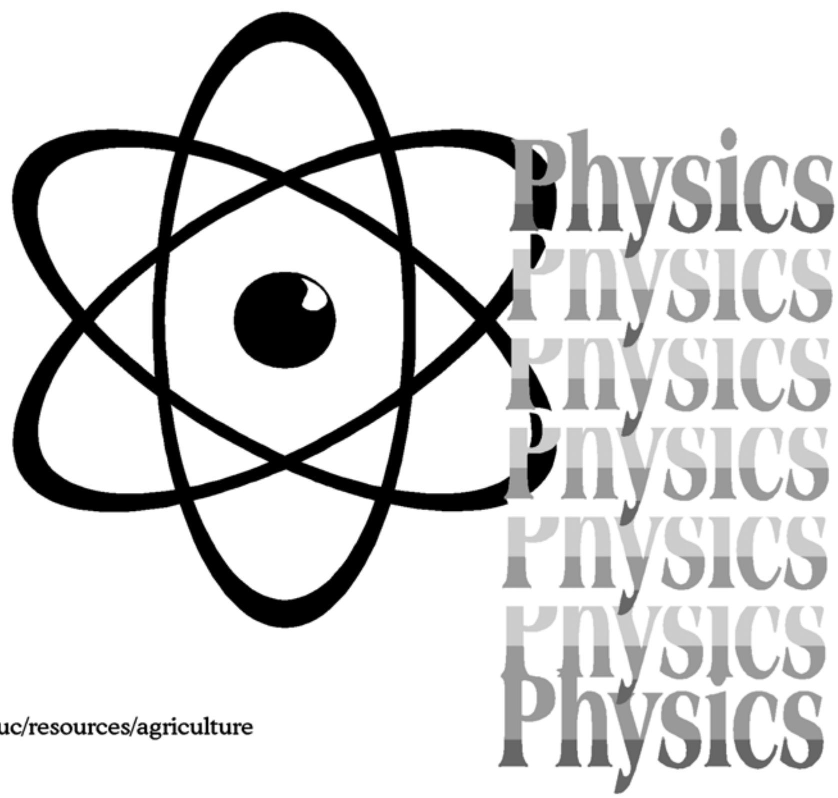
Agri-science Resources for High School Physics



Www.gov.pe.ca/educ/resources/agriculture

Acknowledgments

The first edition of *Agri-science Resources for High School Physics* was designed as a an agriculture learning resource for teachers and students. Through a funding partnership between the agricultural industry, federal and provincial governments, this handbook will be made available to teachers and students in high schools across Prince Edward Island.

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- 4-H Council Office
- Media Technology Centre, Dept. Of Education

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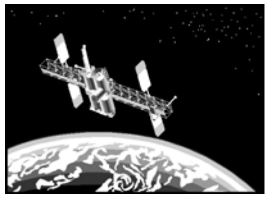


Physics

Individual reading

DESCRIPTION

Information Article describing satellites and the GPS satellite system.

LEARNING OUTCOMES

Students will:

- learn how satellite technology is becoming a very important component of agriculture field work.

READINESS ACTIVITIES

Students should:

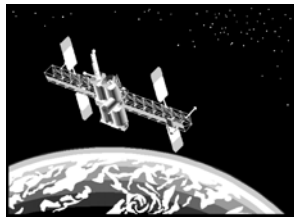
- have a general understanding of satellites
- review the orbit patterns of other celestial objects such as the earth around the sun or the moon around the earth.

MATERIALS

- copy of article
- calculator

Satellite

Technology



Agri-science Resources
for High School Sciences

Satellites

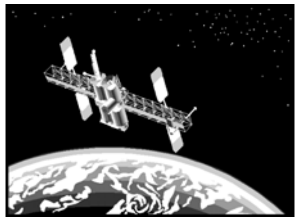
There are many different types of **satellites** orbiting the earth over our heads. Some are used for television, others for telecommunications, and some satellites are top secret and few people know what they are used for. Satellites are brought into space by space shuttles. They are accelerated to the speeds needed to achieve **orbit** by large rockets. Once in space, the satellite is subjected to two main forces:

- **centripetal force** due to the Earth's gravitational pull
- **centrifugal force**, tending to drive the satellite away from the Earth, which varies according to induced velocity and orbit.

If the gravitational pull of the Earth is greater than the centrifugal force, the spacecraft drops back. This will happen when the orbit velocity from the rocket is insufficient. If centripetal and centrifugal forces are equal, the object will orbit the Earth. If the induced velocity is too much, the gravitational pull of the Earth would be overcome, and the object goes into solar orbit. At an even higher velocity, the object can escape from the gravitational field of the sun, and will then become lost in outer space. Therefore, calculations for satellite orbits must be very precise. It would be very bad to have such an expensive piece of equipment get lost in outer space. The period of a satellite is how long it takes to complete one circuit around the earth. The period of the earth's orbit around the sun takes roughly one year.

Satellite

Technology



Agri-science Resources
for High School Sciences

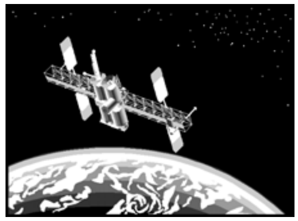
Physics

GPS

In the past, humans have used a variety of methods to determine their exact location. Early travelers used landmarks as guides. Sailors were forced to use the stars to guide them at sea. Recently, electronic gadgets have replaced the old fashioned methods. This technology has continuously become more advanced and more accurate.

To simplify accurate navigation, the United States Department of Defense came up with something called the Global Positioning System or GPS. This is a radio based navigation system that gives three dimensional coverage of the Earth 24 hours a day. The system is very accurate. In some cases, surveyors can use GPS to get measurements down to a centimeter. Since it was initially designed as a defense system, it encounters few problems with jamming and interference. The government has spent over $12 billion dollars to build the system. It appears to be worth it because the system works very well.

