Topics	Engineer's Mini Notebook, Radio Shack
Collection	folkscanomy_electronics; folkscanomy; additional_collections
Language	English

Use these plans to make a simple seismometer; build a sun photometer to make accurate measurements of the atmosphere; study rain, lightening, and sunlight; and build a wide variety of lightwave and radio communication circuits. This is a compilation of three of Mims's best-selling notebooks: Science Projects; Environmental Projects; and Communication projects.

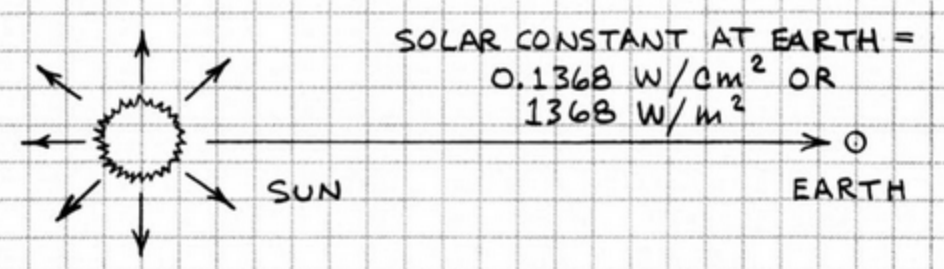
Addeddate	2019-03-03 22:34:06
Identifier	ScienceAndCommunicationCircuitsAndProjects
Identifier-ark	ark:/13960/t8jf2d18g
Ocr	ABBYY FineReader 11.0 (Extended OCR)
Ppi	150
Scanner	Internet Archive HTML5 Uploader 1.6.4

ENERGY FROM THE SUN

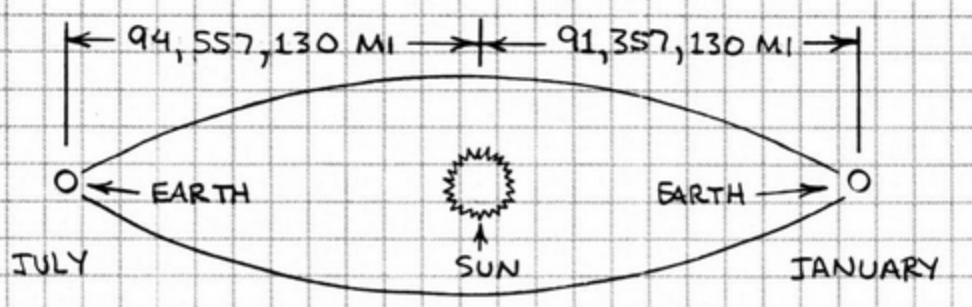
THE SUN EMITS AN INCREDIBLE AMOUNT OF ELECTROMAGNETIC RADIATION. THE TOTAL RADIATED POWER IS 3.83×10^{23} KILOWATTS (KW) OR 383,000,000,000,000,000,000,000,000 WATTS. MOST OF THIS RADIATION IS LOST TO SPACE. ONLY A TINY FRACTION IS INTERCEPTED BY EARTH AND THE OTHER PLANETS. ACCORDING TO THE SOLAR ENERGY INDUSTRIES ASSOCIATION (SEIA), ALL THE ELECTRICITY CONSUMED IN THE UNITED STATES COULD BE PROVIDED BY PHOTOVOLTAIC SOLAR CELL MODULES COVERING 0.3 % OF THE LAND AREA OF THE U.S.

THE SOLAR CONSTANT

THE MEAN AMOUNT OF SUNLIGHT AT THE TOP OF EARTH'S ATMOSPHERE IS CALLED THE SOLAR CONSTANT. MEASUREMENTS MADE BY SEVERAL SATELLITES SHOW THAT THE SOLAR CONSTANT IS 136.8 WATTS PER SQUARE CENTIMETER.



THE SUNLIGHT INTENSITY AT EARTH VARIES BECAUSE EARTH'S ORBIT AROUND THE SUN IS SLIGHTLY ELLIPTICAL. THE MEAN DISTANCE OF EARTH FROM THE SUN IS 92,957,130 MILES (149,600,000 KILOMETERS). IN EARLY JANUARY EARTH IS ABOUT 1,600,000 MILES (2,575,000 KM) CLOSER TO THE SUN. IN EARLY JULY EARTH IS ABOUT 1,600,000 MILES (2,575,000 KM) FARTHER FROM THE SUN. (SEE DRAWING ON FACING PAGE.)



THE DIFFERENCE IN THE INTENSITY OF SUNLIGHT BETWEEN PERIHELION (CLOSEST POINT) AND APHELION (FARTHEST POINT) IS ABOUT 6.7 %. USE THE SOLAR CONSTANT TABLE TO FIND THE SOLAR CONSTANT FOR THE FIRST DAY OF ANY MONTH.

SOLAR CONSTANT TABLE

MULTIPLY THE MEAN SOLAR CONSTANT (1,368 WATTS PER SQUARE METER OR 136.8 MILLIWATS PER SQUARE CENTIMETER) BY THE CORRECTION NUMBERS IN THIS TABLE TO FIND THE ACTUAL SOLAR IRRADIANCE ON THE GIVEN DATES.

