



Welcome to the Wonderful World of APES!

This summer assignment is designed to give you a good foundation to start the year in AP Environmental Science. If you are not familiar with the course you should visit the College Board website and view the course description:

<http://apcentral.collegeboard.com/apc/public/courses/descriptions/index.html> . You will be investigating the history of environmental science as well as current trends. This is due the third day of school for the 09-10 school year. If you have any questions during the summer do not hesitate to email me at kazelenakas@smcps.org. Enjoy your summer! Ms. Zelenakas

Please put all work in a binder or folder for grading. This assignment will be worth 200pts!

You may also want to buy a review book for this course. Go to the following website for ordering information:

<http://www.awesomeguides.com/ap%20environmental%20science%20products.htm> , choose the 2nd edition. it is around \$28 with shipping- you can get a discount if you order 2 or more so you can partner up with a classmate if you like.

Part I: Environmental Movement:

Compare and contrast the Conservation Movement and the Environmental Movement. Complete the following table.

Conservation Movement- Late 1800- Early 1900s	Environmental Movement 1960s
Spark:	Spark:
Definition:	Definition:
Keywords:	Keywords:
Key People or Factors-Identify their important contributions	
Thoreau-	Rachel Carson-
Perkins/Marsh:	Clean Water Act

Pinchot:	Clean Air Act
T. Roosevelt:	Endangered Species Act
Olmstead:	Apollo 11
Muir	National Environmental Policy Act-
Dustbowl-	Love Canal-

Part II: Essays & Questions: Read the following essays: Tragedy of the Commons and Worst Mistake in History. Answer the questions at the end of each essay.

The Tragedy of the Commons
Garrett Hardin (1968)

Population, as Malthus said, naturally tends to grow "geometrically," or, as we would now say, exponentially. In a finite world this means that the per-capita share of the world's goods must decrease. Is ours a finite world?

A fair defense can be put forward for the view that the world is infinite or that we do not know that it is not. But, in terms of the practical problems that we must face in the next few generations with the foreseeable technology, it is clear that we will greatly increase human misery if we do not, during the immediate future, assume that the world available to the terrestrial human population is finite. "Space" is no escape. A finite world can support only a finite population; therefore, population growth must eventually equal zero.

Tragedy of Freedom in a Commons

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.

1. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly + 1.
2. The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision making herdsman is only a fraction of - 1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit -- in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

Pollution

In a reverse way, the tragedy of the commons reappears in problems of pollution. Here it is not a question of taking something out of the commons, but of putting something in -- sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free enterprisers.

The air and waters surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, by coercive laws or taxing devices that make it cheaper for the polluter to treat his pollutants than to discharge them untreated. Our particular concept of private property, which deters us from exhausting the positive resources of the earth, favors pollution. The owner of a factory on the bank of a stream -- whose property extends to the middle of the stream -- often has difficulty seeing why it is not his natural right to muddy the waters flowing past his door. The law, always behind the times, requires elaborate stitching and fitting to adapt it to this newly perceived aspect of the commons.

The pollution problem is a consequence of population. It did not much matter how a lonely American frontiersman disposed of his waste. "Flowing water purifies itself every ten miles," my grandfather used to say, and the myth was near enough to the truth when he was a boy, for there were not too many people. But as population became denser, the natural chemical and biological recycling processes became overloaded, calling for a redefinition of property rights.

Freedom to Breed Is Intolerable

The tragedy of the commons is involved in population problems in another way. In a world governed solely by the principle of "dog eat dog" --if indeed there ever was such a world--how many children a family had would not be a matter of public concern. Parents who bred too exuberantly would leave fewer descendants, not more, because they would be unable to care adequately for their children.

If each human family were dependent only on its own resources; if the children of improvident parents starved to death; if thus, over breeding brought its own "punishment" to the germ line -- then there would be no public interest in controlling the breeding of families. But our society is deeply committed to the welfare state, and it is a mistake to think that we can control the breeding of mankind in the long run by an appeal to conscience. People vary. Confronted with appeals to limit breeding, some people will undoubtedly respond to the plea more than others. Those who have more children will produce a larger fraction of the next generation than those with more susceptible consciences. The differences will be accentuated, generation by generation.