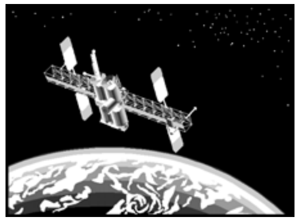
The technology is not brand new. But thanks to today's integrated circuit technology, GPS receivers are becoming small enough and cheap enough to be carried by just about anyone. The GPS system has enormous potential. Some possible applications include delivery vehicles being able to pinpoint locations, emergency vehicles being more prompt, and cars with electronic maps that will show the quickest way to any destination. This will result in less congested highways, saving millions of dollars in gasoline and tons of air pollution. The system can locate things in three dimensions, so it can work for aircraft as well. Travel aboard ships and aircraft will be safer in all weather conditions. This system could also allow nations to monitor and use natural resources more efficiently than ever before.



Parts of a GPS

There are three segments to this system: the user segment, the space segment, and the control segment. The user segment is the user, which can be any person, and a GPS receiver. A GPS receiver is designed to listen to the radio signals being transmitted from the satellites and calculate a position based on that information. The space segment is composed of the GPS satellites that are transmitting time and position to the user. There are 24 satellites in the NAVSTAR GPS system of the U.S. Department of Defense. Each one orbits approximately 20,200 km above the Earth. These satellites constantly direct coded signals on two different carrier frequencies (L1 - 1575.42 MHz and L2 - 1227.60 MHz) toward the Earth. The signals are broadcast at a **frequency** and strength that allow them to easily penetrate fog, rain, snow, dust, and inclement weather. The satellite orbit is arranged in six orbital planes so that at any given time, from any vantage point on the earth, a minimum of five satellites are visible in the sky to any user, anywhere in the world. The control segment is composed of all the ground-based facilities that are used to monitor and control the satellites. The control center calculates each satellite's orbit a week or so into the future, predicts ionospheric conditions over that time, and then uploads this information into the satellite's computer. This is done to avoid any slight errors which may occur.

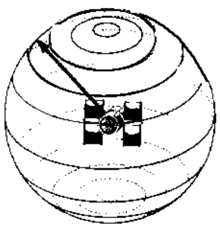
Satellite Technology



Agri-science Resources for High School Sciences

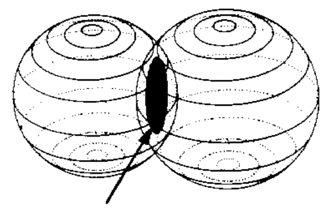
Physics

How does it Work?



Person must be somewhere on sphere that is 18,000 km from satellite A.

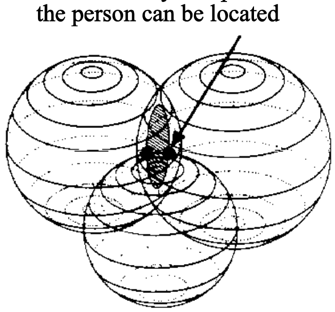
The basic principles behind GPS are quite simple. GPS is based on satellite ranging. This means that we figure out exactly where a satellite is in space and exactly how far we are from it. Let's say a person is lost and trying to locate themselves. The person discovers they are a certain distance from satellite A, say 18,000 kilometers. This tells the person that he must be somewhere in the universe on an imaginary sphere that has a radius of 18,000 km with the satellite in the exact middle.



Person must be somewhere in the circle where the two spheres overlap

If the person also knows he is 19,000 km from another satellite, satellite B, that narrows down where the person is even more. Now the only place in the universe where the person can be 18,000 km from satellite A and 19,000 km from satellite B is on the circle where those two spheres intersect.

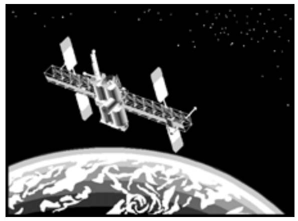
Now there are only two points where the person can be located



If at the same time the person is 20,000 km from a satellite C, there are only two points in space where that can be true. Those two points are where the 20,000 km sphere cuts through the circle that's the intersection of the 18,000 km sphere and the 19,000 km sphere. Usually a fourth measurement is made from another satellite. However, most times three measurement are sufficient. This is because one of the two points is usually a ridiculous answer. The incorrect point may be in deep space or behind the satellites. The computers in GPS receivers have various techniques for distinguishing the correct point from the incorrect one. That is the basic principle behind GPS. Satellites are used as reference points to triangulate a position somewhere on earth. The rest of the system is used to make the process more accurate and easier to do.

Satellite

Technology



Agri-science Resources
for High School Sciences

Physics

Calculation

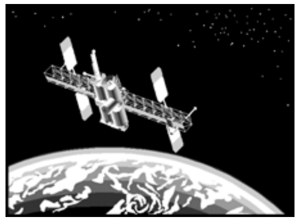
The basic idea behind measuring a distance to a satellite uses the velocity versus time equation. The GPS system works by timing how long it takes a radio signal to reach a receiver from a satellite and then calculates the distance using that time. Radio waves, which are a form of **electromagnetic radiation**, travel at the speed of light: 297,600 km per second. Multiplying the time in seconds that it took for the radio message to arrive from the satellite by 297,600 km/s will give the range to the satellite. Very precise clocks are needed because light moves awfully fast. For example, if a GPS satellite were overhead, it would only take about 6/100ths of a second for the radio message to get to us.

Exercise

You are trying to determine your location on earth without using the proper GPS equipment. All that is available to you is the time it takes for a radio message to arrive from four different satellites. It takes 0.0735 seconds for the message to arrive from satellite A, 0.0698 seconds from satellite B, 0.0709 seconds from satellite C, and 0.0636 seconds from satellite D. Based on the above information, what is the distance to each satellite from your current position?

Code

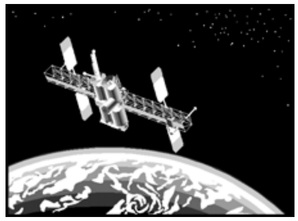
The trick is to figure out exactly when the signal left the satellite. Remember, we are dealing with fractions of a second, so precision is very important. To do this, the satellites and receivers are synchronized to generate exactly the same code at exactly the same time. When the code is received from the satellite, the time difference is determined by looking back and seeing how long ago the receiver generated the same code. Both the satellites and receivers generate a very complicated set of digital codes. They are carefully chosen “pseudo-random” sequences that actually repeat every millisecond.



