INSTRUMENTATION

"Sunlight in its many guises, is the force that has shaped and driven the miraculous living fabric of this planet for billions of years. It embodies the best engineering, the widest safety margins, and the greatest design experience we know. It is safe, eternal, universal and free. It falls justly and equitably on South & North, East & West."

Ted Taylor, U.S. nuclear physicist and former bomb designer

"The amount of solar energy absorbed by the earth and its atmosphere in just one year is equivalent to one hundred times the energy stored in the worlds proven reserves of fossil fuels. If we could capture just one ten thousandth of this energy, using solar collectors, specially designed buildings, wind and water turbines, wave energy converters, trees and other fuel crops, we could supply more useful energy in a year than we currently get from burning coal, oil and gas. Unlike fossil fuels, renewable energy can not be exhausted. Over the last twenty years a whole range of more efficient, advanced renewable technologies have been developed. Yet industrialised countries, having grown dependent on fossil fuels, are only just beginning to take advantage of abundant opportunities to shift to renewable energy."

Dr. Michael Flood, Friends of the Earth

Influenced by the above and pressured by budgetary constraints, the governors of the school have requested an investigation of the micro-climate of the school grounds to decide on the best site for the location of a solar panel or a wind generator.

TASK

As technology students with specialist skills your task is to provide appropriate equipment (anemometer and solarimeter) to resource the investigation.

Collection of solar radiation or windspeed data will be a necessary part of testing your product, as well as being the first step in helping to identify the best spot for siting the planned wind generator or solar panel.

RESEARCH

You will need to make full use of all sources of information available to you when developing your design specification, including: libraries, commercial leaflets, computer databases, CD ROM, yellow pages, videos, teachers and specialists, visitors and speakers, school-industry links, and through writing letters, site visits, market research of existing designs, questionnaires, testing.

DESIGN PROCESS

This is a design and make project, therefore each student must:

- Analyse the problem
- Assess existing designs in the market place
- Develop a suitable specification to meet the defined need
- Use appropriate graphical media to generate ideas and develop solutions.
- Use appropriate materials to produce developmental models.
- Produce orthographic working drawings of a design solution.
- Construct your design solution
- Produce an instruction booklet providing guidance for the final user
- Evaluate all stages of designing - produce evidence of product testing with verification by independent observers.

DESIGN SPECIFICATION

The full design specification for your chosen instrument should consider:

Cost of production
Quantity to be produced
Method of catching wind and quantifying wind movement (anemometer)
Use of bearings (anemometer)
Method of measuring solar radiation (solarimeter)
The effect of glazing (solarimeter)
Use of materials
Operating range
The required level of accuracy
Data collection and display
The use of the finished product

Your final design specification will develop as you further your research.

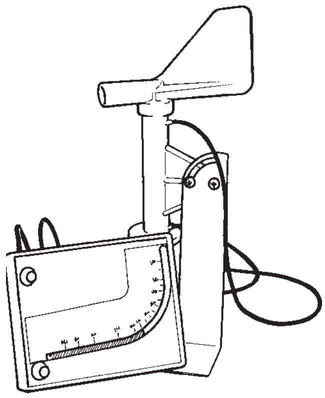
DESIGN FEATURES

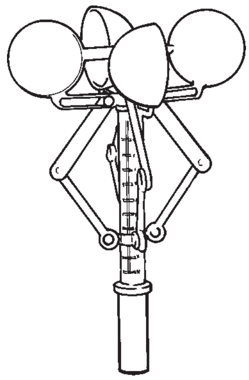
Your design should also consider:

Aesthetic appearance
Anthropometrics
Manufacturing methods available
Ease of production
Ease of calibration
Ensuring quality
Weather proofing
Safety

Briefing Sheet 1

Assessing Commercial Designs





Evaluating existing products in a clear and structured way can develop an understanding of how other people have approached similar design problems. This evaluation process can be a valuable guide to your own design solution.

Data about existing designs can be gathered through an assessment of commercial literature available for each product. This enables a broad based assessment, however it is obviously far better if you can obtain the actual devices themselves. Information about where you might try to obtain existing products, to buy or borrow, is provided at the end of this briefing sheet.

When faced with several objects designed to do more or less the same job it is important to apply some kind of criteria to judge which is best. The following checklist represents a good starting point from which to consider the range of different devices you might be assessing.

- Is it suited to its purpose?
- Is it easy to use?
- Is it good looking?
- Is it simple to maintain?
- Is it well made?
- Is it safe?
- Is it good value for money?

To analyse a product in greater detail requires more precise questioning, for example:

- Are the controls easy to operate?
- Are dials and markings easy to see and read?
- Is it easy to dismantle and store?
- Are the operating instructions easy to follow?
- Is data logging a feature?
- Have human factors been applied to the design? i.e. ergonomic and anthropometric data.

To assess the product in such detail will require you to carry out a survey. Recording and presenting your results is important. You may choose to use a database or spreadsheet. An example of a suitable layout is shown below.

Anemometer or Solarimeter Survey

Make	Price	Ease of use	Remote sensing	Accuracy	Legibility of scales	Choice of units

The awarding of a score for each of the evaluation criteria is essential. Using a five point scale, 1 poor to 5 excellent, might be appropriate.