Mutual Coercion Mutually Agreed Upon

The social arrangements that produce responsibility are arrangements that create coercion, of some sort. Consider bank robbing. The man who takes money from a bank acts as if the bank were a commons. How do we prevent such action? Certainly not by trying to control his behavior solely by a verbal appeal to his sense of responsibility. The morality of bank robbing is particularly easy to understand because we accept complete prohibition of this activity. We are willing to say "Thou shalt not rob banks," without providing for exceptions. But temperance also can be created by

coercion. Taxing is a good coercive device. To keep downtown shoppers temperate in their use of parking space we introduce parking meters for short periods, and traffic fines for longer ones. We need not actually forbid a citizen to park as long as he wants to; we need merely make it increasingly expensive for him to do so. Not prohibition, but carefully biased options are what we offer him. A Madison Avenue man might call this persuasion; I prefer the greater candor of the word coercion.

The most important aspect of necessity that we must now recognize, is the necessity of abandoning the commons in breeding. No technical solution can rescue us from the misery of overpopulation. Freedom to breed will bring ruin to all. The only way we can preserve and nurture other and more precious freedoms is by relinquishing the freedom to breed, and that very soon. "Freedom is the recognition of necessity" -- and it is the role of education to reveal to all the necessity of abandoning the freedom to breed. Only so, can we put an end to this aspect of the tragedy of the commons.

QUESTIONS- Answer on a separate sheet of paper

1. What analogy did Garrett Hardin use to illustrate the concept of the tragedy of the commons?
2. Why did he use the term commons in the first place?
3. What are several examples of "global commons" in today's world?
4. What do people usually end up doing with something that is seen as a commons? Why?? What is their attitude?
5. What are some examples of a commons in our school?
6. What freedom is bringing the commons to ruin and why?
7. What are several solutions that Garrett Hardin has offered to stop the tragedy of the commons from happening?

Worst Mistake in History

The Worst Mistake in the History of the Human Race By Jared Diamond, UCLA Medical School, Discover Magazine, May 1987, Pages 64-66, Illustrations by Elliott Danfield

To science we owe dramatic changes in our smug self-image. Astronomy taught us that our earth isn't the center of the universe but merely one of billions of heavenly bodies. From biology we learned that we weren't specially created by God but evolved along with millions of other species. Now archaeology is demolishing another sacred belief: that human history over the past million years has been a long tale of progress. In particular, recent discoveries suggest that the adoption of agriculture, supposedly our most decisive step toward a better life, was in many ways a catastrophe from which we have never recovered. With agriculture came the gross social and sexual inequality, the disease and despotism, that curse our existence.

At first, the evidence against this revisionist interpretation will strike twentieth century Americans as irrefutable. We're better off in almost every respect than people of the Middle Ages, who in turn had it easier than cavemen, who in turn were better off than apes. Just count our advantages. We enjoy the most abundant and varied foods, the best tools and material goods, some of the longest and healthiest lives, in history. Most of us are safe from starvation and predators. We get our energy from oil and machines, not from our sweat. What neo-Luddite among us would trade his life for that of a medieval peasant, a caveman, or an ape?



For most of our history we supported ourselves by hunting and gathering: we hunted wild animals and foraged for wild plants. It's a life that philosophers have traditionally regarded as nasty, brutish, and short. Since no food is grown and little is stored, there is (in this view) no respite from the struggle that starts anew each day to find wild foods and avoid starving. Our escape from this misery was facilitated only 10,000 years ago, when in different parts of the world people began to domesticate plants and animals. The agricultural revolution spread until today it's nearly universal and few tribes of hunter-gatherers survive.

From the progressivist perspective on which I was brought up, to ask "Why did almost all our hunter-gatherer ancestors adopt agriculture?" is silly. Of course they adopted it because agriculture is an efficient way to get more food for less work. Planted crops yield far more tons per acre than roots and berries. Just imagine a band of savages, exhausted from searching for nuts or chasing wild animals, suddenly grazing for the first time at a fruit-laden orchard or a pasture full of sheep. How many milliseconds do you think it would take them to appreciate the advantages of agriculture?

The progressivist party line sometimes even goes so far as to credit agriculture with the remarkable flowering of art that has taken place over the past few thousand years. Since crops can be stored, and since it takes less time to pick food from a garden than to find it in the wild, agriculture gave us free time that hunter-gatherers never had. Thus it was agriculture that enabled us to build the Parthenon and compose the B-minor Mass.