JANUARY	1.0335	JULY	0.9666
FEBRUARY	1.0288	AUGUST	0.9709
MARCH	1.0173	SEPTEMBER	0.9828
APRIL	1.0009	OCTOBER	0.9995
MAY	0.9841	NOVEMBER	1.0164
JUNE	0.9741	DECEMBER	1.0288

FROM KINSELL L. COULSON, "SOLAR AND TERRESTRIAL RADIATION," ACADEMIC PRESS, 1975.

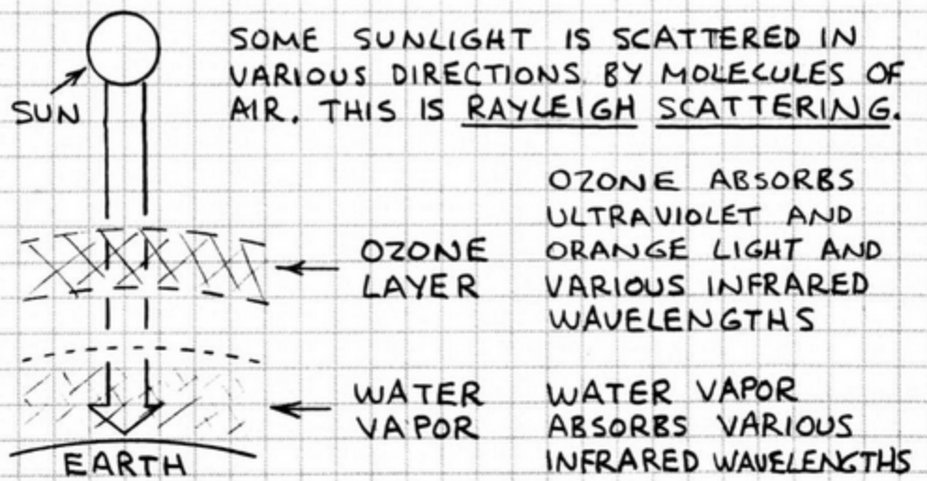
EXAMPLE: WHAT IS THE SUN'S IRRADIANCE AT THE TOP OF THE ATMOSPHERE ON MAY 1? THE IRRADIANCE ON MAY 1 IS 0.9841 OF THE MEAN SOLAR CONSTANT OF 136.8 MILLIWATTS PER SQUARE CENTIMETER. 0.9841×136.8 IS 134.625 MILLIWATTS PER SQUARE CENTIMETER.

SUNLIGHT AND THE ATMOSPHERE

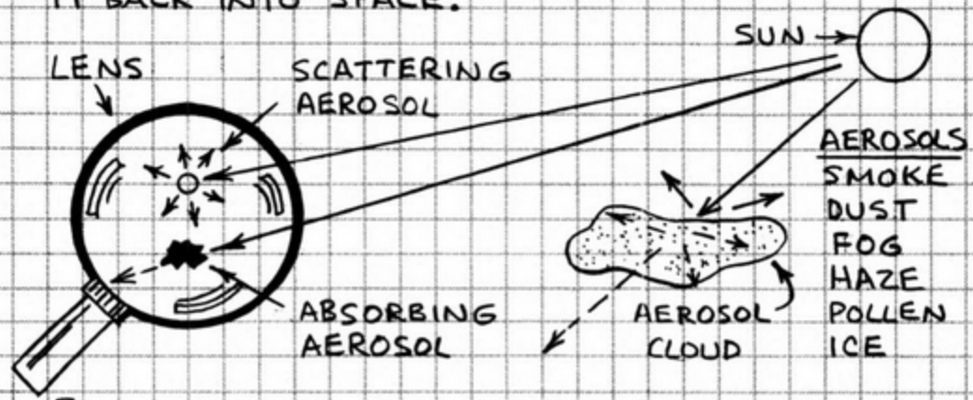
A SOLAR CELL ON A SATELLITE RECEIVES AT LEAST 15% MORE SOLAR ENERGY THAN AN IDENTICAL SOLAR CELL ON EARTH. FOR EXAMPLE, AT NOON ON JULY 1 THE SOLAR IRRADIANCE AT ALBUQUERQUE, NEW MEXICO, IS ABOUT 100 MILLIWATTS PER SQUARE CM (100 mW/cm^2) IF THE SUN IS NOT BLOCKED BY A CLOUD. FROM THE SOLAR CONSTANT TABLE (P.9) THE IRRADIANCE AT THE TOP OF THE ATMOSPHERE ON JULY 1 IS 0.9666 × 136.8 mW/cm^2 OR 132.2 mW/cm^2. THUS ONLY 75.6% OF THE INTENSITY OF THE SUNLIGHT AT THE TOP OF THE ATMOSPHERE REACHES ALBUQUERQUE ON JULY 1. ALBUQUERQUE IS ABOUT 1 MILE (1.6 KILOMETERS) ABOVE SEA LEVEL AND THE AIR IS OFTEN DRY. LESS SUNLIGHT REACHES REGIONS NEARER SEA LEVEL, ESPECIALLY WHEN THE AIR IS MOIST. MUCH LESS SUNLIGHT IS RECEIVED EVERYWHERE DURING WINTER AND WHEN CLOUDS BLOCK THE SKY.