Before applying the scores ask yourself:

- What do you mean by poor? In what way was it bad?
- What do you mean by average? Perhaps you can not see any good or bad points
- What do you mean by good? Some definite qualities perhaps

In the context of this project you should also evaluate the products from someone else's point of view. You may find as a result that your 'best product' will change.

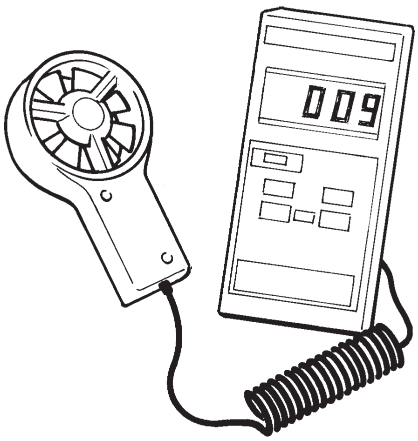
Using the same evaluation criteria and scale consider the products from the perspective of:

- A person with poor vision
- Someone with a physical disability
- Someone from another culture who does not read or speak English

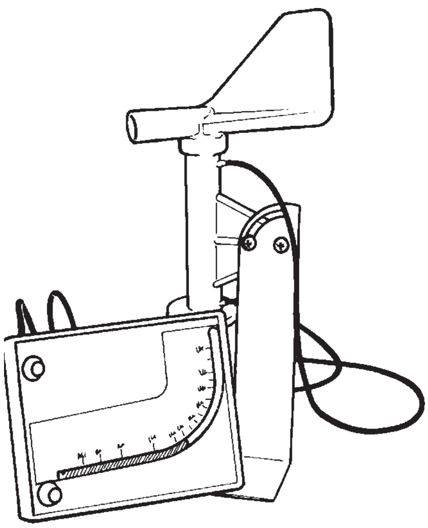
The application of this type of product analysis and evaluation should not be seen as a separate activity from designing and making. It is very much an integral part of the whole process. In evaluating existing products you will gain valuable insight into the work of other designers. Use this to develop a questioning approach to all aspects of your design work.

EXAMPLES OF COMMERCIALLY AVAILABLE ANEMOMETERS

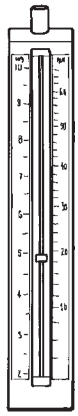
If the school does not possess some of the more expensive anemometers then it should be possible to borrow examples from the local university or college, or the local council (possibly the Highways Department) or maybe a local company.



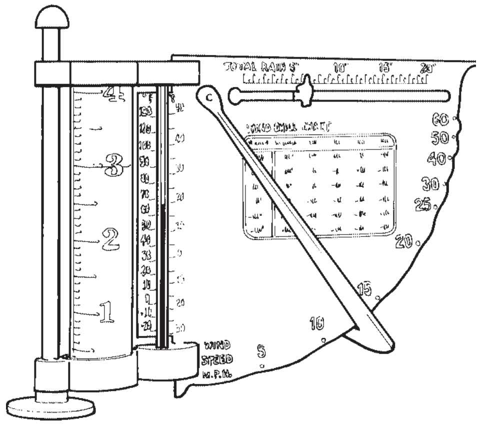
- Digital. Features - portable accurate with remote sensor. Large easy to read display. Choice of units (m/s, km/hr, feet/min or knots). Data hold Function. Cost - £150



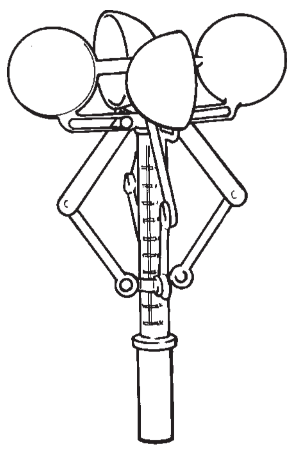
- Windspeed Indicator. Features - permanent installation operating on the pitot tube principle (aircraft airspeed indicator). Measuring tube fits onto a rotatable plastic vane. Reading is given by movement of coloured liquid along a tube calibrated 0 to 80 mph and 0 to 12 on the Beaufort scale. Supplied with instructions for assembly and use. Cost - £100



- Windspeed Meter. Features - hand held therefore portable. Hold into wind, speed given by twin scales reading from 2 to 10 mph and from 4 to 66 mph. Supplied in waterproof, plastic case with maintenance kit. Cost - £30



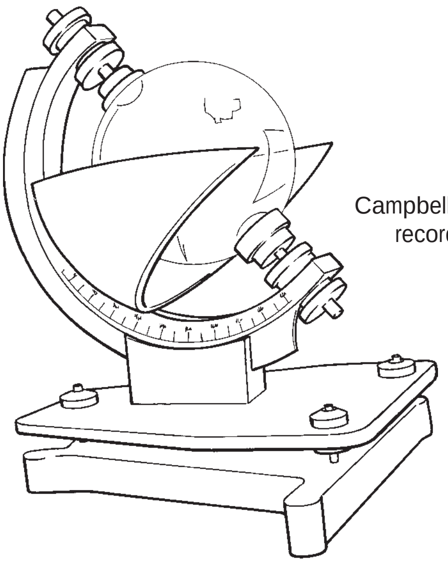
- 6 in 1 Weather Station. Features - Records rainfall, measures temperature, and shows both direction and speed of the wind together with 'wind chill' factor. Measures 6.75" x 4.75", fixes to post or fence. Cost - £8



