

MECHANICS LAB

ENGINEERING SCIENCE – MECHANICAL
ENR 1108

DEPARTMENT OF MECHANICAL
ENGINEERING

FACULTY OF ENGINEERING



STUDENTS' ACTIVITY

This lab work will be carried out as a group activity. Students will be divided into groups by their supervisor and then it is up to the students to organise themselves. It is always essential to have a team leader !

The students have to read the introduction to the theory behind simple machines and centrifugal force (given on pages 5-6) **and augment it by means of further literature search**. Students need only refer to mechanics textbooks.

The students need to perform the test on one machine / experimental setup in the mechanics lab situated on ground level on the west side of the Faculty of Engineering building. Usually there are set three hour laboratory periods during which students can meet with and get help from their supervisor. If students wish to perform further investigation they can arrange with the lab officer in charge in order to use the lab and the equipment outwith these set periods.

Each team is required to write one report (not more than 10 pages long) and present their work in front of their colleagues and supervisor in the form of a formal presentation (see attached practical tips on presentations). Each presentation must be of 15 minutes duration with 10 minutes left for questions. In the report (see attached notes) and presentation, students need to highlight how the test was performed, what readings were taken, difficulties met, etc. It is essential that each statement that is presented is backed up by an explanation.

For the case of the simple machine tests students are encouraged to investigate the various aspect of the simple machine such as the effort v.s. load response, the mechanical advantage v.s. load response, the friction effort v.s. load response and the efficiency v.s. load response. This is best done by plotting curves and drawing conclusions from them.

For the case of the speed governor and centrifugal force experiments more instructions on students' activities are given in the respective sections.

In the course of the test, students will be required to make measurements on certain components of the machine. **It is of paramount importance that students prepare beforehand for the lab session in the sense that they know what measurements they need to take and how to carry out the test.** After the test is completed students need to plot the required curves and perform the necessary calculations to check whether there is some gross mistake in their testing. If so, the test or parts of the test have to be repeated.

Students will be given a mark as a whole team so it is important that everybody gives an input in the work.

Students are encouraged to try to limit questions asked to the supervisor and lab officer to a minimum. The idea of the exercise is to leave the students to carry out their own investigations and obtain their own conclusions and results. Experience has shown us that in this way the lab session is more interesting and students learn more. The aim of the presentations is so that students learn from each others' work through the discussion after the presentation. So enjoy !

Looking forward to meet you in the lab !

SOME NOTES ON LAB WORK

The purposes of experimentation as a subject in the curriculum are many, but perhaps the most important ones are to provide opportunities for the student to

1. Verify certain theories
2. Become familiar with methods of measurements
3. Organise his/her own work and carry it through systematically and carefully
4. Help to organise the work of a team
5. Analyse data, assess their reliability and draw conclusions from them

The student is advised to enter every detail of his work as he proceeds into a notebook. The student needs to acquire this habit which he will find to be very useful in his career. The student should not try to seek the help of supervisory staff during a lab session except in cases of emergency or difficulties which cannot be resolved otherwise.

Reporting the work:

Structure of the report:

A formal report will usually consist of sections falling under some or all of the following headings:

- Front page which includes the heading, the student names, academic year, group number
- Title
- Object of the experiment
- Table of contents
- Introduction
- Notation used
- Theory
- Procedure and apparatus used (drawing or sketch)
- Results
- Discussion
- Conclusions or recommendations
- References
- Figures
- Appendices

Plotting graphs:

1. Always give a title and number to each graph
2. Include the scales and units of the variables
3. Mark the points clearly - +, *, □, O, ⊕, ●, ▲, ▼
4. Include a legend
5. If you plot curves on the same axes distinguish between them by using different kinds of ruling (colour, continuous, dotted, dash dot, etc)

Finally be sure to present a well structured report which shows that you understood your work.