Potential Problems

One potential problem is assuring that the receiver and the satellites are generating the codes at exactly the same time. This is not a problem for the satellites because they all contain four atomic clocks. These are very precise and expensive clocks. Each one costs one hundred thousand dollars. Remember there are four clocks in each satellite, and a total of 24 satellites, so this is obviously a very expensive system. However, they are used because atomic clocks are the most stable and accurate time reference ever developed. Obviously receivers could not contain atomic clocks because few people could afford to buy them. Fortunately, receivers can contain only moderately accurate clocks. This is where the fourth satellite measurement comes into play. Trigonometry rules say that if three perfect measurements locate a point in 3-dimensional space, then four imperfect measurements can eliminate any timing offset. Remember that for a person to discover his position, all four circles from the satellites must intersect at that point. If the clock in a receiver were slightly offset, there would be no physical way that those measurements could intersect. The computers in GPS receivers are programmed so that when they get a series of measurements that do not intersect at a single point, they realize that something is wrong. They assume the cause is that their internal clock has some offset. Therefore, the computer starts subtracting or adding time until all the ranges go through one point. By adding the fourth measurement any consistent clock errors in the receivers are canceled out.

Although the GPS system contains many devices to avoid errors, there are some potential problems which are unavoidable. The earth's **ionosphere** contains charged particles which affects the speed of light and so affects the speed of GPS radio signals. Water vapor in the atmosphere can also affect the signals. Slight inaccuracies can also occur with the clocks of satellites and receivers. Fortunately all of these inaccuracies still don't add up to much of an error.



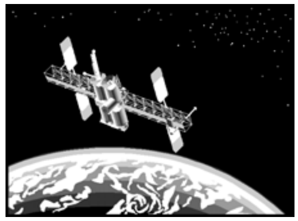
Differential GPS

The incredible accuracy of the GPS system can be boosted using a technique called differential GPS. With it, GPS can achieve measurement accuracies of better than a meter. This process is based on the principle that most of the errors seen by GPS receivers in a local area will be common errors. These common errors can be caused by receiver or satellite clocks, satellite position, or ionospheric and atmospheric delays. Differential GPS (DGPS) is the regular Global Positioning System with an additional corrective signal added. This method is so accurate because if a GPS receiver is placed at a location for which the coordinates are known and accepted, the difference between the known coordinates and the GPS-calculated coordinates is the error. The error which the receiver has determined can be applied to other GPS receivers in the area. This allows many of these errors to be reduced or even eliminated.

The Canadian Coast Guard runs a marine DGPS service in Canadian waters. This service is used for commercial navigation, Coast Guard Fleet operations and other government operations. The system is made up of a network of reference/broadcast stations. These radiobeacons are strategically located on shores across Canada to enable effective use of DGPS. These differential beacons are accurate and reliable and are free to users in locations covered by the signal. Prince Edward Island is in an ideal location to take advantage of this service. The Island is surrounded by water. Therefore, there are a few Canadian Coast Guard radiobeacons in this area.

Satellite

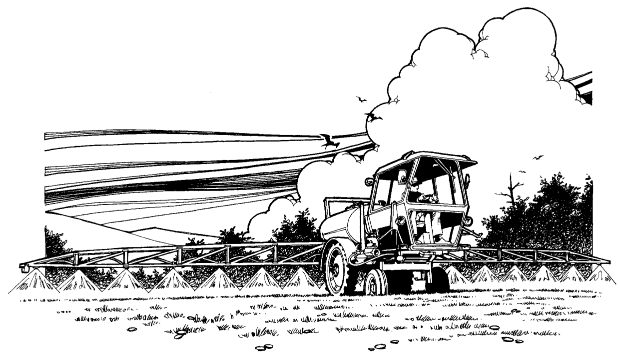
Technology



Agri-science Resources
for High School Sciences

Physics

Precision Farming



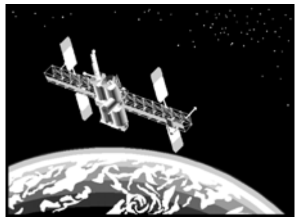
The agriculture industry has taken advantage of GPS technology for several applications. It is used in a division of agriculture called **precision farming**.

Fields which are used to grow crops have sections with differences in soil type, fertility, weed and disease incidence. Despite these differences, the entire field receives the same amount of fertilizers, seeds, water and pesticides. This often results in lower crop yields and wasted chemicals. Precision farming takes any differences that sections of a field may have into consideration. This way fertilizer, seeds, water and agrichemicals are applied precisely at varying rates according to the needs of that area. Each section of the field receives the correct amount of substance that is necessary to provide optimum yield and quality.

Applications

There are several applications that are currently being used in precision farming. Some of these include:

- **<u>Yield mapping</u>**: combines and other harvesting equipment have weighing devices that are coupled to a GPS which measures yield. A yield map can be produced from this data which shows the yield variation throughout the field. This allows farmers to inspect the precise location of the highest and lowest yielding areas of the field and determine what caused the yield difference.
- **<u>Soil map</u>**: soil samples and laboratory results can be used to determine the soil type, organic matter content, fertility and pH of different areas of the field.
- **<u>Variable rate application</u>** of nutrients, animals wastes, pesticides and water. Farmers can preprogram the rate of pesticide or fertilizer to be applied so that only the amount needed is applied from one area of the field to another. This saves money and allows for safer use of these materials.