- Invicta Anemometer. Features - hand held therefore portable. Hold device into wind. Readings of windspeed are read directly off two scales. Calibrated in km/hr and the Beaufort scale. Cost - £11

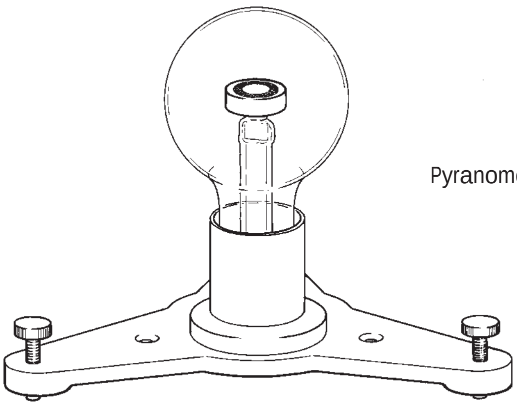
EXAMPLES OF COMMERCIALLY AVAILABLE SOLARIMETERS

The traditional Solarimeters used by the Meteorological Office (known as Campbell-Stokes recorders) consist of a glass ball, a few inches in diameter, which focuses sunlight onto a card strip mounted behind it. The energy from the sun actually burns a line across the card, which is marked to show the numbers of hours of sunlight. The card has to be replaced each day. One limitation is that these devices will only register solar radiation of 300 W/m^2 and above. They do not record diffuse radiation at all.



Campbell-Stokes recorder

A popular type of commercial solarimeter is the pyronometer. This consists of a small black disc in the centre of another reflective disc. Both are completely encased in glass dome. The temperature difference between the two discs is then measured. The temperature difference is entirely dependent on the light level, because the light is reflected from the shiny surface and absorbed by the black, making the black surface hotter. Heat from the surroundings will affect both discs equally and therefore will not cause a temperature difference. The temperature difference is measured either by two thermometers or thermocouples.



Pyranometer

BRIEFING SHEET 2

PRODUCTION PLANNING

Project planning is an organised way of ensuring that a product or service meets the required standards of quality and is delivered on time with the least amount of disruption or distress.

In industry, planning touches all aspects of a Company, the product or services, the working environment, the management structure, decision making strategies as well as research and development, marketing, product quality, prices and so on. In todays economic climate, planning plays an important part in the success of most commercial enterprises. In relation to your work, planning the production stage is all important if you are to complete your project by a given date.

A number of techniques are available to you,

- Bubble diagrams for example are very helpful for dividing activities into smaller topics.
- Flow diagrams or flow charts are a form of graphical representation of certain activities.
- Critical Path Analysis (CPA) is another graphical method of recording the sequences and timing of the various tasks which together form a project.

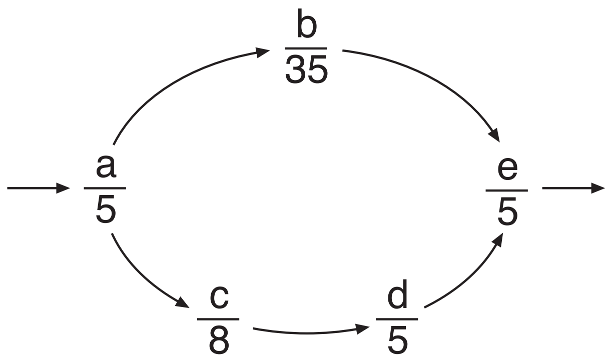
At this stage it is important to understand the following definitions:

'The project is the goal, it can be broken down into a number of sub projects or tasks.'

'The sub project also has a goal but is a part of the overall project. It can be broken down into a number of tasks.'

'A task is an activity identified and understood by you. It does not have to be broken down into smaller steps.'

The graphical representation of the above is as shown in the diagram below. Each task is represented by a 'node'. Nodes are usually identified by a task letter and also contain a figure representing time. The arrows between the nodes point towards the next task in the sequence. When several tasks are carried out simultaneously paths are drawn separately.



The longer path, the one through (a) (b) (e), is the critical path. It is important because if you want to save time this is the path which is critical to the whole activity.

Students are reminded that they must provide evidence of production planning. This can be achieved by:

1. Subdividing the production activity into sub projects and tasks. (Bubble diagrams can be helpful).
2. Specifying or making a reasonable estimate of the time required to complete each task.
3. Drawing a flow diagram to determine the duration to the production activity.

BRIEFING SHEET 3

PRODUCT DEVELOPMENT AND EVALUATION

Testing Product Performance
When a product is designed and manufactured, either in school or in industry, it will need to work and should be a pleasure for the user to operate. It will need to be effective, efficient and safe.

As soon as possible during the design process the designer needs to answer the following questions:

- Are the materials used in the product strong enough?
- Is there too much material in the product, making it more expensive than need be?
- Will parts of the product wear out too soon?
- How long will the product last?
- What are the running costs of the product?
- Does the product carry out the job it is meant to?
- Is the product safe?

To find answers, various tests are carried out. The earlier in the design process that tests are done the less complicated it is to make modifications. Some of the important tests can be done during the design stage on small samples.

These include tests on:

Materials -	will they be strong enough? Are they flexible enough? What is the minimum size that each component can be?
Jointing methods -	will they cope with the stress that will be applied?
Finishes -	will they stand up to the environment in which they are to be used?