PRACTICAL TIPS FOR PRESENTATIONS

Before giving a presentation it is always helpful to ask some questions to yourself :

1. What is the purpose of your presentation ?
2. What will your audience want to know ?

In an oral presentation it is always a good idea to:

1. Introduce yourself and your group
2. Highlight your main points i.e. give a brief overview of your presentation

Other practical tips :

1. Keep slide special effects to a minimum – these distract the attention of your audience.
2. Use only two colours or maximum three in your slides.
3. Use a large enough font so that words can be read by someone sitting at the back seat.
4. While presenting try not to read too much from your slides which must be concise and to the point. On the other hand slides must make sense if your audience tries to read some of them.
5. Do not flip forward or backward to search for a figure – it is better to repeat it and put it in place.
6. Do not show complicated figures but try to simplify them as much as possible – remember that in a presentation usually you only have 15 minutes to deliver what you want to deliver.
7. When using a projector or slide projector try to stand by the screen and point with a laser pointer or with some other pointer such as a slender rod.
8. Remember to breathe well during your presentation.
9. Speak slowly and distinctly.
10. Avoid too much slang.
11. Dress should be slightly smarter than your audience' – shoes clean and shiny, conservative business office dress, well groomed hair.
12. Presentations require practice, practice and more practice especially if it is to be delivered in the English language.
13. During question time be sure to understand the question well.
14. Do not be shy to admit on drawbacks of your work or whatever you presented.
15. Always show respect to your audience and especially build a good rapport with the session chair.
16. Finally enjoy presenting your work and making people interested. Keep in mind that your audience want you to succeed so that they gain from your presentation.

SIMPLE MACHINES

Introduction

A machine is an assembly of rigid bodies designed for the purpose of converting energy or for transmitting a force or torque thus doing work. An example of a simple machine found in the Mechanics laboratory is that of a worm and wheel.

Mechanical Advantage

A machine is usually designed so that the load overcome is greater than the effort applied. The ratio of load to effort is known as the mechanical advantage of the machine. Therefore

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}}$$

In an ideal machine there is no friction and the ratio load/ideal effort is then called the ideal mechanical advantage. In practice the actual mechanical advantage is always less than the ideal and is obtained by experiment.

The Effort - Load graph – the law of the machine

If an experiment is carried out on a machine to determine the effort E required to lift a load W for a range of values of the load then a straight line is usually obtained. Since the graph is a straight line, the relation between E and W may be represented by the equation

$$E = aW + b \quad \text{where } a \text{ and } b \text{ are constants which are obtained from the graph.}$$

This equation is known as the law of the machine

The Mechanical advantage - Load curve

A graph of mechanical advantage against load can be plotted from experimental values. From such a graph the mechanical advantage at any load may be obtained. Usually the mechanical advantage increases with load but there is no straight line relationship between these two quantities.

Friction effort

The effort required at any particular load to overcome friction alone is called the friction effort. The actual effort E required at any load is made up of two parts:

1. The effort required to move the load if the machine was ideal
2. The effort to overcome friction

Therefore friction effort = actual effort – ideal effort

$$= E - \frac{W}{\text{ideal mechanical advantage}}$$

Usually the friction effort increases linearly with load, but the increase in friction effort is not as great as the corresponding increase in load.

Velocity Ratio

To obtain a mechanical advantage greater than unity, the effort must move through a greater distance than that through which the load moves. Since the distances moved by the load and effort take place at the same time, the ratio of these distances is the same as the ratio of the velocities. The velocity ratio of the machine is therefore defined as:

$$\text{velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

The velocity ratio of a machine usually remains constant for all loads.

Using the principle of work it can be shown that for an ideal machine the velocity ratio is equal to the ideal mechanical advantage. But note that for a real machine the velocity ratio is not the same as the mechanical advantage since there is always some friction present and the actual mechanical advantage is always less than the ideal.

Efficiency

The efficiency of a machine is defined as the ratio of the useful work done by the machine to the actual work put into the machine. It can be shown that:

$$\text{efficiency} = \eta = \frac{\text{mechanical advantage}}{\text{velocity ratio}}$$

For a simple machine, efficiency usually increases with load until it reaches a limiting value.

CENTRIFUGAL FORCE

When a body of mass m is moving at an angular velocity ω along an arc such as a circle of radius r then there is a force, called the centrifugal force, which is acting on the body and which is trying to prevent the body from moving along that circle. This means that to keep that body moving in a circle we need to provide an opposing force equal to the centrifugal force. This force is called the centripetal force which is given theoretically by $m\omega^2r$.

This phenomenon is used beneficially in speed governors in order to control the speed of steam turbines, diesel engines, etc. The centrifugal force can also be a nuisance as well. Such a case occurs while rounding a corner in a slippery road while driving a car.