HERE ARE SOME OF THE CHIEF FACTORS THAT AFFECT SUNLIGHT:

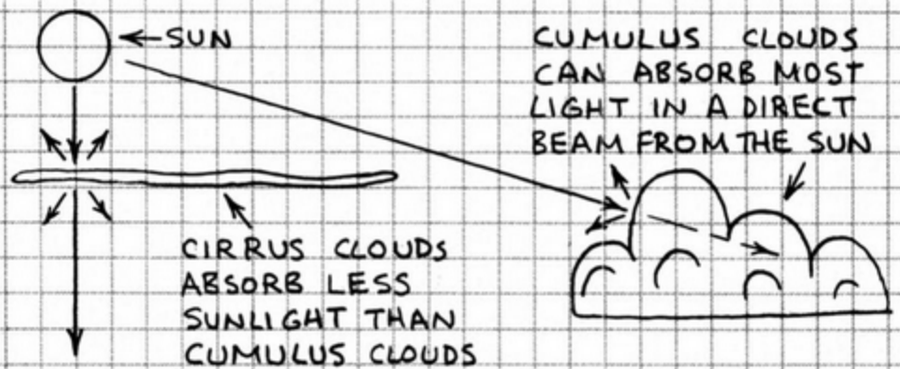
1. WATER VAPOR, OZONE AND OTHER GASES IN THE ATMOSPHERE ABSORB SUNLIGHT.



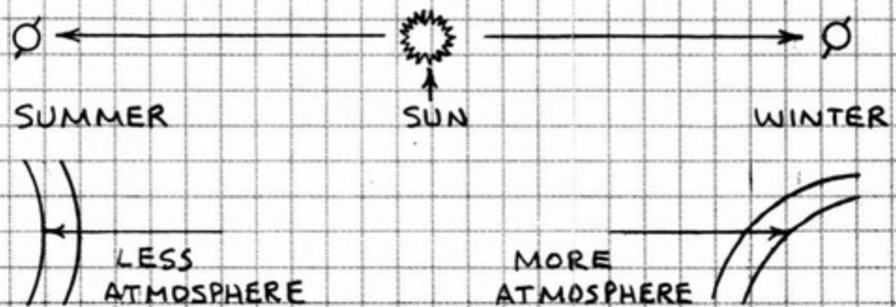
2. AEROSOLS ARE TINY PARTICLES AND DROPLETS IN THE ATMOSPHERE THAT CAN ABSORB CONSIDERABLE SUNLIGHT OR SCATTER IT BACK INTO SPACE.



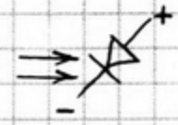
3. CLOUDS ARE FORMED FROM ENORMOUS NUMBERS OF TINY WATER DROPLETS OR ICE CRYSTALS. CLOUDS ABSORB AND SCATTER LIGHT.



4. THE TILT OF THE EARTH CAUSES SUNLIGHT TO PASS THROUGH MORE ATMOSPHERE DURING FALL, WINTER AND SPRING.



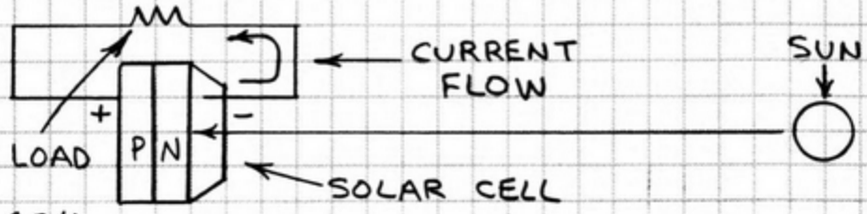
SOLAR CELLS



MANY SEMICONDUCTORS WILL GENERATE ELECTRICITY FROM SUNLIGHT. THE MOST COMMON AND BEST DEVELOPED SOLAR CELLS ARE MADE FROM SILICON. SINCE SILICON FORMS 27.7% OF EARTH'S CRUST, SILICON SOLAR CELLS ARE POTENTIALLY INEXPENSIVE. BUT TRANSFORMING SILICON INTO SOLAR CELLS IS AN EXPENSIVE PROCESS THAT REQUIRES CONSIDERABLE ELECTRICITY.