While the case for the progressivist view seems overwhelming, it's hard to prove. How do you show that the lives of people 10,000 years ago got better when they abandoned hunting and gathering for farming? Until recently, archaeologists had to resort to indirect tests, whose results (surprisingly) failed to support the progressivist view. Here's one example of an indirect test: Are twentieth century hunter-gatherers really worse off than farmers? Scattered throughout the world, several dozen groups of so-called primitive people, like the Kalahari bushmen, continue to support themselves that way. It turns out that these people have plenty of leisure time, sleep a good deal, and work less hard than their farming neighbors. For instance, the average time devoted each week to obtaining food is only 12 to 19 hours for one group of Bushmen, 14 hours or less for the Hadza nomads of Tanzania. One Bushman, when asked why he hadn't emulated neighboring tribes by adopting agriculture, replied, "Why should we, when there are so many mongongo nuts in the world?"

While farmers concentrate on high-carbohydrate crops like rice and potatoes, the mix of wild plants and animals in the diets of surviving hunter-gatherers provides more protein and a better balance of other nutrients. In one study, the Bushmen's average daily food intake (during a month when food was plentiful) was 2,140 calories and 93 grams of protein, considerably greater than the recommended daily allowance for people of their size. It's almost inconceivable that Bushmen, who eat 75 or so wild plants, could die of starvation the way hundreds of thousands of Irish farmers and their families did during the potato famine of the 1840s.

So the lives of at least the surviving hunter-gatherers aren't nasty and brutish, even though farms have pushed them into some of the world's worst real estate. But modern hunter-gatherer societies that have rubbed shoulders with farming societies for thousands of years don't tell us about conditions before the agricultural revolution. The progressivist view is really making a claim about the distant past: that the lives of primitive people improved when they switched from gathering to farming. Archaeologists can date that switch by distinguishing remains of wild plants and animals from those of domesticated ones in prehistoric garbage dumps.

How can one deduce the health of the prehistoric garbage makers, and thereby directly test the progressivist view? That question has become answerable only in recent years, in part through the newly emerging techniques of paleopathology, the study of signs of disease in the remains of ancient peoples.

In some lucky situations, the paleopathologist has almost as much material to study as a pathologist today. For example, archaeologists in the Chilean deserts found well preserved mummies whose medical conditions at time of death could be determined by autopsy (Discover, October). And feces of long-dead Indians who lived in dry caves in Nevada remain sufficiently well preserved to be examined for hookworm and other parasites.

Usually the only human remains available for study are skeletons, but they permit a surprising number of deductions. To begin with, a skeleton reveals its owner's sex, weight, and approximate age. In the few cases where

there are many skeletons, one can construct mortality tables like the ones life insurance companies use to calculate expected life span and risk of death at any given age. Paleopathologists can also calculate growth rates by measuring bones of people of different ages, examine teeth for enamel defects (signs of childhood malnutrition), and recognize scars left on bones by anemia, tuberculosis, leprosy, and other diseases.

One straight forward example of what paleopathologists have learned from skeletons concerns historical changes in height. Skeletons from Greece and Turkey show that the average height of hunter-gatherers toward the end of the ice ages was a generous 5' 9" for men, 5' 5" for women. With the adoption of agriculture, height crashed, and by 3000 B. C. had reached a low of only 5' 3" for men, 5' for women. By classical times heights were very slowly on the rise again, but modern Greeks and Turks have still not regained the average height of their distant ancestors.

Another example of paleopathology at work is the study of Indian skeletons from burial mounds in the Illinois and Ohio river valleys. At Dickson Mounds, located near the confluence of the Spoon and Illinois rivers, archaeologists have excavated some 800 skeletons that paint a picture of the health changes that occurred when a hunter-gatherer culture gave way to intensive maize farming around A. D. 1150. Studies by George Armelagos and his colleagues then at the University of Massachusetts show these early farmers paid a price for their new-found livelihood. Compared to the hunter-gatherers who preceded them, the farmers had a nearly 50 per cent increase in enamel defects indicative of malnutrition, a fourfold increase in iron-deficiency anemia (evidenced by a bone condition called porotic hyperostosis), a threefold rise in bone lesions reflecting infectious disease in general, and an increase in degenerative conditions of the spine, probably reflecting a lot of hard physical labor. "Life expectancy at birth in the pre-agricultural community was about twenty-six years," says Armelagos, "but in the post-agricultural community it was nineteen years. So these episodes of nutritional stress and infectious disease were seriously affecting their ability to survive."