EFFICIENCY TEST OF A MACHINE – WORM AND WORM WHEEL

The worm and wheel

This simple machine is usually used for lifting heavy objects, for steering gears and for traversing tables in machine tools. The worm and wheel is used to transfer drive through 90° usually incorporating a high gear ratio and output torque. Figure 1 shows two views of a worm and wheel. The worm is basically a single or multiple start screw which meshes with a gear wheel whose teeth are inclined to the axis at the lead angle of the screw. In a cross section of the wheel, the teeth are concave so as to give line contact with the worm instead of point contact, as would be obtained with straight teeth. Thus the wheel is a helical gear. The pitch p of the worm corresponds to the circular pitch of the wheel. The lead of the worm L is the axial advance of the thread per revolution and for a multiple start worm having n starts $L=np$.

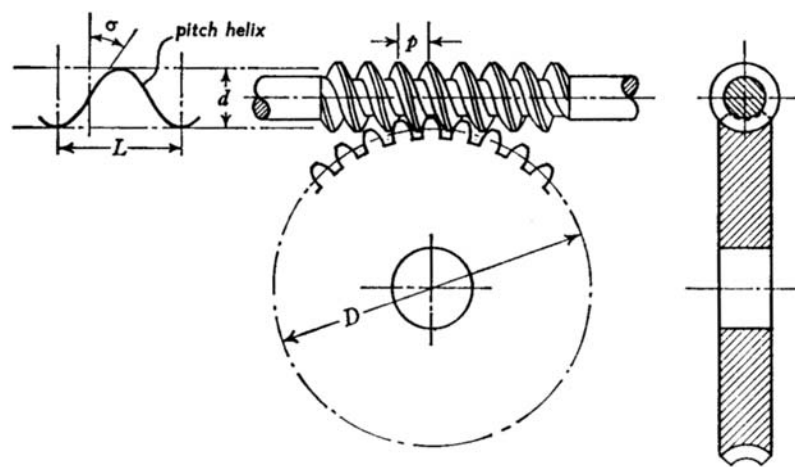


Figure 1 – Worm & wheel (Reproduced from Mechanics of Machines – J.Hannah, R.C.Stephens)

Object

To carry out an efficiency test on the worm and wheel lifting machine found in the mechanics lab and plot various parameters against load.

Apparatus

Worm and wheel lifting machine assembled as shown in figure 2

Various weights

Metre rule

Vernier calipers

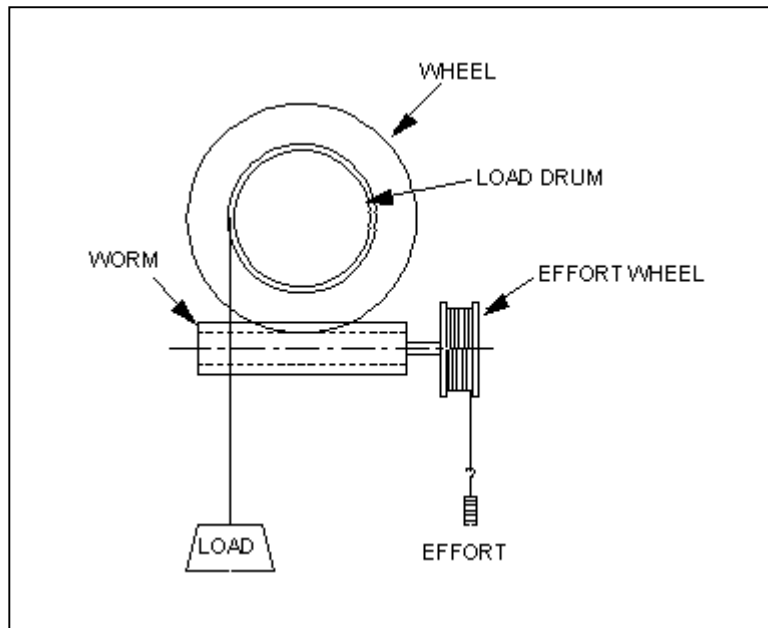


Figure 2 – Worm and wheel assembly

EFFICIENCY TEST OF A MACHINE – THE SQUARE THREADED SCREW JACK

The screw jack

A screw thread is a continuous helical groove which is cut around a cylindrical external surface. When a quick axial advance is required, two or more threads are cut side by side to form a multi-start thread. A good example for the use of a screw jack is that of raising a car. A screw jack is used in various mechanisms found in an engineering workshop. An example of this is the thread used to traverse the saddle of a lathe over the lathe bed. Another simple example which is familiar with everybody (hopefully !) is the screw used on most commercial toothpaste.

The *pitch* of a thread is the distance from a point on one thread to the corresponding point on the adjacent thread, measured parallel to the axis of the thread.