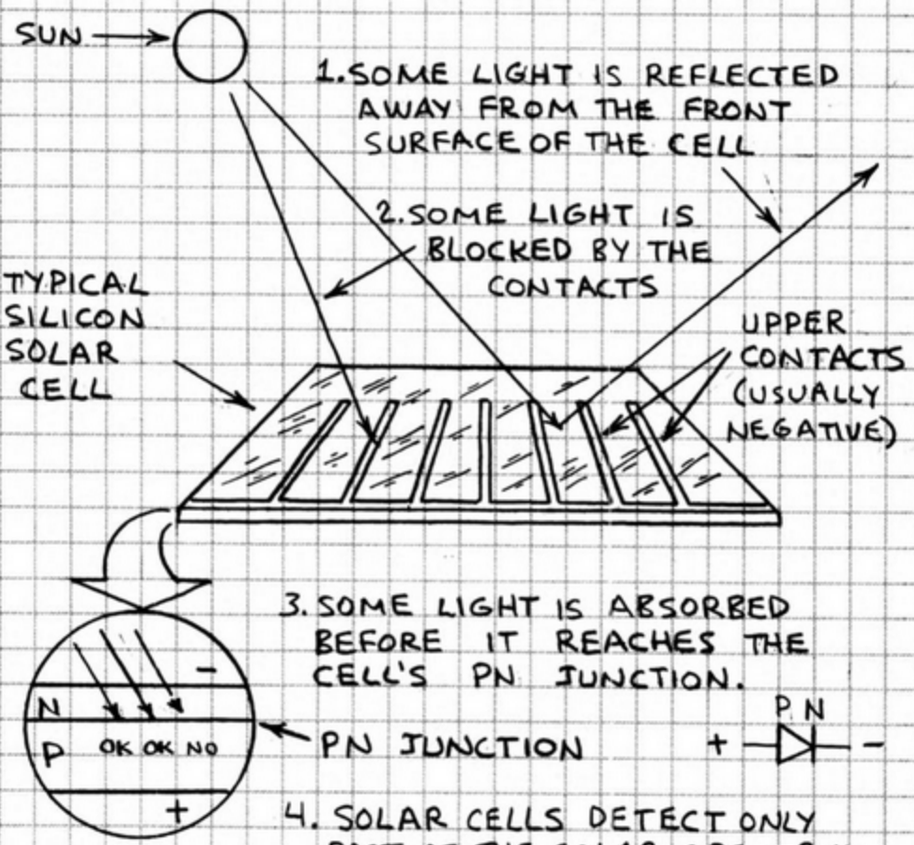
HOW SOLAR CELLS WORK

LIGHT CONSISTS OF PACKETS OF ENERGY CALLED PHOTONS THAT TRAVEL IN A WAVE-LIKE FASHION. WHEN PHOTONS STRIKE SILICON ATOMS THEY DISLODGE ELECTRONS. THE MISSING ELECTRONS LEAVE BEHIND POSITIVELY CHARGED ATOMS. THESE ATOMS ATTRACT FREE ELECTRONS IN THE SILICON. THIS RANDOM MOVEMENT OF ELECTRONS CAN BE CONVERTED INTO A FLOW OF ELECTRONS IF A PN JUNCTION IS FORMED IN THE SILICON. ELECTRONS DISLODGED BY PHOTONS NEAR THE PN JUNCTION ARE ATTRACTED TO THE P SIDE OF THE JUNCTION. THE RESULT IS A FLOW OF ELECTRICAL CURRENT WHEN LIGHT IS PRESENT. THE LEVEL OF CURRENT IN AMPERES IS DIRECTLY PROPORTIONAL TO THE LIGHT INTENSITY. THE POTENTIAL OF THE CURRENT IN VOLTS IS UNRELATED TO THE LIGHT INTENSITY. A TYPICAL SILICON SOLAR CELL GENERATES 0.45 TO 0.55 VOLT IN DIRECT SUNLIGHT.

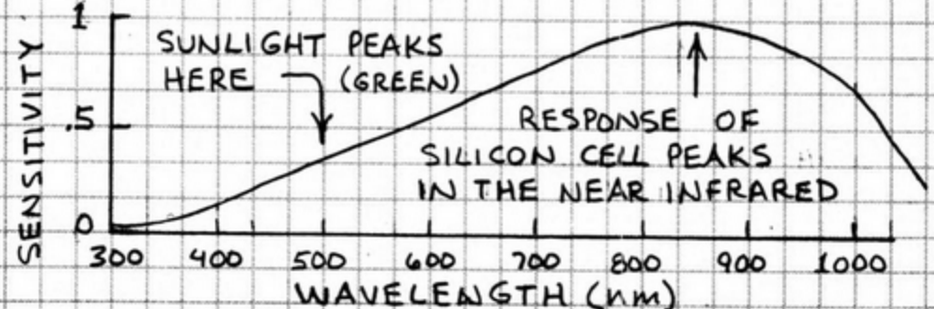


SOLAR CELL EFFICIENCY

IF EVERY PHOTON STRIKING A SOLAR CELL DISLODGES AN ELECTRON, THE CELL WILL TRANSFORM NEARLY 100% OF THE LIGHT THAT STRIKES IT INTO ELECTRICITY. THE ACTUAL EFFICIENCY OF REAL SOLAR CELLS IS FROM ABOUT 5% TO 20%. THERE ARE SEVERAL REASONS FOR REDUCED EFFICIENCY:



4. SOLAR CELLS DETECT ONLY PART OF THE SOLAR SPECTRUM.



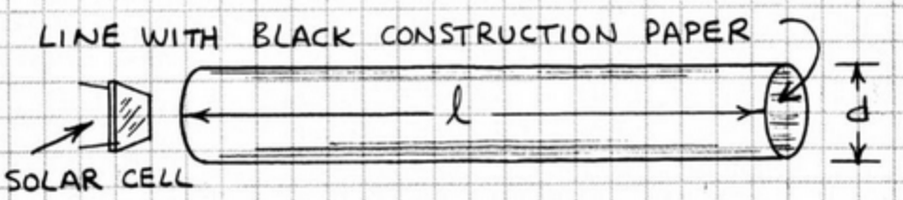
TAKE A SOLAR CELL INTO SPACE

SOLAR CELLS ARE SENSITIVE TO ONLY PART OF THE SOLAR SPECTRUM. THEREFORE A SOLAR CELL CAN NOT MEASURE THE POWER OF THE TOTAL AMOUNT OF SUNLIGHT AT THE TOP OF THE ATMOSPHERE (THE SOLAR CONSTANT), EVEN IF YOU COULD TAKE ONE THERE.

