DESIGNING AND MAKING A PAPER FEEDER

WHAT YOU WILL LEARN

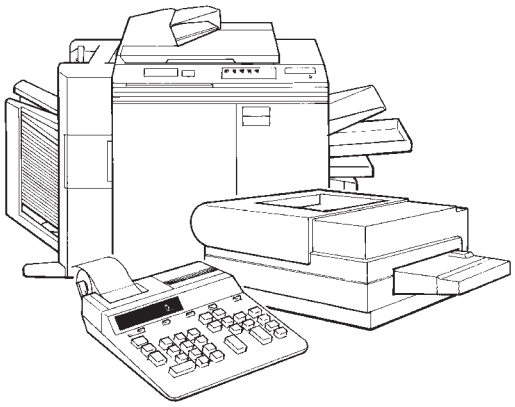
After completing this unit, you should understand:

- How paper can be fed by a mechanism.
- The importance of friction in feed mechanisms.
- How to calculate a transmission ratio for pulleys.
- How to calculate linear (paper feed) rates.
- How to calculate the size of pulleys needed for a motorised drive.
- The importance of quality checking for accuracy.

After completing this unit, you should be able to:

- Work to a design brief and write a specification.
- Recognise constraints when designing.
- Design and make some parts for a paper feed system.
- Assemble and adjust a motorised paper feeder.
- Produce parts to an accuracy of ±0.5mm.

In many products such as calculators, cash registers and computer printers, there are mechanisms to feed paper. In a photocopier, much of the space is taken up just controlling and feeding paper. In industry, large sums of money are spent designing things to handle and feed paper - especially in the printing industry. It is only when paper gets stuck in the photocopier or a till roll jams that we try to understand how these things work.

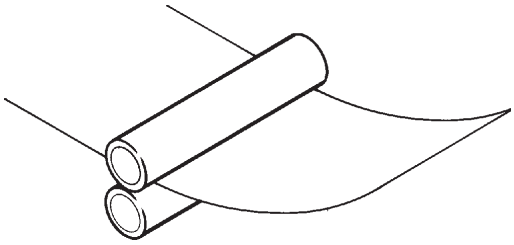


PAPER FEEDING MECHANISMS

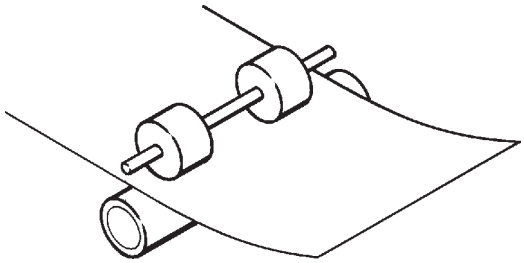
In all paper feeding mechanisms, there has to be a way of making contact with the paper and pushing or pulling it along. This is often done using rollers or wheels made from rubber or with a rubber covering. The material used is extremely important because it has to grip the paper. In most mechanisms, we try to avoid friction between parts coming into contact. In paper feeders, however, we use rubber materials that provide a lot of friction between paper and the driving wheel or roller.

There are several ways of feeding paper by 'pinching' it between rollers or wheels on two shafts. These include:

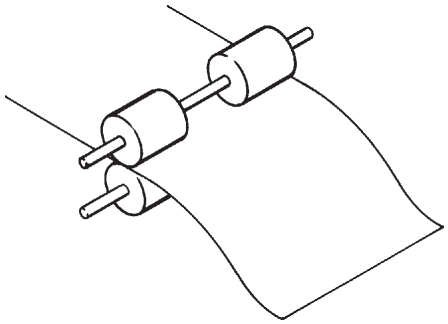
- Two rubber rollers or rubber covered rollers.



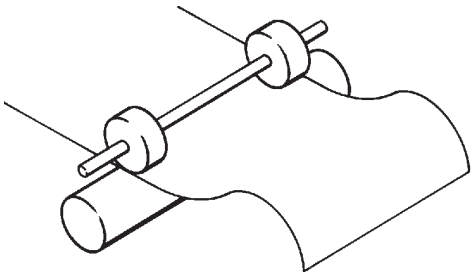
- One rubber roller and one shaft with rubber wheels.



- Wider rubber wheels on two shafts.