The *lead* is the axial distance moved by a screw during one revolution. For a single start thread the lead is equal to the pitch and for a two start thread the lead is equal to twice the pitch.

There are two main classes of thread forms: vee threads, which are principally used for fastening purposes and square threads, which are used for power transmission.

Figure 3 shows some various other thread terms.

Object

To carry out an efficiency test on the square threaded screw jack found in the mechanics lab and plot various parameters against load.

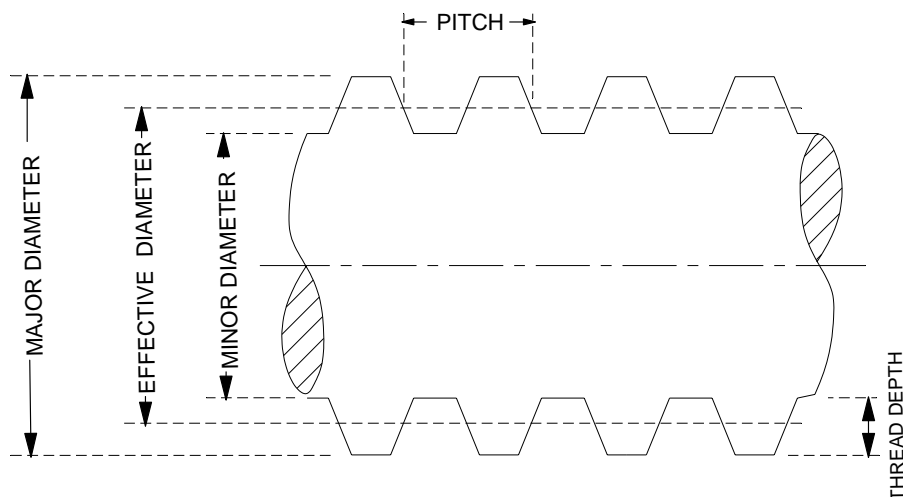


Figure 3 – Screw thread

Apparatus

Screw jack assembled as shown in figure 4

Various weights

Metre rule

Vernier calipers

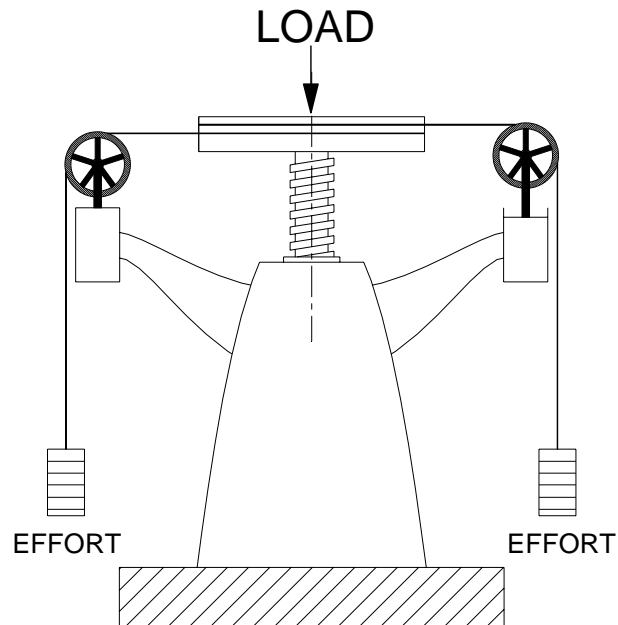


Figure 4 – Screw jack

EFFICIENCY TEST OF A MACHINE – THE DIFFERENTIAL WHEEL AND AXLE

The differential wheel and axle

In this type of winch, an effort applied to a large wheel winds the load rope on to a smaller wheel having a common axle with the larger. When the machine is of the differential type there are two axles of varying diameters and the load rope is wound on to the larger axle at the same time as it is unwound off the smaller as shown in figure 5. The result is that for every revolution of the effort wheel, the load is raised a distance equal to one-half the difference between the circumferences of the axles. This is because the loop, supporting the load pulley is shortened an amount equal to the differences in the circumferences of the two axles and half the shortening will occur on each half of the loop.