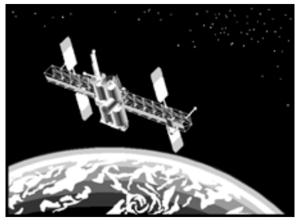
- **<u>Tillage adjustments</u>**: the ability to vary the depth of tillage along with soil conditions. This allows for proper seedbed preparation, control of weeds and lower fuel consumption which all saves costs for the farmer. The use of GPS in making equipment adjustments as one goes across the different soil types would lead to higher yields and safer production.
- **<u>Seeding</u>**: seeds grow best when placed at spacing that allow the plant to obtain maximum sunlight and moisture. Varying the seeding rate according to soil conditions will provide the maximum yield. A computerized soil map of a specific field on a computer fitted on a tractor along with a GPS can tell farmers where they are in the field. This would allow them to adjust the seeding rate as they go across the field.
- **<u>Crop Scouting and Remote Sensing</u>**: any problems in the crop due to disease can be recorded. Physical positions such as field boundaries or rocks can be recorded and mapped.

GPS on Prince Edward Island

The Global Positioning System is being used by the agriculture industry on Prince Edward Island. Both the Prince Edward Island Department of Agriculture and Forestry and Agriculture and Agri-food Canada are working projects involving DGPS technology. The goal of one project is to study the spatial variability of potato yields as impacted by soil erosion. Another project is testing the potato yield mapping system. Although most DGPS equipment has only appeared on the Island within the last few years, its use is growing continuously. It appears as if precision farming will grow in popularity as the technology continues to advance.

Satellite

Technology



Agri-science Resources
for High School Sciences

Physics

Glossary of Terms

centrifugal force	force that is moving or tending to move away from a centre
centripetal force	force that causes acceleration toward centre of circular motion
electromagnetic radiation	energy carried by electromagnetic waves through space
frequency	number of occurrences per unit time
ionosphere	a region of the upper atmosphere consisting of layers of ionized gases that produce the northern lights and reflect radio waves
orbit	the circular pathway followed by a body about another
precision farming	carefully tailoring soil and crop management to fit the different conditions found in each field
satellites	electronic devices with many different functions that are manually put into orbit in outer space

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Prince Edward Island Department of Agriculture, Fisheries and Forestry, Agriculture and Agri-food Canada. 1996. Project to Evaluate Impacts on Potato Yield of Soil Degradation Using DGPS and Yield Mapping Technology.

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Agri-science Resources for High School Sciences

Body Energy

Physics

Science

Grade 10-12

Physics Classroom

Individual reading

DESCRIPTION

The human body requires energy to perform all body functions. This energy is derived from the food we eat. In this exercise, students will see how much of the food that is consumed can be converted into mechanical energy.

LEARNING OUTCOMES

Students will:
- learn how the body can convert food energy into muscular work

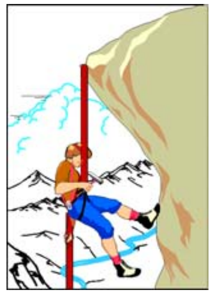
READINESS ACTIVITIES

Students should:
- review the concepts of work, energy and power in physics

MATERIALS

- Copy of exercise

Body Energy



Agri-science Resources
for High School Sciences

Physics

Introduction

Students have done many examples of **work**, **energy** and **power** in physics class. Most of these examples are made up word problems about hypothetical examples. One aspect of energy that is rarely considered is that humans require energy to power our body. Just like a light bulb needs electricity, humans must consume food in order to live. This exercise will try to relate the two subjects of nutrition and energy.

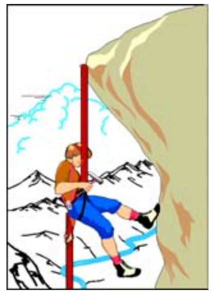
Energy

The chemical energy contained in the food we eat serves many functions. It is used to maintain body temperature, to drive bodily metabolic processes, some is used for growth and replacing worn-out tissue, and the energy that is no longer available to us is excreted. Most importantly, food energy is used to perform **mechanical work**. This includes running, pulling, lifting, hauling, and many other tasks. But just how much of the food we eat can be converted to muscular activity?

Conversion

All of the processes described above require a great deal of energy. Because there are so many of them, the fraction of the food energy converted to mechanical work must be fairly small. To prove that point, think about what you did this morning. Whether you sat in class all day or ran all morning in gym class, you were still hungry at lunchtime. This is because a large fraction of the **caloric intake** you ingest is used for maintenance and is not available for muscular work. In the following examples, a 15% conversion for food to muscular work will be used.

Body Energy



Agri-science Resources for High School Sciences

Physics

Consider how far a person can climb after consuming a specific food substance.

We will use the formula : Work = m g h where h = height
g = gravity
m = mass

Example 1 - Milk

For a liter of milk, the energy content is about 2.4×10^6 Joules. Using a conversion efficiency labeled ε, the amount of work that can be performed is related to the food energy input, Q, by $W = \varepsilon Q$
If the person weighs 50 kg, we know the conversion of milk calories to muscular work is about 15%, and the force of gravity ($g = 9.8\ m/sec^2$). Ignoring all the other possible complicating factors, what is the height a person could climb on a liter of milk?

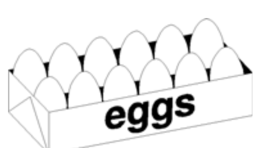
Solution

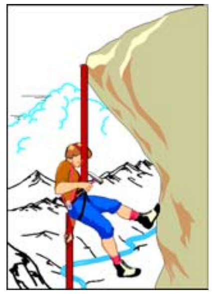
$$h = \frac{(\text{conversion efficiency})(Q)}{mg} = \frac{(.15)(2.4 \times 10^6)(kgm^2/sec^2)}{(50\ kg)(9.8\ m/sec^2)}$$

$$= 700\ m$$

Example 2 - Eggs

a) A serving of two large eggs provides 149 kilocalories of energy. What is the height a person could climb after eating two eggs for breakfast? Use the same values as the previous problem with milk. Given: 1 Joule = 0.2390 calories





Solution

- First convert kcals into Joules $149\ \text{kcal} \times \frac{1000\ \text{cal}}{1\ \text{Kcal}} \times \frac{1\ \text{J}}{0.2390\ \text{cal}} = 623{,}430.96\ \text{J}$

