Some Facts. The area of Colorado is 104,000 sq.mi. Manhattan has an area of 23 sq. mi and population of 1.6 million people. A nickel is 2.1 cm diameter, 0.16 cm thick, and masses 4.9 g. An aluminum beverage can masses 11 gram; the density of aluminum is 2.7 g/cc.

1. What is the population density, people per sq. mi., of the United States (contiguous 48 states)?
2. Estimate the population of Colorado.
3. If Colorado had the same population density as Manhattan, how many people would be living there?
4. How many sq. mi. of land (above sea level) are on the Earth?
5. What is the average population density, people per sq. mi., of the Earth?
6. If every person in Colorado donated a nickel to a charity, how many dollars would that be?
7. What is the weight, pounds, of nickels donated in problem 6?
8. What is the mass, in grams, of a cubic centimeter of air?
9. How many liters of air would be equivalent in mass to $100 of nickels?
10. What is the mass of water, in grams, equivalent in volume to $100 of nickels?
11. How many nickels, placed side by side, would be needed to surround Colorado?
12. What is the volume, in liters, of the nickels of problem 11?
13. How high a stack, in miles, would be formed if the nickels of problem 11 were place one atop the other?
14. What velocity, mph (miles per hour), is a wind gust equivalent to a tidal wave travelling 20 mph?
15. How many aluminum beverage cans were bought by U.S. customers in 2003?
16. About 60% of the cans are recycled. In 30 years, how many cans were not recycled?
17. What is the weight, in tons, of the unrecycled cans of problem 16?
18. If the cans of problem 16 were placed end-to-end, how many miles into space would they reach?
19. How many jet air liners (Boeing 737s) could be built from the aluminum of problem 16?
20. For every 6-pack of cans not recycled, the energy equal to a can full of gasoline is wasted. How many gallons of gasoline are wasted each year by not recycling the cans?
21. How many gallons of gasoline were consumed by cars in the U.S. in 2003?
22. Assuming that gasoline is heptane, C_7H_{16}, density 0.69 g/cc, how many tons of heptane were used in problem 21?
23. How many tons of CO_2 were produced by the combustion of heptane of problem 21?
24. How many gallons of water are produced by the heptane combustion of problem 21?
25. If some flavoring and CO_2 is added to the water of problem 24, how many cans of soda pop could be filled?
26. What is the ratio of cans (problem 25) to those bought (problem 15)?
27. What is the ratio (gasoline combustion : not recycling cans) of greenhouse gas, CO_2, produced in a year by the two processes?
28. If the water of problem 24 were poured onto Colorado, how deep, cm, would it be?
29. If rain dumped 1 cm over the entire U.S. (lower 48 states), what is the total volume, cc, in that storm?
30. How many tons is the weight of water in problem 29?

FERMI

PLEASE PRINT ALL INFORMATION

School Name _____ **Team Number** _____

Your Names _____ _____

WRITE YOUR ANSWERS * EXPONENTS ONLY *** ON THIS SHEET TO THE RIGHT OF THE APPROPRIATE QUESTION NUMBER.**

1. _____	**11.** _____	**21.** _____
2. _____	**12.** _____	**22.** _____
3. _____	**13.** _____	**23.** _____
4. _____	**14.** _____	**24.** _____
5. _____	**15.** _____	**25.** _____
6. _____	**16.** _____	**26.** _____
7. _____	**17.** _____	**27.** _____
8. _____	**18.** _____	**28.** _____
9. _____	**19.** _____	**29.** _____
10. _____	**20.** _____	**30.** _____

DO NOT WRITE BELOW THIS LINE

Score _____ **Number Correct** _____

Time Handed Answer Sheet In _____ **Elapsed Time** _____

Fermi Questions - Solutions - Problems 1-15

States - 2005 c/o Lloyd Abrams

1. 3×10^8 people $/ 2.5\times10^6\ mi^2 \simeq 1\times10^2\ \frac{people}{mi^2}$ [2]

2. estimate $40/mi^2$ $\quad 1\times10^5\ mi^2 \times 40\ people/mi^2 = 4\times10^6$ people [6]

3. $10^5\ mi^2 \times \frac{1.6\times10^6\ people}{23\ mi^2} = 1.6\times10^{11}/0.2\times10^2\ people = 8\times10^9 \sim 10^{10}$ [10]

4. Area $= \pi D^2 = 3\times(8\times10^3\ mi)^2 = 3\times64\times10^6\ mi^2 \sim 2\times10^8\ mi^2$
   About $\frac{1}{3}$ of the earth's surface is land $\sim 10^8$ [18]

5. 6×10^9 people $/ 0.6\times10^8\ mi^2 = 10^2$ people$/mi^2$ [2]

6. 4×10^6 people $\times\ 5\times10^{-2}\ \$/p = \#20\times10^4 = \$2\times10^5$ [5]

7. 4×10^6 nickels $\times\ 4.9\ g/Ni = 2\times10^7\ g \times 1\ lb/500\ g = 2\times10^7/0.5\times10^3 = 4\times10^4$ [4]

8. $29\ g/mole / 22.4\ L/mole = 1.3\ g/L \times 1L/10^3\ cc = 1.3\times10^{-3}\ g/cc$ [-3]

9. $\$100 \times 20\ Ni/\$ \times 4.9\ g/Ni\ /\ 1.3\ g/L = 5\times2\times10^3/1.3 = 10^4$ [4]