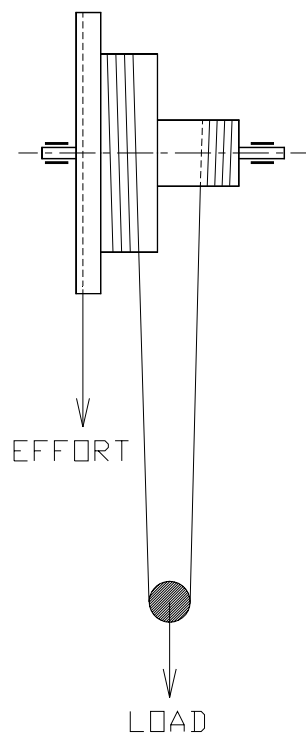


Figure 5 – Differential wheel and axle

Object

To carry out an efficiency test on the differential wheel and axle found in the mechanics lab and plot various parameters against load.

Apparatus

Differential wheel and axle assembled as shown in figure 5

Various weights

Metre rule

Vernier callipers

EFFICIENCY TEST OF A MACHINE – THE GEARED WINCH

The geared winch

In this type of winch, spur gears are used for transmitting motion between the input shaft and the output shaft thus raising the load. Gears, usually helical gears, are frequently used in gear boxes such as an automobile gearbox. Therefore a good knowledge on the behaviour of gear systems is paramount for a good and efficient design

Object

To carry out an efficiency test on the geared winch found in the mechanics lab and plot various parameters against load.

Apparatus

Geared winch

Various weights

Metre rule

Vernier calipers



CENTRIFUGAL FORCE APPARATUS

(N.B. : 1lb = 0.4536 kg & 1" = 25.4mm)

Introduction

With the apparatus provided experiments can be performed to show how the centrifugal force varies with

- a) The mass of the rotating body
- b) The distance of the centre of gravity of the body from the axis of rotation
- c) The speed of rotation

Description of apparatus

The heavy box type bed is mounted on three point supports with two levelling screws, so that the masses can be arranged to rotate in a horizontal plane. The speed reduction from the motor is by means of a worm drive and a Vee belt and the electronic control unit can vary the speed from approximately 0 to 250 RPM. The vertical spindle is mounted in ball bearings and a drive shaft is provided, through the side of the bed for taking tachometer readings.

Brackets attached to the rotating platform, carry the two rods on which the rotating masses can be mounted at any radius from 4.5" to 8". These masses each weighing 0.25lb are arranged on each rod and the masses can be unclamped from the rod so that experiments can be performed with either one, two or three masses or with the rod alone.

The pull, due to the centrifugal force, is transferred to the spring balance by means of fine Bowden wires which pass over large aluminium pulleys mounted in the turret. The ends of these wires are attached to a crosshead, fitted with ball bearings which can slide in the two slots of the turret. The crosshead is supported from a ball thrust bearing, the housing of which is prevented from rotating by a claw. Two vertical pillars support a guard ring and a cross-arm from which the spring balance is suspended.

The knurled nut can be rotated to increase the tension in the spring of the balance until a steady reading is obtained at the initial radius of the rotating masses. Scales are provided between the sliding rod brackets to facilitate the positioning of the masses.

With the masses at rest, release the spring balance adjusting screw so that the lower line engraved on the square block, coincides with the line engraved on the claw. The claw prevents rotation of the square block.

In preparing for the experiment pull out the rods so that all the slack in the wires is taken up. The masses can now be set on the rods at the correct radius for the experiment.

The pull on the spring balance has to be adjusted so that it just overcomes the centrifugal forces due to the weights, the rods, the friction of the rods in their guides and the weight of the thrust housing. This happens when the lower line on the block just begins to move upwards while the knurled nut is rotated.

The speed adjusted by the variable speed control unit, is taken with a tachometer pressed into the centre of the horizontal shaft protruding from the bed.

Before taking readings with the weights at different speeds and radii, the pull P_1 in the spring balance required to overcome the weight of the thrust housing and the friction of the rods must be found. This will not vary with speed. The friction was given to be approximately 0.7lb by the manufacturer for the equipment as new.

Student's activity

Starting from the centrifugal force equation $m\omega^2 r$ show theoretically that the centrifugal force due to the rods alone is given by $2W_l \omega^2 R_{c.g.}$, where W_l is the mass of each rod (0.128lb) and $R_{c.g.}$ is the radius of each rod's centre of gravity from the axis of rotation (7"). N.B.: The equation given is in S.I. units.

Using experimental values plot a graph to show how the centrifugal force (P in Newtons) due to the rods acting alone varies with the speed of rotation (in rpm). Check whether the theoretical equation is correct.

Can you deduce the value of the force P_l necessary to overcome the weight of the thrust housing and the friction of the rods ?

By plotting a family of curves show that the theoretical equation that gives centrifugal force depends on the mass, the speed of rotation squared and the radius at which the mass rotates.