The evidence suggests that the Indians at Dickson Mounds, like many other primitive peoples, took up farming not by choice but from necessity in order to feed their constantly growing numbers. "I don't think most hunter-gatherers farmed until they had to, and when they switched to farming they traded quality for quantity," says Mark Cohen of the State University of New York at Plattsburgh, co-editor with Armelagos, of one of the seminal books in the field, *Paleopathology at the Origins of Agriculture*. "When I first started making that argument ten years ago, not many people agreed with me. Now it's become a respectable, albeit controversial, side of the debate."

There are at least three sets of reasons to explain the findings that agriculture was bad for health. First, hunter-gatherers enjoyed a varied diet, while early farmers obtained most of their food from one or a few starchy crops. The farmers gained cheap calories at the cost of poor nutrition. (today just three high-carbohydrate plants—wheat, rice, and corn—provide the bulk of the calories consumed by the human species, yet each one is deficient in certain vitamins or amino acids essential to life.) Second, because of dependence on a limited number of crops, farmers ran the risk of starvation if one crop failed. Finally, the mere fact that agriculture encouraged people to clump together in crowded societies, many of which then carried on trade with other crowded societies, led to the spread of parasites and infectious disease. (Some archaeologists think it was the crowding, rather than agriculture, that promoted disease, but this is a chicken-and-egg argument, because crowding encourages agriculture and vice versa.) Epidemics couldn't take hold when populations were scattered in small bands that constantly shifted camp. Tuberculosis and diarrheal disease had to await the rise of farming, measles and bubonic plague the appearance of large cities.



Besides malnutrition, starvation, and epidemic diseases, farming helped bring another curse upon humanity: deep class divisions. Hunter-gatherers have little or no stored food, and no concentrated food sources, like an orchard or a herd of cows: they live off the wild plants and animals they obtain each day. Therefore, there can be no kings, no class of social parasites who grow fat on food seized from others. Only in a farming population could a healthy, non-producing elite set itself above the disease-ridden masses. Skeletons from Greek tombs at Mycenae c. 1500 B. C. suggest that royals enjoyed a better diet than commoners, since the royal skeletons were two or three inches taller and had better teeth (on the average, one instead of six cavities or missing teeth). Among Chilean mummies from c. A. D. 1000, the elite were distinguished not only by ornaments and gold hair clips but also by a fourfold lower rate of bone lesions caused by disease.

Similar contrasts in nutrition and health persist on a global scale today. To people in rich countries like the U. S., it sounds ridiculous to extol the virtues of hunting and gathering. But Americans are an élite, dependent on oil and minerals that must often be imported from countries with poorer health and nutrition. If one could choose between being a peasant farmer in Ethiopia or a bushman gatherer in the Kalahari, which do you think would be the better choice?

Farming may have encouraged inequality between the sexes, as well. Freed from the need to transport their babies during a nomadic existence, and under pressure to produce more hands to till the fields, farming women tended to have more frequent pregnancies than their hunter-gatherer counterparts—with consequent drains on their health.



Among the Chilean mummies for example, more women than men had bone lesions from infectious disease.

Women in agricultural societies were sometimes made beasts of burden. In New Guinea farming communities today I often see women staggering under loads of vegetables and firewood while the men walk empty-handed. Once while on a field trip there studying birds, I offered to pay some villagers to carry supplies from an airstrip to my mountain camp. The heaviest item was a 110-pound bag of rice, which I lashed to a pole and assigned to a team of four men to shoulder together. When I eventually caught up with the villagers, the men were carrying light loads, while one small woman weighing less than the bag of rice was bent under it, supporting its weight by a cord across her temples.

As for the claim that agriculture encouraged the flowering of art by providing us with leisure time, modern hunter-gatherers have at least as much free time as do farmers. The whole emphasis on leisure time as a critical factor seems to me misguided. Gorillas have had ample free time to build their own Parthenon, had they wanted to. While post-agricultural technological advances did make new art forms possible and preservation of art easier, great paintings and sculptures were already being produced by hunter-gatherers 15,000 years ago, and were still being produced as recently as the last century by such hunter-gatherers as some Eskimos and the Indians of the Pacific Northwest.

Thus with the advent of agriculture and élite became better off, but most people became worse off. Instead of swallowing the progressivist party line that we chose agriculture because it was good for us, we must ask how we got trapped by it despite its pitfalls.