ACCORDING TO SOLAREX, A MAJOR SOLAR CELL MANUFACTURER, A SOLAR CELL PRODUCES ABOUT +14.6 % MORE POWER IN SPACE THAN THE SAME CELL PRODUCES ON EARTH. LET'S CALL THIS PERFORMANCE INCREASE A SOLAR CELL'S SPACE EFFICIENCY.

YOU DON'T NEED TO BECOME AN ASTRONAUT TO DETERMINE HOW MUCH MORE POWER A SOLAR CELL WILL PRODUCE IN SPACE. THE METHOD DESCRIBED HERE WILL REVEAL A SOLAR CELL'S SPACE EFFICIENCY FROM EARTH. FOLLOW THESE STEPS:

1. MOUNT A SOLAR CELL AT THE END OF A PVC OR CARDBOARD TUBE:

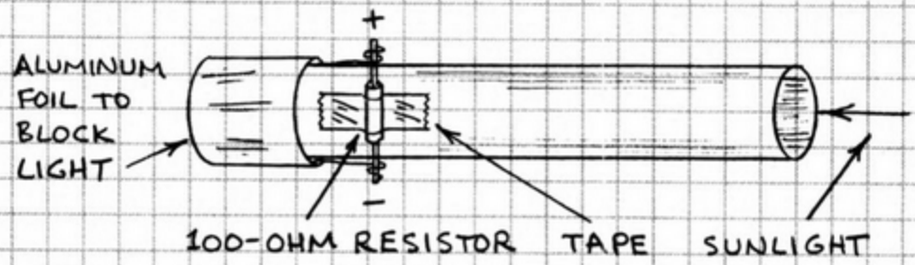


l SHOULD BE AT LEAST 5 TIMES d.

USE DOUBLE SIDED TAPE TO ATTACH A BARE SOLAR CELL TO A THIN CARDBOARD DISK. USE DARK TAPE TO ATTACH THE CELL AND DISK TO THE END OF THE TUBE. ALTERNATIVELY, INSTALL THE SOLAR CELL IN A THIN, CLEAR PLASTIC BOX AND TAPE THE BOX TO THE END OF THE TUBE. IF THE SOLAR CELL IS LARGER THAN d, THE EXPOSED PORTION OF THE CELL MUST BE SHIELDED FROM LIGHT.

ONE WAY IS TO WRAP THE SOLAR CELL END OF THE TUBE WITH ALUMINUM FOIL. TAPE THE FOIL TO THE SIDE OF THE TUBE. BE SURE IT DOES NOT CONNECT TOGETHER OR SHORT THE SOLAR CELL LEADS.

2. CONNECT THE SOLAR CELL LEADS ACROSS A 100-OHM RESISTOR. TAPE THE RESISTOR TO THE SIDE OF THE TUBE AS SHOWN:



3. ON A CLEAR DAY MEASURE THE VOLTAGE ACROSS THE 100-OHM RESISTOR WHEN THE TUBE IS POINTED DIRECTLY AT THE SUN. THE TUBE IS PROPERLY POINTED WHEN ITS SHADOW DISAPPEARS AND WHEN THE VOLTAGE ACROSS THE 100-OHM RESISTOR REACHES A PEAK.

MAKE MEASUREMENTS FROM EARLY MORNING TO NOON OR FROM NOON TO LATE AFTERNOON. IF YOU DO NOT HAVE INTERNET ACCESS YOU WILL NEED TO MEASURE THE ANGLE OF THE SUN OVER THE HORIZON AT EACH MEASUREMENT. RECORD YOUR DATA IN A NOTEBOOK UNDER THESE HEADINGS:

DATE:
LOCATION: (TOWN AND COORDINATES)
SKY CONDITION: (CLEAR? BLUE?)
OBSERVER: (YOUR NAME)

TIME	SIGNAL (VOLTS)	SIGNAL (LN)	SUN ANGLE	AIR MASS

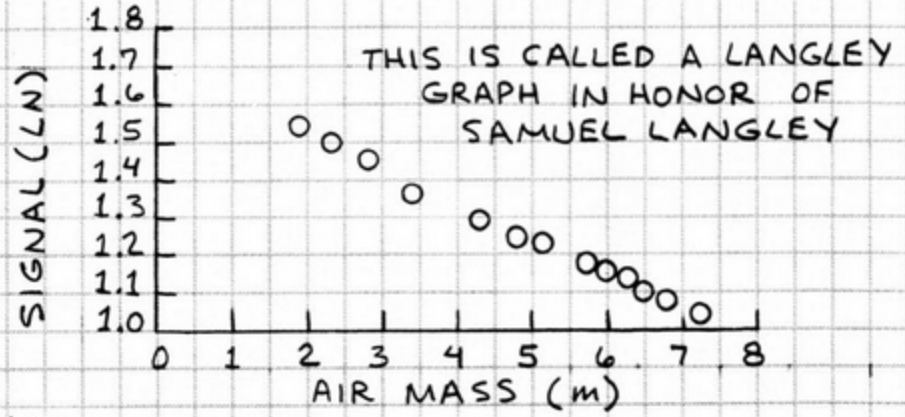
4. AIR MASS (m) IS THE THICKNESS OF THE ATMOSPHERE BETWEEN YOU AND THE SUN. $m = 1/\sin\theta$, WHERE θ IS THE ANGLE OF THE SUN ABOVE THE HORIZON. FIND m FOR EACH TIME YOU MADE A MEASUREMENT. USE THE SUN ANGLES YOU MEASURED. OR VISIT A SEARCH ENGINE ON THE WORLD WIDE WEB AND ENTER "SUN ANGLE CALCULATOR." CHECK THE WEB SITES AND SELECT A CALCULATOR YOU LIKE. FOLLOW THE INSTRUCTIONS TO FIND THE SUN ANGLE FOR EACH TIME. CALCULATE m FOR EACH ANGLE AND ENTER THE RESULTS IN YOUR NOTEBOOK.