Once the product is in prototype form, other tests can be carried out:

Is the product comfortable to use?
Can the product be used safely?
Is the product efficient?

Final Product Evaluation
(Come back to this when you have finished your product)
When you have your final product you must evaluate your device both in terms of how well it meets your original specification as well as, how well it will meet the demands that will be placed on it during use.

If your final product deviates in any way from your original specification, you will need to explain these differences in terms of the design process you went through.

It would be useful to carry out the same tests you carried out on the commercial instruments if available, how does yours compare?

An important stage in helping to assess the problems that might be encountered during the use of your product is to write an instruction booklet for prospective users.

Designing an Instruction Sheet for your Anemometer or Solarimeter

What are the important bits of information any prospective user of your device will need to know?

You should assume that these people will know nothing at all, except that they want to find out how much wind energy or solar radiation there is on their property, with a view to putting up a wind generator or solar panel, and that they have bought your instrument.

So they take their shiny new toy out of its box and look for the instructions.

What things do they need to know, in what detail and in what order?

How will you present it so that they can follow and understand it easily?

It is a good idea to try to think yourself into the mind of the people who will be reading it. Go through the instructions as you develop them. What have you missed out? There will always be something you didn't think of.

You need to provide a methodology for getting them from taking the instrument out of the box to identifying their best site for their renewable energy technology.

So your instructions will need to:

- Identify the practical things that they will need to know about how to set it up, down to the level of what bolt fits where.
- Highlight how the device will need to be used to ensure accurate data collection.
- Outline precisely what data they will need to collect and how the data should be interpreted.

Having written your instruction booklet, try it out on someone who has never seen it before. Did they understand it? Were any problems they came up against due to a failing in the instructions, or in the design itself? Include your findings in the overall evaluation of your product.

Briefing Sheet 4

Graphics Techniques

Your Introduction to the Topic asks you to complete various stages including:

- use of appropriate graphical media to generate ideas and develop solutions

- produce orthographic working drawings of a design solution.

When you have finished your research you can start to generate ideas. This is the most creative area of the designing activity and involves thinking and sketching. At this stage you may wish to draw complete solutions: DON'T. It is better that you make quick sketches of outlines and rough forms which can be easily modified. This development of your idea must be carried out with reference to the materials, processes and time available to you. Eventually you will prepare working drawing which will be used to make your final solution.

To help you in this activity there are many excellent books available. The titles referred to below are but a few.

Useful References
Suggested reading for developing graphical skills:

Design Graphics	*Blackwell*
Design & Communication	*Collins CDT series*
Design Topics Series	*Oxford University Press*

BRIEFING SHEET 5

MODELLING

Models are a useful aid to the development of design ideas and can be effectively used at a number of different times during the design process

- **Exploratory models** - use any suitable material to make a mock up or rough model to investigate the idea. Found materials such as unwanted packaging are particularly useful.
- **Prototype models** - made with care to resemble the 'real thing'. These detailed models can be made using Balsawood, Perspex, Polystyrene etc., as well as fillers, such as Plastic Padding and Isopon. Spray paints, transfer lettering and 'go - faster' stripes such as those used on cars can be added to improve the appearance of the prototype.
- **Demonstration models** - prove that an idea will work. Usually made of card or sheet plastic, with specialist fittings such as eyelets or paper fasteners to achieve mechanical movements. Components from construction kits (Lego, Fischer-Technik, Meccano) may be added to demonstrate a mechanical or pneumatic system.

Modelling Checklist

Before you model:

* decide on the exact purpose of the model
* decide on the level of detail which will be needed
* select the appropriate materials to make the model. (Cost is usually the main consideration).
* choose a suitable material scale for the model
* consider the method of construction

After you model:

* Reflect on how many things fitted together
* Does the model look right? - a value judgement
* Does the model work as expected?
* Do the systems operate?
* Is the shape and size correct?

Material Checklist
Paper and cardboard
Balsa
Styrofoam
Plastic sheet
Plaster of Paris
Wire and welding rod
Florists wire
Construction kits
Found materials

Useful References
Product Modelling
Design Topic Series
Oxford University Press

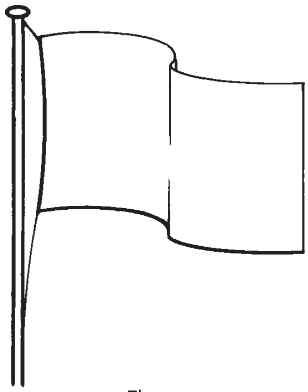
BRIEFING SHEET 6

CATCHING AND QUANTIFYING WIND MOVEMENT

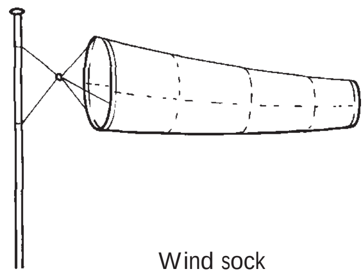
Catching the wind
Your objective is to design an anemometer that can be used to help discover the best possible wind power site on the school grounds. What is needed is a place with a good steady wind. This is not necessarily the windiest spot as turbulence may be a problem. Obstructions, such as hedges, trees, walls and buildings can create turbulence. With height the wind becomes 'cleaner'. These factors need to be considered when designing your anemometer as well as during the collection of the windspeed data