- now solve $h = \frac{(\text{conversion efficiency})(Q)}{mg} = \frac{(.15)(623{,}430.96)(\text{kgm}^2/\text{sec}^2)}{(50\text{kg})(9.8\text{m/sec}^2)}$

$$= \frac{93{,}514.64}{490} = 190.85\ \text{m}$$

b) How high will a person weighing 250 pounds be able to climb? Given: 1kg = 2.2 lbs

Solution:

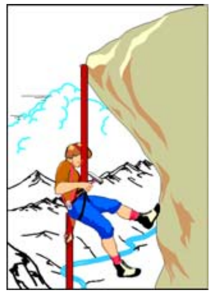
- first convert pounds into kilograms $\frac{250\ \text{lbs} \times 1\text{kg}}{2.2\ \text{lbs}} = 113.64\ \text{kg}$

- solve $h = \frac{(\text{conversion efficiency})(Q)}{mg} = \frac{93{,}514.64}{(113.64\text{kg})(9.8\text{m/sec2})}$

$$= 83.97\ \text{m}$$

c) This time use the same factors from the first problem. If two large eggs provide 149 Kcal of energy, how many eggs would a person have to eat in order to climb a mountain that was 500 meters high. Round up to find the exact number of eggs.

Body Energy



Agri-science Resources for High School Sciences

Physics

Solution

- find the amount of energy required to climb the mountain (E)

$$h = \frac{(\text{conversion factor})(Q)}{mg}$$

$$500\text{m} = \frac{(0.15)(E)(\text{kgm2/sec2})}{(50\text{kg})(9.8\text{m/sec2})}$$

$$(500)(490) = 0.15(E)$$

$$E = 1{,}633{,}333.33 \text{ Joules}$$

- convert joules to kilocalories $$1{,}633{,}333.33\text{J} \times \frac{0.2390 \text{ cal}}{1\text{J}} \times \frac{1\text{kcal}}{1000\text{cal}} = 390.37 \text{ kcal}$$

149 kcal divided by 2 = 74.5 kcal for every egg

$$390.37 \text{ kcal} \times \frac{1 \text{ egg}}{74.5 \text{ kcal}} = 5.24 \text{ eggs}$$

This person would have to eat about 6 eggs to be able to climb the 500 meter mountain

Body Energy

Agri-science Resources
for High School Sciences

Physics

Glossary of Terms

work product of force and displacement in the direction of the force
energy non-material property capable of causing changes in matter
power rate of doing work or rate of energy consumption
mechanical work physical activity that requires energy
caloric intake the number of calories contained in consumed food

Source

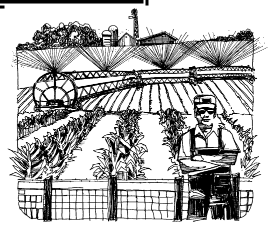
Harte, J. 1985. Consider a Spherical Cow: A course in Environmental Problem Solving. William Kaufmann, Inc., California.

Reference

Zitzewitz, P.W., R.F. Neff and M. Davids. 1992. Merrill Physics: Principles & Problems. Maxwell Macmillan Canada Inc., Toronto.

Agri-science Resources
for High School Sciences

Soil Erosion



Physics

Science

Grade 10-12

Physics Classroom

Individual reading

DESCRIPTION

Soil erosion is a major problem in Agriculture. Tonnes of soil are lost from fields every year. This not only reduces crop production, the soil acts as a pollutant to rivers, lakes, and other water systems. Soil erosion can be controlled with the proper techniques. This article describes soil erosion and some methods of prevention.

LEARNING OUTCOMES

Students will:
- learn how damaging soil erosion can be to agriculture and the environment
- learn how to estimate the rate of soil loss in a field

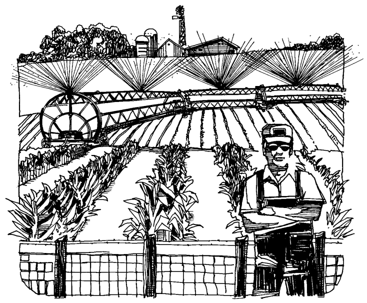
READINESS ACTIVITIES

Students should:
- find any fields in their area that are highly prone to soil erosion and determine the cause

MATERIALS

- Copy of article
- calculator

Soil Erosion



Agri-science Resources for High School Sciences

Physics

Introduction

Soil is the top layer of the earth's surface that is capable of sustaining life. Therefore, soil is very important to farmers, who depend on soil to provide abundant, healthy crops each year. One major problem in agriculture is soil erosion. **Soil erosion** is the deterioration of soil by the physical movement of soil particles from a given site. Wind, water, ice, animals, and the use of tools by man are usually the main causes of soil erosion. It is a natural process which usually does not cause any major problems. It becomes a problem when human activity causes it to occur much faster than under normal conditions.

Facts and Figures

Worldwide, farmers are losing an estimated 24 billion tonnes of topsoil each year. In developing countries erosion rates per acre are twice as high as the standard, partly because population pressure forces land to be more intensively farmed. Although soil erosion is a physical process, it also affects productivity and growth. Reductions in yield of up to 50% have been documented on severely eroded soils in Ontario. When soils are **depleted** and crops receive poor **nourishment** from the soil, the food provides poor nourishment to people. Losses of soil take place much faster than new soil can be created. It takes thousands of years to form just a few centimetres of soil. The difference between creation and loss represents an annual loss of 7.5 to 10 tonnes per acre worldwide.

Soil

Topsoil contains most of the soil's **nutrients**, **organic matter**, and **pesticides**. Soil erosion causes these substances to move also. What is left behind is soil with poorer structure, lower water-holding capacity, different pH values, and low nutrient levels. Therefore, fertilizers and organic matter must be added in an attempt to restore the soil to its original composition. The soil also has a lower resistance to **drought**.

Where does it go?