10. $V = \#No. \times \frac{\pi D^2}{4} \times H = {}^5100\times20\ Ni/\$ \times \frac{\pi\,(2.1cm)^2}{4} \times 0.16\ cm$

    $\simeq 2\times10^3 \times 3 \times 4^+ \times 1.6\times10^{-1}/4 = 2\times10^3\times3\times1.6\times10^{-1} = 9\times10^2 \sim 10^3$ [3]

11. Assume a square Colorado; Side $\sim 3.2\times10^2$ mi; perimeter $= 4\times3.2\times10^2\ mi = 12.8\times10^2$ mi.
    $\simeq 13\times10^2\ mi \times 1.6\ km/mi \times 10^5\ cm/km \times 1\ Ni/2\ cm = 20\times10^2\times10^5/2 = 10\times10^7$ [8]

12. $10^8\ Ni \times \frac{\pi D^2}{4} \times H = 10^8 \times \pi\times(2.1cm)^2 \times 0.16cm/4 = 10^8\times5\times10^{-1} = 5\times10^7 \sim 10^8$ [8]

13. $10^8 \times 0.16\ cm \times 1km/10^5\ cm \times 1mi/1.6km = 1.6\times10^7/1.6\times10^5 = 10^2$ [2]

14. $D(MV)_1 = D(MV)_2$ $\quad 1g/cc \times 20\ mph = 1\times10^{-3}\ g/cc \times V;\ V = 2\times10^4\ mph$ [4]

15. Assume 1 can/person/day $\quad$ Cans $= 3\times10^8\times365 = 1\times10^3\times10^8 \sim 10^{11}$ [11]

16. Cans not recycled/yr $= 0.4\times10^{11} = 4\times10^{10}$ cans/yr $\times 30\,yr = 120\times10^{10} = 1.2\times10^{12}$ [12]

17. 1.2×10^{12} cans $\times$ 11g/can $\times$ 1lb/450g $\times$ 1 ton/2×10^{3} lb $= 1.3\times10^{13}/9\times10^{5} \approx 1.5\times10^{7}$ [7]

18. 1.2×10^{12} cans $\times$ 5 in/can $\times$ 1 ft/12 in $\times$ 1 mi/5×10^{3} ft $= 6\times10^{12}/6\times10^{4} = 10^{8}$ [8]
the same distance as the Earth is to the Sun!

19. Assume 1 plane ~ 15 tons of Al $1.5\times10^{7}/15 = 10^{6}$ [6]

20. 4×10^{10} cans/6 $\times$ 12 oz. $\times$ 1gal/128 oz. ~ $4\times2\times10^{10}/1.3\times10^{2} = 6\times10^{8}$ [9]

21. 10^{8} drivers $\times 12\times10^{3}$ mi/yr $\times$ 1gal/12 mi $= 10^{8}\times10^{3} = 10^{11}$ [11]

22. 10^{11} gal $\times$ 4L/gal $\times$ 10^{3} cc/L $\times$ 0.7 g/cc $\times$ 1 lb./450g $\times$ 1 ton/2×10^{3} lb
$= 4\times0.7\times10^{14}/9\times10^{5} \sim 0.3\times10^{9} \sim 3\times10^{8}$ [8]

23. $C_7H_{16} + O_2 \rightarrow 7CO_2 + 8H_2O$
100 7(44) 8(18)
$\frac{3\times10^{8}}{100} = \frac{CO_2}{7\times44}$
$CO_2 \sim 3\times10^{6}\times3\times10^{2} = 9\times10^{8} \sim 10^{9}$ [9]

24. $H_2O = 3\times10^{6}\times8\times18 = 2.4\times10^{7}\times1.8\times10^{1} = 4\times10^{8}$ tons $\times 2\times10^{3}\frac{lb}{ton}\times\frac{1gal}{8lb} = 10^{11}$ [11]

25. 10^{11} gal $\times$ 128 oz./gal $\times$ 1can/12 oz. $= 10^{12}$ cans [12]

26. $10^{12}/10^{11} = 10^{1}$ [1]

27. tons CO_2 = same ratio as gasoline 10^{11} gal $/10^{9}$ gal $= 10^{2}$ [2]

28. 10^{11} gal $\times$ 1 cuft/8gal $/ 10^{5}$ mi^2 $\times (5\times10^{3}\frac{ft}{mi})^2 = 10^{11}/8\times10^{5}\times25\times10^{6}$ ft $= 1/2\times10^{2}$
$1/2\times10^{2}$ ft $\times$ 30 cm/ft $= 1.5\times10^{-1}$ cm [-1]

29. Vol $= 2.5\times10^{6}$ mi^2 $\times (5\times10^{3}$ ft/mi$)^2 \times$ 144 in^2/ft^2 $\times$ 6 cm^2/in^2 $\times$ 1 cm^3 = $25\times10^{6}\times25\times10^{6}\times8\times10^{2}$
$\sim 25\times200\times10^{14} = 5\times10^{2}\times10^{14} \sim 5\times10^{16} \sim 10^{17}$ [17]

30. 5×10^{16} g $\times \frac{1\,lb.}{500\,g} \times \frac{1\,ton}{2000\,lb.} = 5\times10^{16}/10^{6} = 5\times10^{10} \sim 10^{11}$ [11]