How are you going to catch the wind? Your anemometer design will have to effectively catch the wind in such a way as to enable the movement to be calibrated and provide a reading of the current wind speed

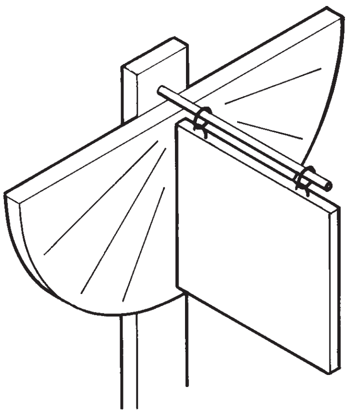
Here are a few common ways that the wind is monitored: Obviously some methods are easier to quantify than others



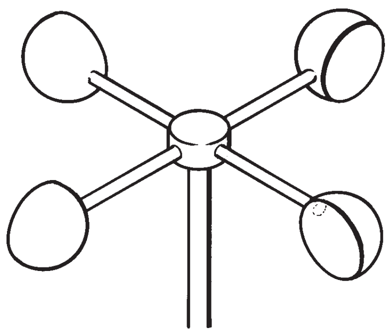
Flags



Wind sock



Flaps - could be aluminium, perspex, polystyrene etc



Cups - could be vacuum formed plastics, bubble blown perspex, etc

Quantifying wind movement

You can get something to move by the force of the wind, but how do you then measure that movement in such a way that you can work out the windspeed?

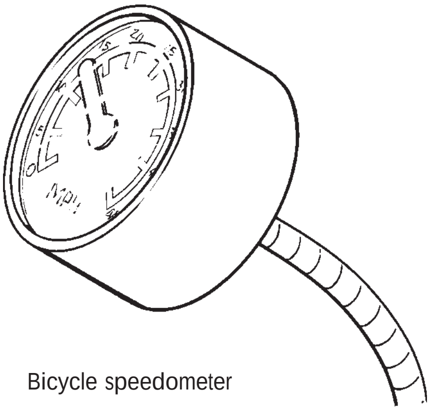
You will have to record the movement over a period of time. This movement might be rotational, but it might also be a linear or curved movement which is proportional to the windspeed. If we are dealing with linear or curved movement (similar to what might be obtained from a flap type system) then quantification is just a case of calibrating the movement of the device in known wind speeds or with another anemometer.

With rotational movement, quantification is more complex. Clearly the device will rotate faster, the faster the wind blows, so, you need to record each rotation against time or something that approximates to this.

There are three main ways this can be achieved:

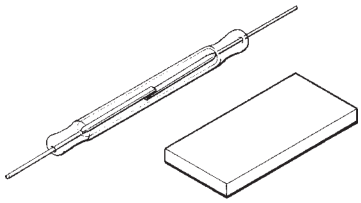
- Physical displacement
- Electrical measurement of frequency of rotation
- Electrical generation

Option 1 is the equivalent of the speedometer on a car or an older bike

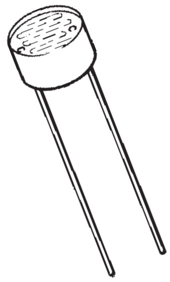


Bicycle speedometer

Option 2 can be achieved through:
- a reed switch, where a passing magnet will turn it on,
- a light sensitive electronic switch
- a light dependant resistor/diode or photovoltaic cell
- a physically operated switch

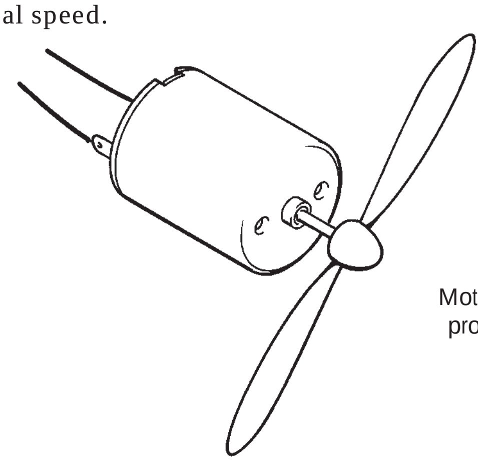


Reed switch and magnet



Light dependent resistor

Option 3 is the equivalent of a small wind generator with the output proportional to the windspeed. You will need to consider the motor operating range to ensure effective matching with the rotational speed.



Motor with propeller

The part of the device that moves in reaction to the wind should not be slowed down so much that it will not move in low wind speeds. This could happen with too much friction or by too strong a magnetic force.

The light sensitive switch option will require effective masking to prevent the sun or artificial light from upsetting the system, unless either of these sources is acting as the stimulus. Don’t forget all this has to be weatherproof.

You will need to research these options to identify the one that is appropriate for your application. You will also need to consider how to calibrate the physical displacement, the rotational frequency, or the electrical output depending on the option you choose.

Calibration is of course essential, and to do this effectively you will need compare your readings with a reliable anemometer. If the school doesn’t have a weather station then it should be possible to borrow an anemometer from a local university or college, or from the local council, quite often the Highways department can be helpful here. Try local industries or if all else fails try another school!

During calibration it is important to test your device in as many different wind speeds so it can be calibrated throughout its range to account for the different frictional effects. Every device will be different, unless it has been mass produced, so don’t rely on someone else’s readings!

