10.2 eV$

$\frac{hc}{\lambda} = 10.2 eV = 10.2 \times 1.6 \times 10^{-19} J = 1.63 \times 10^{-18} J$

$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.63 \times 10^{-18}} = 122 nm$

35. Sodium has eleven electrons. What is the principle quantum number (n) of the last occupied electron orbital

a. 3
b. 1
c. 5
d. 2
e. 11

$n = 1$ $\ell = 0$ $(1s)$ $m_\ell = 0$ $m_s = \pm\frac{1}{2}$ → 2

$n = 2$ $\ell = 0$ $(2s)$ $m_\ell = 0$ $m_s = \pm\frac{1}{2}$ → 2

$n = 2$ $\ell = 1$ $(2p)$ $m_\ell = 0, \pm 1$ $m_s = \pm\frac{1}{2}$ → 6

—— 10

NEXT ELECTRON MUST BE IN $n = 3$ LEVEL SINCE $n = 1$ AND $n = 2$ LEVELS ARE FULL.

36. If a fossil bone is found to contain 1/8th as much Carbon-14 as the bone of a living animal, what is the approximate age of the fossil? (half-life of ^{14}C = 5 730 years)

a. 7640 years
b. 12450 years
c. 45800 years
d. 22900 years
e. 17200 years

$\frac{1}{8} = \left(\frac{1}{2}\right)^3$ ← 3 HALF LIVES

$3 \times 5730 = 1.72 \times 10^4$ YEARS

37. What is the binding energy per nucleon of ^{197}Au (atomic number = 79)? (The following information regarding atomic masses will be needed: ^{197}Au, 196.966543 u; proton, 1.007825 u; neutron, 1.008665 u; also 1 u = 931.5 MeV/c^2)

a. 7.3 MeV
b. 7.7 MeV
c. 7.9 MeV
d. 8.3 MeV
e. 8.5 MeV

197 NUCLEONS
− 79 PROTONS
——
118 NEUTRONS

$79 \times 1.007825 + 118 \times 1.008665 = 198.640645$

− 196.966543
——
1.674102

$1.6741 \times 931.5 = 1559.4$ MeV

$1559.4 / 197$ NUCLEONS = 7.9 MeV / NUCLEON