Much of the eroded soil is deposited either in low areas of the field or it moves off the farm and eventually enters drainage ditches, streams or rivers. Soil that enters a watercourse reduces water quality, reduces the efficiency of drainage systems and the storage capacity of lakes. Soil that settles in water systems is called **sediment**. Accumulation of sediment often requires that it be cleared out manually, which costs money. Sediment fills rivers and reservoirs and reduces their capacity to hold flood waters. Sediment is considered to be a major pollutant. It can inhibit fish spawning and block the sunlight necessary to plant life. Increased runoff of chemical and nutrients from farmers fields must be removed in order for water to be safe to drink.

Geographic Location

The severity of soil erosion can vary from place to place. Wind and water are the main causes of soil erosion. The faster either moves and the amount of plant cover available for protection are two main factors associated with erosion. Wind erosion is a more common problem in dry, windy regions, with a smooth, flat terrain. Water erosion is a problem in wet regions with a sloping or hilly terrain. A significant portion of land used for potato production in Atlantic Canada is vulnerable to erosion.

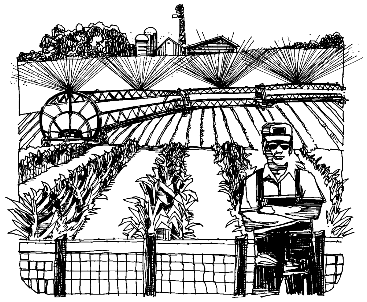
Erosion Factors

The vulnerability of a field to soil erosion is dependent on a number of factors:

- The climatic conditions of the area
- the proportion of sand, **silt** and **clay** sized particles in a particular soil
- the organic matter level
- the **water permeability** of the soil
- the length and slope of the field
- amount of **crop rotation**
- direction of cultivation

Protection

It is vegetation that keeps soil from eroding. This is because soil is usually covered with shrubs and trees, by dead and decaying matter or by a thick mat of grass. The root systems of plants is able to hold the soil together. Plants slow down water as it flows over the land and it allows much of the rain to soak into the ground. Plants also break the impact of a raindrop before it hits the soil. This reduces water erosion. When this covering is stripped away through deforestation, over-grazing, ploughing and fire, soil erosion is greatly accelerated. Over-cultivation and compaction cause the soil to lose its structure and cohesion and it becomes more easily eroded. Soils with high clay content are more cohesive and allow soil particles to stick together. Soil with more clay are less vulnerable to erosion than soil with high sand or silt content.



Prevention

There are a number of other conservation practices which can be used by farmers. Any single conservation practice can significantly decrease soil erosion rates. Combining a number of soil conservation practices is often more effective. The ideal goal would be to achieve a soil loss rate of 6.7 tonnes/ha/year. This is roughly the rate at which soil can rejuvenate itself. Making sure there are always plants growing on the soil and that the soil is rich in organic matter are two key methods in prevention. Organic matter binds soil particles together which reduces erosion. Organic matter in soil can be increased with crop rotation or by incorporating organic fertilizers. Crop rotation is also effective at enhancing soil structure. There are also many other methods used by farmers to reduce soil erosion. Mulching is one example. It involves spreading hay or straw over a field as a substitute for a cover crop.

Exercise: Calculation of Erosion Rates

Soil conservationists around the world use the Universal Soil Loss Equation to estimate soil erosion rates by water. The equation provides an estimate of the Soil Loss Rate in Tonnes/hectare/year. This estimate can be used for soil conservation planning. The Universal Soil Loss Equation is:

$$A = KR(LS)CP$$

where A = Estimate of the Soil Loss Rate in Tons/ha/year
K = Soil erodibility factor
R = Rainfall factor
LS = Length/Slope Factor
C = Crop management Factor
P = Support Practice Factor

K

The soil erodibility factor varies according to soil type and geographic location. The K factor for a particular soil does not change.

Table 1. Soil Erodibility Factor determined by soil texture and organic matter content

	Organic Matter Content (%)		
Soil Texture	0.5	2	4
Fine Sand	0.16	0.14	0.10
Very Fine Sand	0.42	0.36	0.28
Loamy Sand	0.12	0.10	0.08
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Very fine sandy loam	0.47	0.41	0.33
Silt loam	0.48	0.42	0.33
Clay loam	0.28	0.25	0.21
Silt clay loam	0.37	0.32	0.26
Silty clay	0.25	0.23	0.19

For the purposes of this example, the Charlottetown soil type in P.E.I. (K=.38) will be used to calculate the soil loss rate.

R

The R value in the equation takes climatic conditions into consideration. The rainfall factor can vary from year to year, so an average over a number of years is usually used. For this example, the value 60.6 will be used to calculate the soil loss rate.

LS

The length and slope factors vary according to the size and shape of different fields. The standard factor is calculated based on a standard length of 22 m and a 9 percent slope.

Table 2. Approximate LS soil loss factor determined by the length and steepness of slope.

Slope length (m)	Degree of Slope (%)	LS - Soil loss factor
250	2	0.2
200	4	0.4
150	6	1.5
125	8	2
110	10	2.5
100	6	1.2
90	14	4
60	16	4
50	18	4.5
45	20	5

This table gives the LS values which can be used in the universal soil loss equation.

C

The cropping-management factor can vary according to farming practices. This value includes the effects of cover, crop sequence, productivity level, length of growing season, tillage practices, residue management, and the expected time distribution of erosive rainstorms. For example, the approximate C value for a rotation with corn-corn-oats-meadow is 0.18 if good management is used.

P

Another variable that can be altered is the conservation practice factor. This is the ratio of soil loss for a given practice compared to simple up and down the slope farming. Contouring is one practice which involves field operations such as plowing, planting, cultivating, and harvesting approximately on the contour. The P values obtained using contouring vary according to the slope of the field

Table 3. Conservation practice factor values for contouring.