One answer boils down to the adage "Might makes right." Farming could support many more people than hunting, albeit with a poorer quality of life. (Population densities of hunter-gatherers are rarely over one person per ten square miles, while farmers average 100 times that.) Partly, this is because a field planted entirely in edible crops lets one feed far more mouths than a forest with scattered edible plants. Partly, too, it's because nomadic hunter-gatherers have to keep their children spaced at four-year intervals by infanticide and other means, since a mother must carry her toddler until it's old enough to keep up with the adults. Because farm women don't have that burden, they can and often do bear a child every two years.

As population densities of hunter-gatherers slowly rose at the end of the ice ages, bands had to choose between feeding more mouths by taking the first steps toward agriculture, or else finding ways to limit growth. Some bands chose the former solution, unable to anticipate the evils of farming, and seduced by the transient abundance they enjoyed until population growth caught up with increased food production. Such bands outbred and then drove off or killed the bands that chose to remain hunter-gatherers, because a hundred malnourished farmers can still outfight one healthy hunter. It's not that hunter-gatherers abandoned their life style, but that those sensible enough not to abandon it were forced out of all areas except the ones farmers didn't want.

At this point it's instructive to recall the common complaint that archaeology is a luxury, concerned with the remote past, and offering no lessons for the present. Archaeologists studying the rise of farming have reconstructed a crucial stage at which we made the worst mistake in human history. Forced to choose between limiting population or trying to increase food production, we chose the latter and ended up with starvation, warfare, and tyranny.

Hunter-gatherers practiced the most successful and longest-lasting life style in human history. In contrast, we're still struggling with the mess into which agriculture has tumbled us, and it's unclear whether we can solve it. Suppose that an archaeologist who had visited from outer space were trying to explain human history to his fellow spacelings. He might illustrate the results of his digs by a 24-hour clock on which one hour represents 100,000 years of real past time. If the history of the human race began at midnight, then we would now be almost at the end of our first day. We lived as hunter-gatherers for nearly the whole of that day, from midnight through dawn, noon, and sunset. Finally, at 11:54 p. m. we adopted agriculture. As our second midnight approaches, will the plight of famine-

stricken peasants gradually spread to engulf us all? Or will we somehow achieve those seductive blessings that we imagine behind agriculture's glittering façade, and that have so far eluded us?

Write a 2 paragraph essay in response to this paper.- Answer on a separate sheet of paper!

Part III: Conversion Practice- Complete the sheet below. Show all work & circle or highlight all answers!

Procedure

You and your friends are taking a trip. Answer the following problems about your journey. Check the table below for conversion factors. Use scrap paper if necessary.

Conversion Factors	
1 inch (in)	= 2.54 centimeters (cm)
1 mile (mi)	= 1.6 kilometers (km)
1 liter (l)	= .264 gallons (g)
1 fluid ounce (oz)	= 29.57 milliliters (ml)
1 pound (lb)	= .45 kilograms (kg)
1 gallon (g)	= 3.79 liters (l)
1 short ton (2,000 lbs)	= 907.2 kilograms (kg)
1 meter (m)	= 3.28 feet (ft)
1 mile (mi)	= 5,280 feet (ft)

1. Your car uses the metric system, but the gasoline pump you are at uses U.S. measurements. If your car's gas tank holds 57,700 milliliters, how many gallons of fuel will you need to pump?

2. The speed limit is 343,200 feet per hour. How fast can you drive in kilometers per hour?

8. Your car weighs 3,000lbs. or 1.5 short tons. How many grams does your car weigh?
9. You pull into a parking garage and see a sign that says the height limit is 3 meters. Your car is 6 ft 3 in tall. How close, in centimeters, is the ceiling to your car?
10. You find a parking space that is 300 centimeters wide. Your car is 8 feet wide. Is the parking space wide enough for your car? If so, how much room (in centimeters) will you have on each side of your car?

SCIENTIFIC NOTATION: SEE BELOW FOR REVIEW OF CONCEPTS!

Section A: The Definition of the Notation (Decimal => Scientific)

Write the following numbers in scientific notation

- | | |
|------------------|---------------|
| 1. 1001 | 6. 0.13592 |
| 2. 53 | 7. -0.0038 |
| 3. 6,926,300,000 | 8. 0.00000013 |
| 4. -392 | 9. -0.567 |
| 5. 0.00361 | |

Section B: Converting Back (Scientific => Decimal)

- | | |
|------------------------|---------------------------|
| 1. 1.92×10^3 | 6. 1.03×10^{-2} |
| 2. 3.051×10^1 | 7. 8.862×10^{-1} |
| 3. -4.29×10^2 | 8. 9.512×10^{-8} |
| 4. 6.251×10^9 | 9. -6.5×10^{-3} |
| 5. 8.317×10^6 | 10. 3.159×10^2 |

Section C: Multiplication, Division and ... with Scientific Notation

Use Scientific Notation (and only the scientific notation!) to find the answer to the following multiplications, divisions, additions.