THE LOADED PORTER SPEED GOVERNOR

Introduction

A governor is normally driven by the engine whose speed is being controlled by the same governor. It is constructed so that its rotating parts change their relative position with change in speed. These movements may be made to operate valves which control the supply of working fluid and therefore the rotational speed of the output shaft of the engine is kept fairly constant. Absolute control of speed cannot normally be achieved solely by means of a governor because change in speed must occur before the governor will move into another position and so operate the control valve.

Description of apparatus

The aim of this experiment is to investigate the mode of work of the governor and so calculate the weight of the sleeve, assuming friction at the sleeve to be negligible. In the apparatus the force (F) at the sleeve can be deduced from the horizontal equilibrium position of the swivelling arm when the system is in dynamic equilibrium. This will render the height and radius of revolution constant, since for various hanger weights W and corresponding angular speed ω , the arms remain horizontal.

Student's activity

Draw the free body diagram of the swivelling arm when in the horizontal position.

Draw the free body diagram of the governor arms, weights and load sleeve while rotating and when the swivelling arm is in the horizontal position.

Show that the relationship between the angular speed ω and the hanger weights W is given by

$$\omega^2 = \frac{W x}{L m h} + \left(\frac{M + m}{m} \right) \frac{g}{h}$$

where L is the length of the swivelling arm

x is the distance of the hanger from the swivelling arm pivot.

m is the mass of one of the revolving weights

M is the mass of the loading sleeve

h is as shown in figure 6

Plot ω^2 v.s. W and calculate the mass m of the revolving weights and the mass M of the loading sleeve.

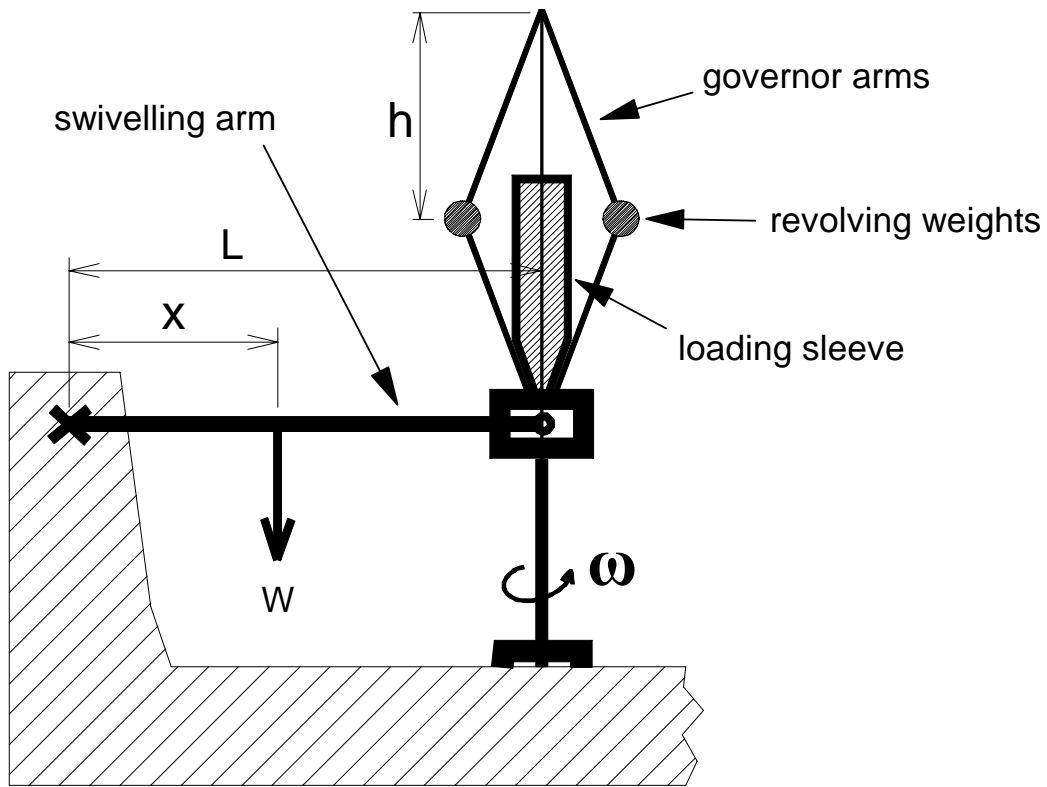


Figure 6 – Schematic diagram of the loaded Porter speed governor