5. USE THE LN KEY ON A SCIENTIFIC CALCULATOR TO CONVERT THE SIGNALS YOU MEASURED TO THEIR NATURAL LOGARITHMS. ENTER THE RESULTS IN YOUR NOTEBOOK. HERE ARE SOME OF MY RESULTS:

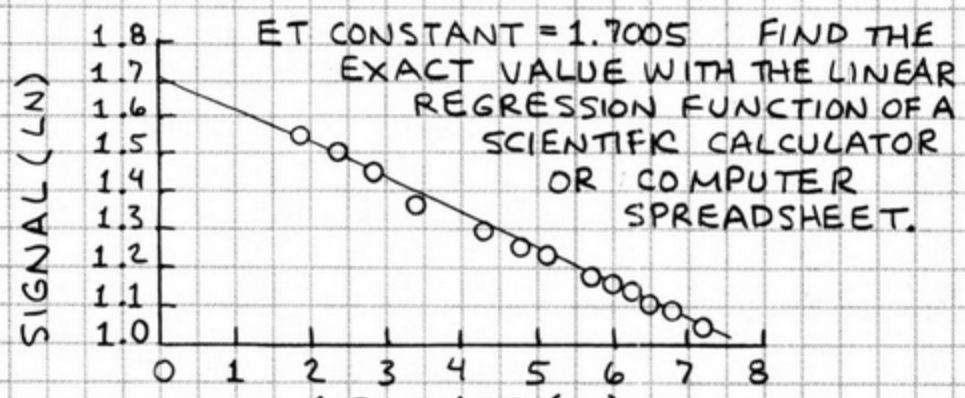
DATE: FEBRUARY 21, 1999
LOCATION: GERONIMO CREEK, TEXAS
SKY CONDITION: CLEAR AND BLUE
OBSERVER: FORREST M. MIMS III

TIME	SIGNAL (VOLTS)	SIGNAL (LN)	SUN ANGLE	AIR MASS
1550:20	4.60	1.5261	30.09°	1.99
1616:00	4.44	1.4907	25.39°	2.33

6. GRAPH THE LN OF THE SIGNALS AND THEIR AIR MASSES. HERE'S MY GRAPH:



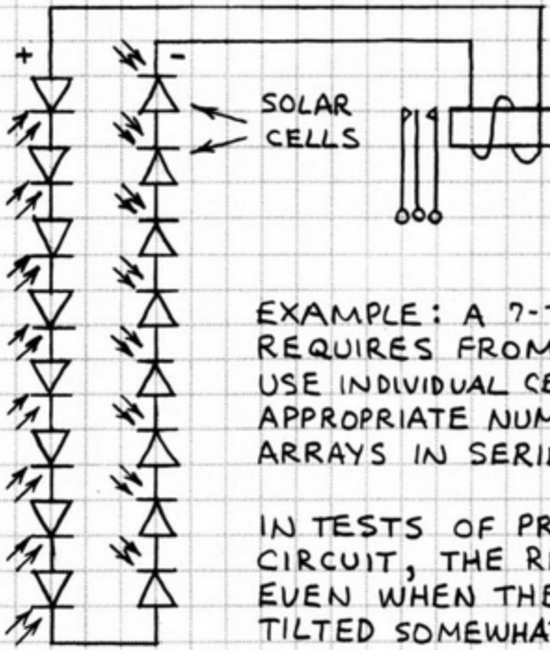
IF THE SKY WAS CLEAR, THE POINTS BETWEEN AN AIR MASS OF ABOUT 2 TO 6 SHOULD FORM A STRAIGHT LINE. DRAW A LINE THROUGH THESE POINTS AND EXTEND IT TO THE Y (VERTICAL) AXIS OF THE GRAPH (AIR MASS = 0). THE LN OF THE SIGNAL THE SOLAR CELL WILL PRODUCE ABOVE THE ATMOSPHERE, THE CELL'S EXTRATERRESTRIAL (ET) CONSTANT, IS WHERE THE LINE CROSSES THE Y AXIS.