- $4.1357 \times 10^{-15} \cdot 5.4 \times 10^2 = ?$
- $1.695 \times 10^4 \div 1.395 \times 10^{15} = ?$
- $4.367 \times 10^5 \cdot 1.96 \times 10^{11} = ?$
- $6.97 \times 10^3 \cdot 2.34 \times 10^{-6} + 3.2 \times 10^{-2} = ?$
- $5.16 \times 10^{-4} \div 8.65 \times 10^{-8} + 9.68 \times 10^4 = ?$

Section D: Significant Figures

For the following, write each with the correct number of significant figures.

- $2.38617954 \times 10^{-1} \cdot 1.15197705 \times 10^6$
- $3.0001 \cdot 5$
- $1.12 \times 10^5 \cdot 6.06 \times 10^5$
- $2.27513 \times 10^3 \cdot 1.9376 \times 10^2$
- $2 \times 10^1 \cdot 3.0 \times 10^1$
- $5.567 \times 10^8 / 2.215 \times 10^8$
- $2.775 \times 10^{-4} \cdot 4.775 \times 10^4$
- $5 / 8.14 \times 10^2$
- $4.7192 \times 10^2 / 3.862 \times 10^{-4}$

Scientific Notation: What is it?

Astronomers deal with quantities ranging from the truly microcosmic to the macrocosmic. It is very inconvenient to always have to write out the age of the universe as 15,000,000,000 years or the distance to the Sun as 149,600,000,000 meters. To save effort, powers-of-ten notation is used. For example, $10 = 10^1$; the exponent tells you how many times to multiply by 10. As another example, $10^{-2} = 1/100$; in this case the exponent is negative, so it tells you how many times to divide by 10. The only trick is to remember that $10^0 = 1$. Using powers-of-ten notation, the age of the universe is 1.5×10^{10} years and the distance to the Sun is 1.496×10^{11} meters.

The general form of a number in scientific notation is $a \times 10^n$, where a must be between 1 and 10, and n must be an integer. (Thus, for example, these are not in scientific notation: 34×10^5 ; $4.8 \times 10^{0.5}$).

If the number is between 1 and 10, so that it would be multiplied by $10^0 (=1)$, then it is not necessary to write the power of 10. For example, the number 4.56 already is in scientific notation (it is not necessary to write it as 4.56×10^0 , but you may write it this way if you wish).

If the number is a power of 10, then it is not necessary to write that it is multiplied by 1. For example, the number 100 can be written in scientific notation either as 10^2 or as 1×10^2 . (Note, however, that the latter form should be used when entering numbers on a calculator.)

The use of scientific notation has several advantages, even for use outside of the sciences:

Scientific notation makes the expression of very large or very small numbers much simpler. For example, it is easier to express the U.S. federal debt as $\$3 \times 10^{12}$ rather than as \$3,000,000,000,000.

Because it is so easy to multiply powers of ten in your head (by adding the exponents), scientific notation makes it easy to do "in your head" estimates of answers.

Use of scientific notation makes it easier to keep track of significant figures; that is, does your answer really need all of those digits that pop up on your calculator?

Converting from "Normal" to Scientific Notation

Place the decimal point after the first non-zero digit, and count the number of places the decimal point has moved. If the decimal place has moved to the *left* then multiply by a positive power of 10; to the right will result in a negative power of 10.

Example: To write 3040 in scientific notation we must move the decimal point 3 places to the left, so it becomes 3.04×10^3 .

Example: To write 0.00012 in scientific notation we must move the decimal point 4 places to the right: 1.2×10^{-4} .

Converting from Scientific Notation to "Normal"

If the power of 10 is positive, then move the decimal point to the right; if it is negative, then move it to the left.

Example: Convert 4.01×10^2 . We move the decimal point two places to the right making 401.

Example: Convert 5.7×10^{-3} . We move the decimal point three places to the left making 0.0057.

Working with Scientific Notation: Addition, Multiplication, ...