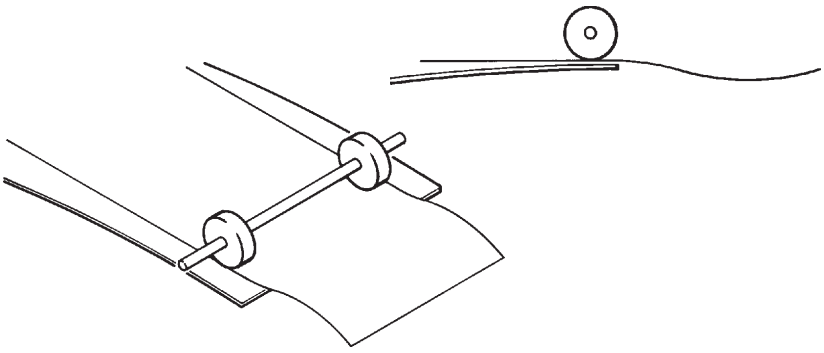
- Rubber wheels on one shaft pressing against a plain metal or plastic roller.



NOTE

See Study File 13 (Friction)

Paper can also be fed through rubber wheels pressed against a pressure plate. (This can be a smooth plate of springy metal such as steel or hard aluminium.)

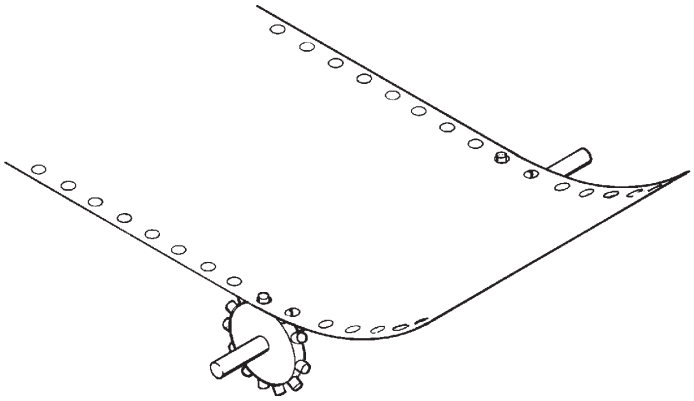


The important thing here is that the paper is 'gripped' by the rubber but slides smoothly over the plate. You can do an experiment to show how this works by taking a soft pencil rubber and trapping a piece of paper between it and a smooth table surface. When you move the rubber the paper moves with it and slides over the smooth surface.

NOTE

This is a method which accommodates a high degree of inaccuracy in alignment of rollers, etc.

Paper can also be fed accurately by punching holes along its edge and fitting the holes over a driving sprocket wheel. Many computer printers use punched paper because it feeds very accurately and cannot possibly slip.



DESIGNING AND MAKING A MOTORISED FEEDER FOR PAPER OR OTHER MATERIALS.

There are many opportunities for designing products that simply feed paper and other materials from long rolls when a button is pressed. For example, hospitals and surgeries need to dispense sterilised paper towelling where loose ends should not be left hanging from a dispenser. Many people find that materials such as kitchen foil and cling film are awkward to unroll even when they use hand-pull dispensers. A similar feed mechanism can be applied to solve most of these problems.

YOUR TASK

DESIGN BRIEF

Design and make a prototype paper feed mechanism for a manufacturer of paper roll products. The purpose of the prototype is to establish if an inexpensive motorised feeder can be used to dispense some of their products. They require you to use their standard size (57 mm wide till roll) in an experimental feeder. The paper should feed at a rate of between 2 and 10 cms per second and it should be possible to tear it off cleanly when the motor has stopped running.

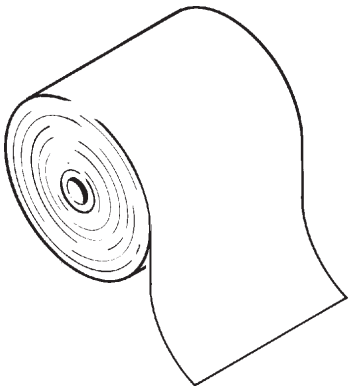
DESCRIBING YOUR TASK

◀ DESIGN SPECIFICATION

First, you need to draw up a design specification for your feeder. A specification is a more detailed description of what a product will be like, what it will do and who will use it. In the case of the paper feeder, you know it is to be used by the firm.