7. USE THE e^x KEY OF YOUR CALCULATOR TO CONUERT THE LN OF THE HIGHEST SIGNAL AT OR NEAR NOON AND THE ET CONSTANT TO THEIR ANTILOGS. DIVIDE THE ET CONSTANT BY THE NOON SIGNAL, SUBTRACT 1 AND ADD A % SIGN. THIS IS THE SOLAR CELL'S SPACE EFFICIENCY, THE INCREASE IN PERFORMANCE THE CELL WILL PROVIDE IN SPACE. THE SOLAR CELL I MEASURED HAS A SPACE EFFICIENCY OF +10.9 %. THIS IS REASONABLY CLOSE TO THE +14.6 % GIVEN BY SOLAREX. SOME OF THE DIFFERENCE IS BECAUSE THE LANGLEY METHOD WORKS BEST WITH A NARROW BAND OF WAVELENGTHS AND A SOLAR CELL DETECTS FROM ABOUT 400 TO 1100 NANOMETERS. DIFFERENCES ARE ALSO CAUSED BY DIFFERING AMOUNTS OF WATER VAPOR AND HAZE WHEN THE TESTS WERE CONDUCTED. WATER VAPOR IS ESPECIALLY IMPORTANT SINCE IT ABSORBS SOME NEAR INFRARED TO WHICH SOLAR CELLS ARE VERY SENSITIVE.

SUNLIGHT ACTUATED RELAY

A SERIES ARRANGEMENT OF SILICON SOLAR CELLS WILL ACTIVATE A RELAY. THE SOLAR CELL ARRAY MUST PROVIDE SUFFICIENT VOLTAGE AND CURRENT TO OPERATE THE RELAY. THE ARRAY SHOWN HERE WILL PULL IN A LOW CURRENT RELAY WITH A 7-TO 9-VOLT COIL.

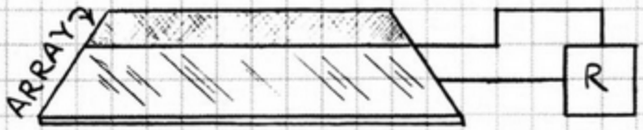


7-TO 9-VOLT LOW CURRENT RELAY (RADIOSHACK 275-005 OR SIMILAR)

EXAMPLE: A 7-TO 9-VOLT RELAY REQUIRES FROM 14 TO 18 CELLS. USE INDIVIDUAL CELLS OR CONNECT APPROPRIATE NUMBER OF SOLAR ARRAYS IN SERIES.

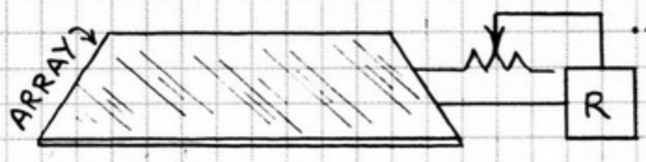
IN TESTS OF PROTOTYPE CIRCUIT, THE RELAY PULLED IN EVEN WHEN THE ARRAY WAS TILTED SOMEWHAT AWAY FROM SUN.

SENSITIVITY ADJUSTMENTS:



RELAY

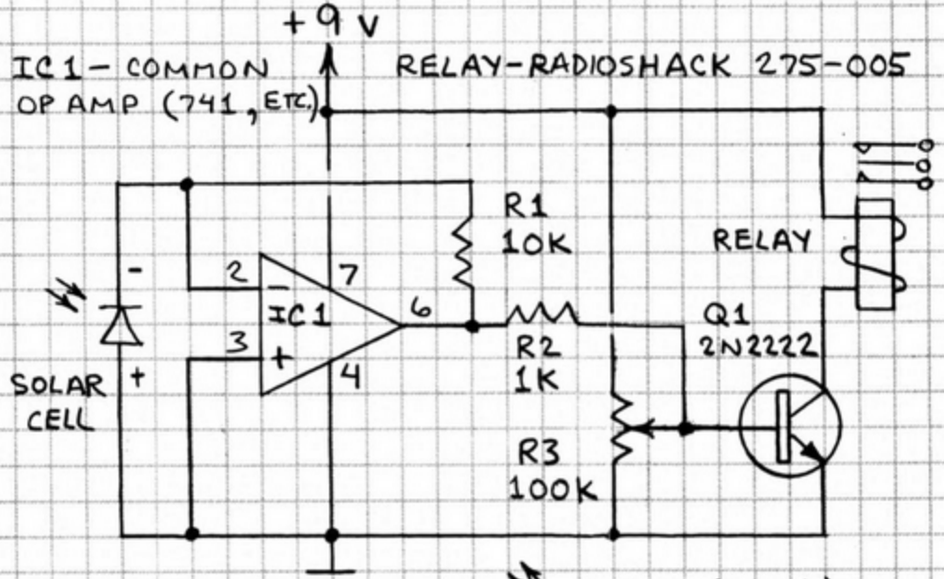
BLOCK PART OF THE ARRAY WITH AN OPAQUE COVER TO REDUCE SENSITIVITY, OR...



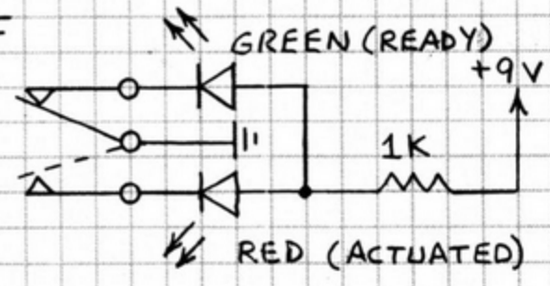
...USE 1K POTENTIOMETER RATED AT POWER OF ARRAY.