BRIEFING SHEET 7

USE OF BEARINGS

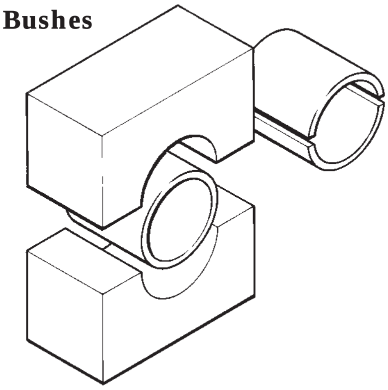
The study of moving surfaces, friction, wear and lubrication is called tribology. In a machine with moving parts e.g. a moving vane anemometer, friction will exist. In other words, no machine is 100% efficient and the effect of friction is to convert mechanical energy into heat energy which is usually lost to the surrounding air. Although accurate calibration will account for the effects of friction, excess friction can prevent effective measurements in low wind speeds.

Bearings are used to support moving surfaces with reduced friction and wear. Lubrication reduces friction by putting a layer of oil or grease between the moving surfaces. Viscosity is a measure of how easily an oil will flow.

As a designer and maker you will need to carefully consider and document the type of bearing you will incorporate in your project:

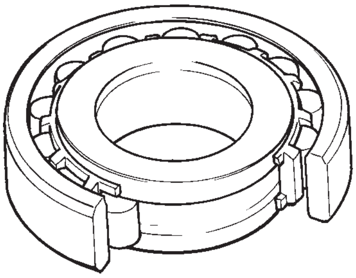
The following is basic information which may serve your needs. Alternatively it may form the foundation upon which you can expand your knowledge through personal research.

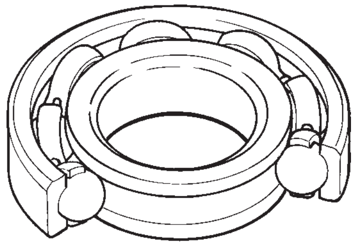
Plain Bearings or Bushes



Materials: *nylon, aluminium or brass*
Application: *low speed, load bearing*
Cost: *Inexpensive*

Ball Bearings and Roller Bearings





Materials: *hardened steel*
Application: *support a moving shaft, high speed and load.*
Cost: *expensive*

Note: these bearings reduce friction better than plain bearings.
Local suppliers: Yellow pages and the telephone directory is the place to begin your search.

Found Materials
Discarded goods are a rich source of bearing materials:
video recorder, record players, tape players, cassette recorders, photocopiers, toys, bicycles, motor cycles, motor vehicles, food mixers, washing machines etc.

Also consider the more basic items found in household dustbins, from time to time:

washing up liquid bottle tops (the nozzle)
jewellery beads
clock parts
kitchen utensils etc.

Remember you are only limited by your own imagination.

BRIEFING SHEET 8

CATCHING AND QUANTIFYING THE SUN'S LIGHT

A solarimeter will measure the amount of solar energy falling on it, and can therefore be used to help identify the most appropriate location on your school site to place solar panels of some sort.

What do you actually need to know?
What range of light levels will you want to measure?

Different types of light will reach your device -

- *direct sunlight*
- *diffuse light (through clouds)*
- *reflected light.*

How do these vary and what are the implications of that?

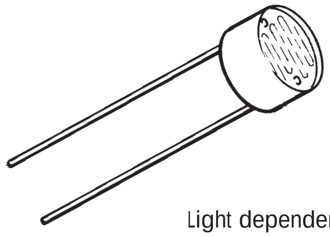
What you need to measure is light and not heat, but you might decide that you could convert the light to heat in order to measure that. If you do you will need to be absolutely sure that what you are measuring in the first place is just light.

How do different materials respond to sunlight? And what type of response do you get?

With some things the response takes the form of heat, while with others there may be an electrical reaction or a chemical change.

Materials respond to the sun by getting hot and therefore expanding, evaporating, burning. The electrical conductivity of some things will change in different temperatures.

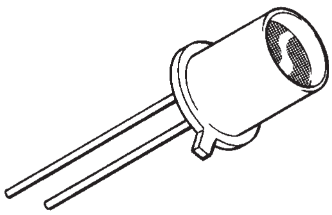
Electronic components that respond to light.
LDRs - light dependent resistors.



Light dependent resistor

The resistance of an LDR increases the darker it is.
Its output is not absolutely linear, i.e. the output does not increase or decrease in direct proportion to the light falling on it through its whole operating range. They also ‘drift’, i.e. after a time the resistance at a given light level is not the same. This is certainly relevant if you will want to use your solarimeter for more than one season. They do not produce a zero reading in the dark.

Photodiodes and photovoltaic cells are the same thing inside. They are both photovoltaic cells made of silicon and will produce electricity when light falls on them. They are packaged differently for different purposes. The photodiode is usually very small and is designed to measure light levels, while the solar cell is usually larger and is designed to produce a useful current.