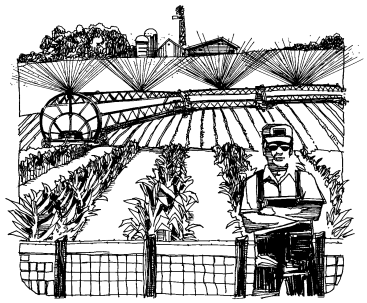
Percent Slope	P value for Contouring (with maximum allowable slope length in metres)
1.1-2	0.6 (150)
2.1-7	0.5 (100)
7.1-12	0.6 (60)
12.1-18	0.8 (20)
18.1-24	0.9 (18)

Calculation

Determine the average annual soil loss (tons/hectare) of a field with the following parameters:

- The field is located in Prince Edward Island and has a Charlottetown soil type.
- The rainfall factor is 60.6
- The slope length is 100 m and the slope is 6 percent
- The crop management factor is a corn-corn-oats-meadow rotation
- The field is to be contoured

Is the average annual soil loss below the Tolerable Soil Loss Rate?



Solution

Use tables 1 through 3 to get the following values:

$$
\begin{aligned}
A &= KR\,(LS)\,CP \\
  &= (.38)(60.6)(1.2)(0.18)(0.5) \\
  &= 2.5 \text{ tons/hectare}
\end{aligned}
$$

Because the Tolerable Soil Loss Rate is 6.7 tons/hectare, this soil loss of this field is occurring under the appropriate levels.

Glossary of Terms

crop rotation	planting of different crops in a given field every year or every several years
depleted	soil that has valuable resources exhausted or used up
drought	continued absence of rain or moisture
nourishment	providing something with the material to keep it alive and make it grow
nutrients	substances necessary for the functioning of an organism
organic matter	dead plant or animal tissue that originates from living sources
pesticides	chemicals used to control pests.
sediment	sand, gravel, or mud which settles at the bottom of a liquid
soil	top layer of the earth’s surface capable of sustaining life
soil erosion	wearing away of soil
water permeability	the rate at which water can pass through the soil profile

References

Cooper, E.L. 1997. Agriscience: Fundamentals & Applications. Delmar Publishers, Albany, New York.

DeHaan, R. 1992. Integrated Erosion Control on Potato Land in Atlantic Canada. Atlantic Committee on Agricultural Engineering.

Holt, Rinehart and Winston. 1974. The Winston Canadian Dictionary for Schools. Holt, Rinehart and Winston of Canada, Ltd., Toronto.

Agri-science Resources
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Science

Grade 10-12

Physics Problems

Physics Classroom

Physics

Individual work

DESCRIPTION

Article contains a few physics problems involving vectors and force.

LEARNING OUTCOMES

Students will:
• see how physics applies to everyday applications in agriculture

READINESS ACTIVITIES

Students should:
• think about how simple chores and work actually involves physics

MATERIALS

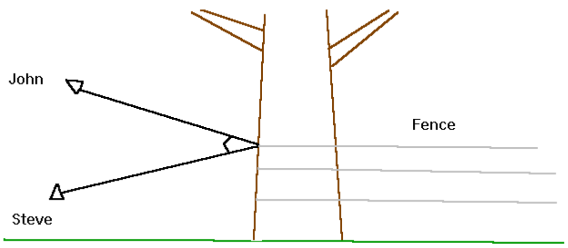
• copy of article
• calculator

Physics Problems

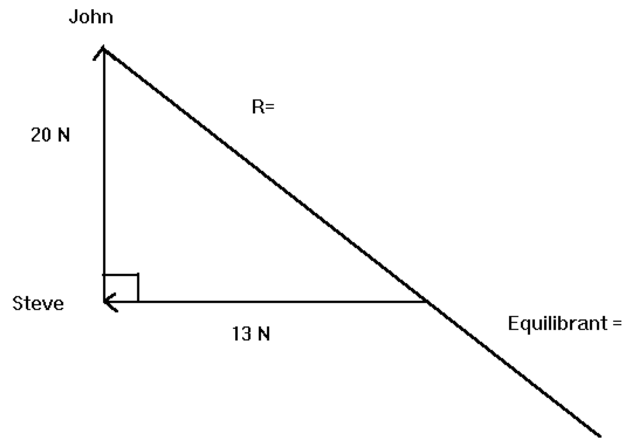
Applications of Vectors

Some farmers are tightening barb-wire fences. John and Steve are using ropes to pull the fence taunt. They are standing at right angles to each other.

John is stronger than Steve and is therefore able to exert more force when pulling on the rope.



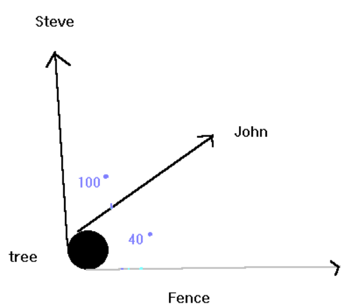
John can pull with a force of 20 N while Steve can only pull with a force of 13 N. When the fence has been pulled tight, what is the equilibrant force exerted by the barb-wire fence? In other words, how tight is the fence after the men have pulled and secured it?



Solution

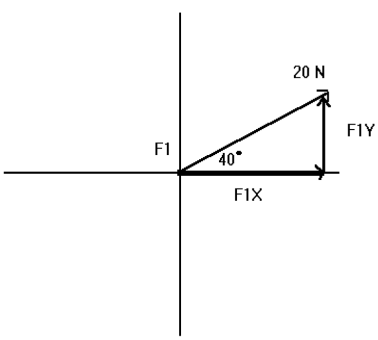
$R^2 = A^2 + B^2$
$R^2 = (20)^2 + (13)^2$
$R^2 = 400 + 169$
$R^2 = 569$
$R = 23.85$

After a few weeks have passed, the men begin to notice they did not tighten the fences tight enough. Their livestock is constantly escaping from the field. This time John and Steve decide to try a new strategy.



Now the tree is used as a pulley.
John pulls at an angle of 40° to the fence. Steve pulls at a 100° angle. The forces exerted by the two men have not changed, but the tension on the fence should. What is it now?