LIGHT ACTUATED RELAY

A SOLAR CELL GENERATES A PHOTOCURRENT WHEN ILLUMINATED. THE CIRCUIT SHOWN HERE AMPLIFIES THE CURRENT FROM A SINGLE SOLAR CELL AND DRIVES A RELAY. THIS CIRCUIT WILL WORK WITH A VERY SMALL SOLAR CELL AND WILL RESPOND TO VERY LOW LEVELS OF LIGHT.



CONNECT THIS PAIR OF LEDs TO THE RELAY TERMINALS TO INDICATE THE CIRCUIT STATUS.



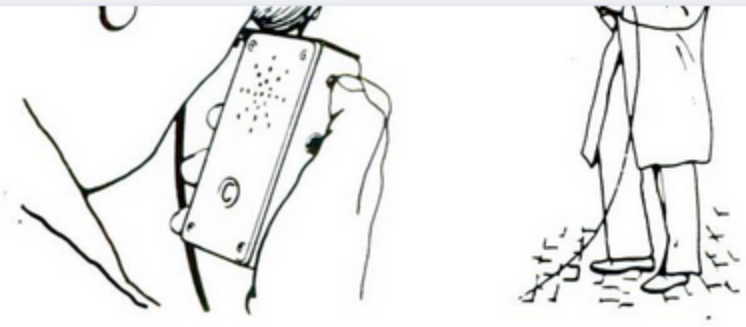
WITH ROOM LIGHTS SUBDUED, ADJUST R3 UNTIL THE RED LED JUST STOPS GLOWING AND THE GREEN LED GLOWS. LIGHT FROM A FLASHLIGHT WILL TRIGGER THE CIRCUIT AND THE RED LED WILL GLOW. THE CIRCUIT WILL RESPOND TO AN LED, MATCH, CANDLE, DAYLIGHT AND A LASER POINTER. SINCE THE CIRCUIT RESPONDS TO MANY LIGHT SOURCES, NEVER USE IT TO CONTROL HAZARDOUS THINGS (MACHINERY, ETC.).

certain lasers: "Let a polarized beam of light be passed through a solution of bisulphide of carbon contained in a vessel inside a helix of insulated wire, through which is passed an undulatory current of electricity from a microphone or telephonic transmitter operated by the voice of the speaker. The passage of the polarized beam should be normally partially obstructed by a Nicols prism, and the varying rotation of the plane of polarization would allow more or less of the light to pass through the prism, thus causing an undulatory beam of light capable of producing speech." [12]

Bell also disclosed a lens inspired by Tainter such that its focus could be altered acoustically. Various transmitter light sources were described as were the assembly details of various selenium detectors.

Most remarkable of all was the paper's description of the development of non-electric photophone receivers in which modulated light falling upon disks of hard rubber, zinc, antimony and many other substances stimulated the direct production of sound. This work led to the discovery by Bell of what is now called *optoacoustic spectroscopy*.

While Bell was in Europe in late 1880 to receive the Volta Prize for his invention of the telephone, Tainter proposed lampblack as a substitute for selenium. When Bell returned in January 1881, they fabricated several lampblack detectors, the most effective of which Bell described in a paper presented before the National Academy of Arts and Sciences on April 21, 1881: "Silver is deposited upon a plate of glass, and a zigzag line is then scratched through the film, dividing the silver surface into two portions insulated from one another, having the form of two combs with interlocking teeth.



Richard Gundlach of Bell Labs listens to Elliot Sivowitch of the Smithsonian Institute speak over a fiber optic transceiver at the site of the invention of the photophone exactly a century earlier.

"Each comb is attached to a screwcup, so that the cell can be placed in an electrical circuit when required. The surface is then smoked until a good film of lampblack is obtained, filling the interstices between the teeth of the silver combs. When the lampblack cell is connected with a telephone and galvanic battery, and exposed to the influence of an undulatory beam of sunlight, a loud musical tone is porduced by the telephone." [13]

In this paper, Bell also elaborated upon his work with a non-electric photophone receiver made by coating the inner surface of a funnel-shaped brass cone with lampblack. A window of plate glass covered the funnel's base and a hearing tube was attached to the opening at the funnel's apex. When sunlight was reflected from a vibrating mirror transmitter to the receiver 40 meters away, "Words and sentences spoken into the transmitter in a low tone of voice were audibly reproduced by the lamp-black receiver."

Legacy of the photophone

Bell and Tainter eventually devised more than 50 means for voice modulating a light wave before shifting their efforts to the development of improved sound recording methods and other projects. The popular press of the period was not overly impressed with their achievements. For example, an unsigned editorial in the *New York Times* on August 30, 1880 allowed that while members of the AAAS might understand the photophone's operation, "The ordinary man. . .may find a little difficulty in comprehending how sunbeams are to be used. Does Prof. Bell intend to connect Boston and Cambridge. . .with a line of sunbeams hung on telegraph posts, and, if so, what diameter are the sunbeams to be, and how is he to obtain them of the required size? What will become of the sunbeams after the sun goes down? Will they retain their power to communicate sound, or will it be necessary to insulate them, and protect them against the weather by a thick coating of gutta-percha? The public has a great deal of confidence in Scientific Persons, but until it actually sees a man going through the streets with a coil of No. 12 sunbeams on his shoulder, and suspending it from pole to pole, there will be a general feeling that there is something about Prof. Bell's photophone which places a tremendous strain on human credulity."