Photodiode

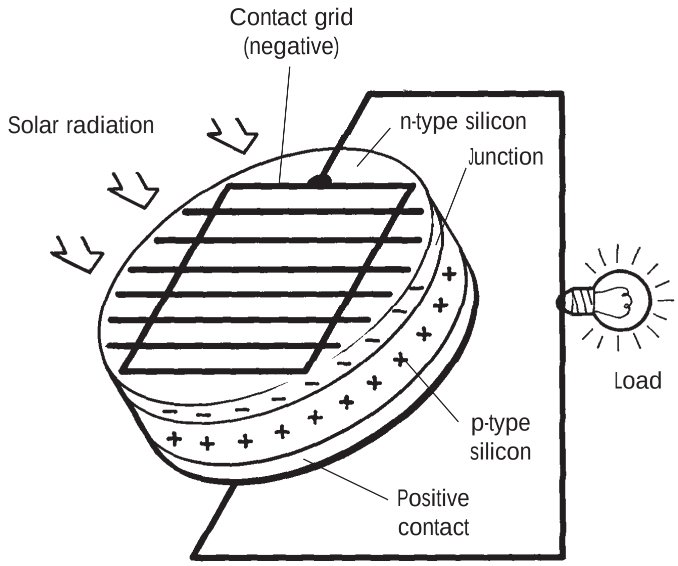
Both produce zero current in the dark. Both produce a linear current output. The current increases, from very low light levels, in direct proportion to the amount of light falling on them. However, their voltage output is not linear.
If they get extremely hot they can be damaged, so you need to beware of increasing the temperature by focusing light.

Photovoltaic Cells (PVs)

Most PVs are made of silicon. Pure silicon is an insulator but the cells have two very thin layers of silicon which each have different trace impurities such as boron, arsenic or phosphorus added. This creates an electrically 'positive' layer and a 'negative' layer and where these layers meet a semi-conductor junction is set up. The negatively charged electrons can pass much more easily in one direction than the other.

When light falls onto a PV cell its electrons are energised. The number of energised electrons is in direct proportion to the intensity of the light reaching the cell. These energised electrons have enough energy to jump across the junction, but are unable to return, so one side ends up with a surplus of electrons. Thus a potential difference is produced.

It is light, i.e. the visible region of the electro magnetic spectrum, which caused the photovoltaic effect, not the ultra violet region or the infra red heat. However, the wider the range of frequencies that PVs can respond to, the greater the amount of the sun's energy they can convert to electricity.



Construction of a silicon photovoltaic cell

If you feel that you need to amplify the electrical signal produced you need to use something which will not be temperature sensitive. A simple transistor would not be stable because the current gain varies with temperature. An op amp amplifier would be better because it is not affected by heat.

You could convert the light to heat and measure that. If so, beware of thermistors as they do not give a linear reading.

The short circuit current of a solar cell can be re-calibrated to show solar radiation levels. If the current increases in a linear way from zero in total darkness to 1000 W/m^2 in clear sunlight at midday during the summer then it is possible to calculate the maximum current generated:

Amps = Watts (1000) ÷ rated max. voltage

and then recalibrate an ammeter to read W/m^2.

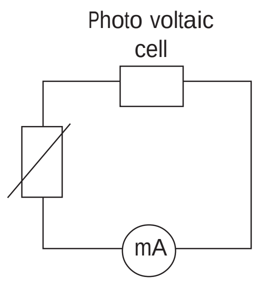
For example, if your cell was 10% efficient, 400 mm^2 in area and had a rated maximum voltage of 0.45 V, you would expect it to produce:

max output for cell =

area/1m^2 × max power output (for 1m^2) × cell efficiency

$$\frac{400\ mm^2}{1,000\,000\ mm^2} \times 1000\ W \times 0.1$$

$$= \frac{1}{2500} \times 1000 \times 0.1 = 0.04\ W$$



Therefore the maximum current would be:

I = W/V

$$\text{Max current} = \frac{0.04}{0.45} = \mathbf{0.089\ A\ or\ 89\ mA}$$

Using an appropriate variable resistor it is then possible to match the full scale deflection on the milliammeter used to the required range.

Briefing Sheet 9

Data Collection, Display and Interpretation (Wind)

An essential stage in designing the final product is assessing the type of information that you actually want from the anemometer. Only then will you be in a position to be able to make the right choice of display system, whether to go for data logging or whether it is possible to achieve your goal by other means, and to what tolerances you need to build the anemometer to in order to achieve the required accuracy.

Data Collection
So what data do you actually need? Clearly continuous measurements for a week will only tell you what the wind regime was for that particular week. How do you know that this was a representative week?

How much longer do you think you need to obtain readings for in order to get an accurate picture of the wind regime in your area?

There are low wind years and even low wind decades so it is impractical to get a full and accurate picture. However you do need to take readings for as long as you possibly can, i.e. months rather than weeks. Commercial suppliers of big systems will put up an anemometer for a few months. You need to consider which few months you will be looking at in order to get some idea of annual figures. Will November to February tell you the same as May to August?
When comparing data from different sites it is important to ensure that the anemometer was at the same height when the readings were taken.

Using Existing Data
Having collected data for a reasonable period of time it is then possible to look at the long term data produced by the Meteorological Office (Met Office). They have collected data for years, covering the whole country. This is not detailed enough or localised enough to give accurate information for siting but will enable the assessment of variations in the data over a longer period. These trends are important to identify because of the limited time span of the initial data collection, and can give valuable clues to how your figures might vary throughout the year.

In some areas there may have been other surveys done that might be more locally detailed and perhaps more accurate. Some local authorities have had surveys done and maybe your school or another local school has a weather station that might be able to provide useful local data.

It remains important however to collect the data in such a way as to enable effective analysis and interpretation of your results.

What is the required level of accuracy that you need to achieve? This can make a big difference to the design of the final product.