Solution



$$\cos \sigma = \frac{adj}{hyp} = \frac{F1x}{20\text{ N}}$$

$$F1x = (20\text{N})(\cos 40^o)$$

$$= (20)(.7660)$$

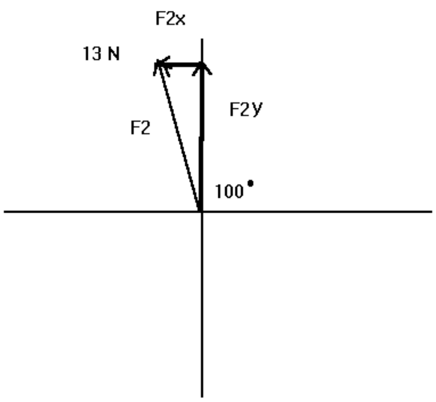
$$= \mathbf{15.32}$$

$$\sin \sigma = \frac{opp}{hyp} = \frac{F1y}{20\text{ N}}$$

$$F1y = (20\text{N})(\sin 40^o)$$

$$= (20)(.6428)$$

$$= \mathbf{12.86}$$



$\cos \sigma = \frac{adj}{hyp}$

$\cos 100^{o} = \frac{F2x}{13N}$

$F2x = (13)(\cos 100^{o})$

$= \mathbf{-2.26}$

$\sin \sigma = \frac{opp}{hyp}$

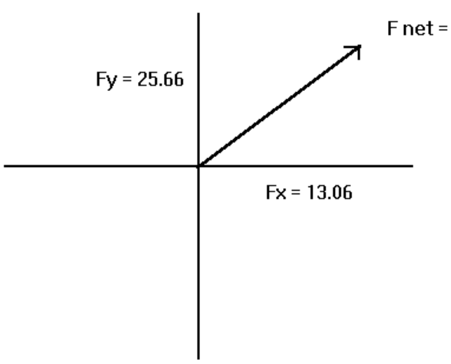
$\sin 100^{o} = \frac{F2y}{13\ N}$

$F2y = (13)(\sin 100^{o})$

$= \mathbf{12.8}$

$Fx = F1x + F2x = 15.32 + (-2.26) = 13.06$

$Fy = F1y + F2y = 12.86 + 12.8 = 25.66$



$F\ net = \sqrt{Fx^2 + Fy^2}$

$= \sqrt{(13.06)^2 + (25.66)^2}$

$= \sqrt{170.56 + 658.44}$

$= \mathbf{28.59\ N}$

Thus the tension on the fence should now be 28.59 N.

Physics Problems

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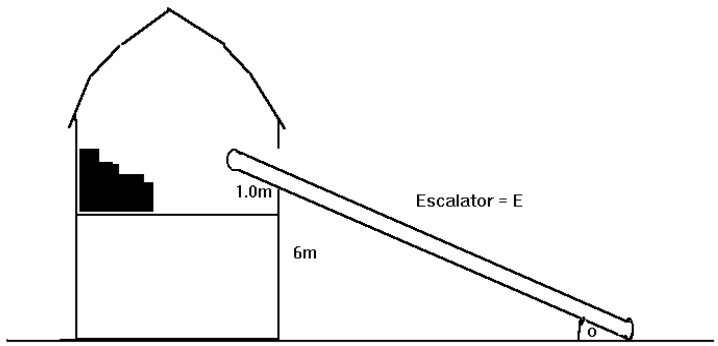
Physics

In this vector problem, hay is being loaded into a hay loft. The barn is 6m high and perpendicular to the ground. If the angle of the escalator to the ground is greater than 55º the hay bales will fall backwards as they are going up. If the angle of the escalator is 30º or less, the escalator would be too long to be sturdy. What are the minimum and maximum lengths that are most suitable for loading the hay into the loft? Don't forget that the escalator must have an extra meter that goes into the loft of the barn.



Solution

sin σ	=	$\frac{\text{opp}}{\text{hyp}}$	sin σ	=	$\frac{\text{opp}}{\text{hyp}}$
sin 55º	=	$\frac{6\text{m}}{E}$	sin 30º	=	$\frac{6\text{m}}{E}$
E	=	(6)(sin 55º)	E	=	(6)(sin 30º)
E	=	**4.9 m**	E	=	**3m**

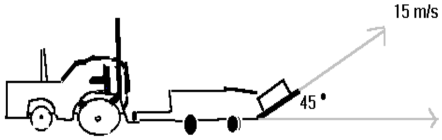
Remember, both of these lenghts need another meter added on to get into the loft. So the ideal lenght for the escalator would be between **5.9** and **4** meters.

Physics Problems

Agri-science Resources
for High School Sciences

Physics

A hay bailer is able to tie off each bale and then project it at an ajustable angle. Let's say the hay projector is set at a 45° angle. Each bale is projected at an average velocity of 15.0 m/s. Given this, how far behind the bailer will the hay get thrown?



Given: initial velocity, $v_i = +15.0$ m/s
initial angle, $\sigma = 45^o$

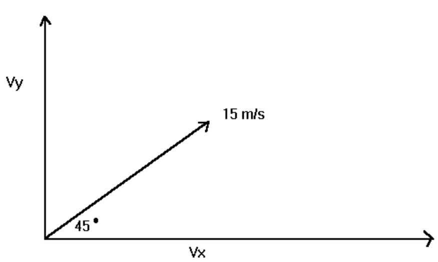
Solution

$$\cos \sigma = \frac{adj}{hyp}$$

$$\cos 45^o = \frac{Vx}{15 \text{ m/s}}$$

$$Vx = (15)(.7071)$$

$$= 10.6 \text{ m/s}$$



$$\sin \sigma = \frac{opp}{hyp}$$

$$\sin 45^o = \frac{Vy}{15 \text{ m/s}}$$

$$Vy = (15)(.7071)$$

$$= 10.6 \text{ m/s}$$

Now find the time:

$y = Vyt + 1/2gt^2$

$0 = Vyt + 1/2gt^2$

$-2Vyt = gt^2$

$t = \frac{-2Vy}{g} = \frac{-2(10.6 \text{ m/s})}{-9.8 \text{ m/s}^2} =$ **2.16 seconds**

use time to determine distance:

$R = Vxt = (10.6 \text{ m/s})(2.16 \text{ s}) =$ **22.9 m**

PARTNERSHIPS

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