Addition and Subtraction

When adding or subtracting numbers in scientific notation, their powers of 10 must be equal. If the powers are *not* equal, then you must first convert the numbers so that they all have the same power of 10.

Example: $(6.7 \times 10^9) + (4.2 \times 10^9) = (6.7 + 4.2) \times 10^9 = 10.9 \times 10^9 = 1.09 \times 10^{10}$. (Note that the last step is necessary in order to put the answer in scientific notation.)

Example: $(4 \times 10^8) - (3 \times 10^6) = (4 \times 10^8) - (0.03 \times 10^8) = (4 - 0.03) \times 10^8 = 3.97 \times 10^8$.

Multiplication and Division

It is very easy to multiply or divide just by rearranging so that the powers of 10 are multiplied together.

Example: $(6 \times 10^2) \times (4 \times 10^{-5}) = (6 \times 4) \times (10^2 \times 10^{-5}) = 24 \times 10^{2-5} = 24 \times 10^{-3} = 2.4 \times 10^2$. (Note that the last step is necessary in order to put the answer in scientific notation.)

Approximations with Scientific Notation

Because working with powers of 10 is so simple, use of scientific notation makes it easy to estimate approximate answers. This is especially important when using a calculator since, by doing mental calculations, you can verify whether your answers are reasonable. To make approximations, simply round the numbers in scientific notation to the nearest integer, then do the operations in your head.

Example: Estimate $5,795 \times 326$. In scientific notation the problem becomes $(5.795 \times 10^3) \times (3.26 \times 10^2)$. Rounding each to the nearest integer makes the approximation $(6 \times 10^3) \times (3 \times 10^2)$, which is 18×10^5 , or 1.8×10^6 (the exact answer is 1.88917×10^6).

Example: Estimate $(5 \times 10^{15}) + (2.1 \times 10^9)$. Rounding to the nearest integer this becomes $(5 \times 10^{15}) + (2 \times 10^9)$. We see immediately that the second number is nearly $10^{15}/10^9$, or one million, times smaller than the first. Thus, it can be ignored in the addition problem and our approximate answer is 5×10^{15} . (The exact answer is 5.0000021×10^{15}).

Significant Figures

Numbers should be given only to the accuracy that they are known with certainty, or to the extent that they are important to the topic at hand. For example, your doctor may say that you weigh 130 pounds, when in fact at that instant you might weigh 130.16479 pounds. The discrepancy is unimportant and will change anyway as soon as a blood sample has been drawn.

If numbers are given to the greatest accuracy that they are known, then the result of a multiplication or division with those numbers can't be determined any better than to the number of digits in the *least* accurate number.

Example: Find the circumference of a circle measured to have a radius of 5.23 cm using the formula:

$C = (2 \times \pi \times R)$. Since the value of π stored in your calculator is probably 3.141592654, the numerical solution will be

$$(2 \times 3.141592654 \times 5.23 \text{ cm}) = 32.86105916 = 3.286105916 \times 10^1 \text{ cm.}$$

If you simply write down all 10 digits as your answer, you are implying that you know, with absolute certainty, the circle's circumference to an accuracy of one part in 10 billion! That would mean that your measurement of the radius was in error by no more than 0.000000001 cm; that is, its true value was at least 5.229999999 cm, but no more than 5.230000001 cm (otherwise, your calculator would have shown a different number for the circumference).

In reality, since your measurement of the radius was known to only three decimal places, the circle's circumference is also known to only (at best) three decimal places as well: you round the fourth digit and give the result as 32.9 cm or 3.29×10^1 cm. It may not look as impressive, but it's an honest representation of what you know about the figure.

Since the value of "2" was used in the formula, you may wonder why we're allowed to give the answer to *three* decimal places rather than just one: 3×10^1 cm. The reason is because the number "2" is *exact* - it expresses the fact that a diameter is *exactly* twice the radius of a circle - no uncertainty about it at all. Without any exaggeration, we could have represented the number as 2.000000000000000000, but merely used the shorthand "2" for simplicity - so we really didn't violate the rule of using the least accurately-known number



Summer Assignment Grading Sheet for _____ Pd _____
 Please Place this sheet in the front of your binder

Part	Pts Worth	Pts Earned/Comments
I- Enviro Movement	40	
II-Essays	50	
III- Math Practice	50	
IV- Current Events	60	
Total	200	
Bonus Points- For typing your work on Parts I, II and IV. Math part should be handwritten! 😊	20	