Data Analysis and Interpretation (wind)
There are a number of different ways of analysing the data and therefore different ways of interpreting it. One is to work out the average wind speed over the year (annual mean windspeed). What is wrong with only doing that?

Consider, for example, the following three sites, which each had a daily mean wind speed of 5 m/s -

a) On site A the wind blew steadily at 5m/s all day and the wind generator produced 100 watts all day.

Energy production totalled

$$\frac{100 \times 24}{1000} = 2.4 \text{ KWh}$$

b) On site B the wind was still for 12 hours but blew at 10m/s for the other 12 hours. The wind generator produced 800 watts in this stronger wind, because of the doubling of the wind speed.

Energy production totalled

$$\frac{800 \times 12}{1000} = 9.6 \text{ KWh}$$

c) On site C the wind blew at 5m/s for 12 hours, 10 m/s for 6 hours and was still for the other 6 hours, so it produced 100 watts for 12 hours and 800 watts for 6 hours.

Energy production totalled

$$\frac{100 \times 12}{1000} = 1.2 \text{ KWh} \quad \text{plus}$$

$$\frac{800 \times 6}{1000} = 4.8 \text{ KWh}$$

$$= \text{total } 6 \text{ KWh}$$

There are several points to note from this:

- The energy production can be much higher if the wind speed varies widely for sites with the same daily windspeed.
- Mean wind speeds do not necessarily show what the windspeed is most of the time.
- You will have to decide what you actually want in terms of energy production, i.e. a lot of energy for a limited period of time or less energy over a longer period.

Does the total amount of energy produced matter?

Is it a useful thing to know?

Does it matter if you get little or no wind for long periods of time?

Can you always use what is produced?

You need to consider then what you are going to power, how often and whether and how you will store the electricity.

Each design of wind generator has a range of speeds at which it will work most efficiently. An extreme example - supposing you got 10m/s for about 10% of the time and about 5m/s for the other 90%. If you designed your wind generator for the higher wind speed but only achieved this during November and December and the wind generator produced very little or nothing at 5 m/s, then your overall output would be very poor.

Therefore it becomes very important to consider the wind speed variations and the type of wind generator together with the identified energy need when you come to choosing the most appropriate site for your application.

This conclusion also has important implications for several major design decisions about the data collection and display aspects of the anemometer.

Briefing Sheet 10

Data Collection, Display and Interpretation (Sun)

An essential stage in designing the final product is assessing the type of information that you actually want from the solarimeter. Only then will you be in a position to be able to make the right choice of display system, whether to go for data logging or whether it is possible to achieve your goal by other means, and to what tolerances you need to build the solarmeter to in order to achieve the required accuracy.

Data Collection

So what data do you actually need? Clearly continuous measurements for a week will only tell you what the levels of solar radiation were for that particular week; how do you know that this was a representative week?

Do you need to log figures continuously over a period of time or would a series of instantaneous readings be adequate? You would need to make a realistic assessment of how you could take instantaneous readings, given the restraints of your timetable and see if that matches the data you need to collect.

Would it be reasonable to take a series of readings and extrapolate a solar regime from that?

What about seasonality? How long a period of time do you need to take the readings for?

Clear sunlight provides different amounts of solar energy depending on how high the sun is in the sky and your readings will relate to what angle the sun hits your device. How are you going to decide what angle to set it at?

Using Existing Data

Having collected data for a period of time it is then possible to look at the long term data produced by the Meteorological Office (Met Office). They have collected data for years, covering the whole country. This is not detailed enough or localised enough to give accurate information for siting but will enable the assessment of variations in the data over a longer period. These trends are important to identify because of the limited time span of the initial data collection, and can give valuable clues to how your figures might vary throughout the year.

In some areas there may have been other surveys done that might be more locally detailed and perhaps more accurate. Maybe your school or another local school has a weather station that might be able to provide useful local data.

It remains important however to collect the data in such a way as to enable effective analysis and interpretation of your results.

What is the required level of accuracy that you need to achieve? This can make a big difference to the design of the final product.

Data Analysis and Interpretation (sun)
Your solarimeter will tell you how much solar energy is falling on that particular spot at a particular moment.

The lumen is the SI unit by which the rate of flow (lux) of luminous energy is evaluated in terms of its visual effect.
1 lumen at 5550 A (wavelength) = 0.0015W.

A lux is the SI unit of illumination which is equal to 1 lumen per sq m.

However, it is usual in this context to measure solar energy in Watts. The intensity of the solar radiation just outside the earth's atmosphere has an average value of 1.353kW/m^2. This figure is known as the solar constant.

The maximum intensity reached in Britain (measured at noon on a clear midsummer day) is about 1kW/m^2. Over a year the intensity averages about 105W/m^2.

What do you need to know about the path of the sun through the sky at different times of day and in different seasons of the year? Does this have any implications for siting?

What impact does the angle of the sun in the sky at different times of day and times of year have on the amount of solar energy?

You need to decide whether you need to know -
- the total solar energy falling on a spot over the whole year,
- the amount of solar energy during limited periods of the year,
- the length of time that the solar energy exceeds a certain wattage,
- the number of hours in shade per day.

Your decision will be based on an understanding of the requirements for the technology to be installed, which in turn will be led by the use identified for the solar energy. In addition it is important to understand when the energy will be needed, Don't forget school holidays.