Here are some other questions to help you produce your feeder specification:

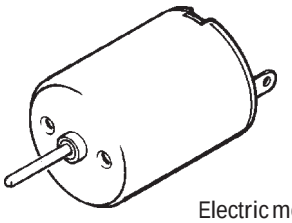
- What is the diameter of the roll you will be using?
- What overall size of feeder will you aim at?
- What do you think the firm will be looking for when it comes to changing the paper roll or tearing off paper?



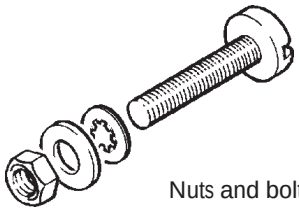
WHAT HAVE YOU GOT TO WORK WITH?

◀ DESIGN CONSTRAINTS

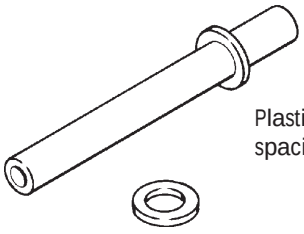
Before you get on with your design work you need to know what materials and equipment are available. Your teacher will provide you with some of the items listed below. Make a note of what is available.



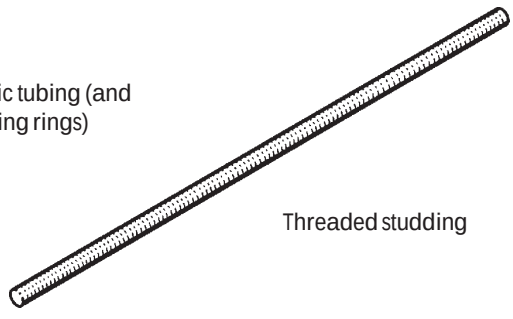
Electric motor



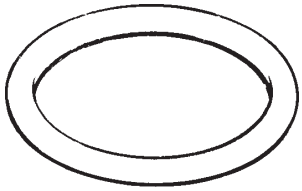
Nuts and bolts



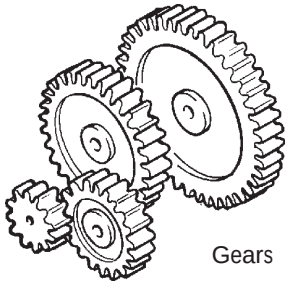
Plastic tubing (and spacing rings)



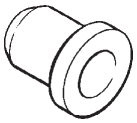
Threaded studding



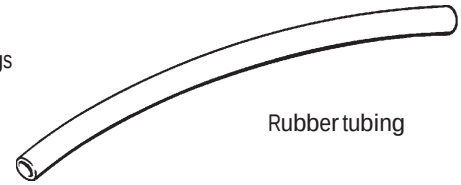
'O' ring seals (for rubber tyres)



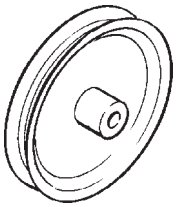
Gears



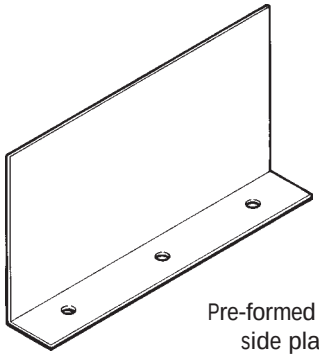
Plastic bearings



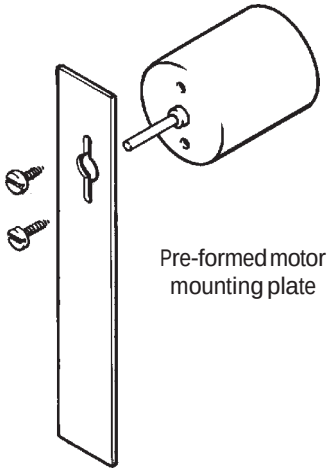
Rubber tubing



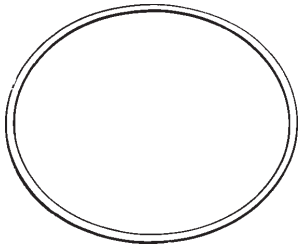
Pulleys



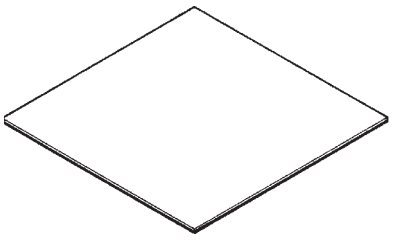
Pre-formed metal side plate



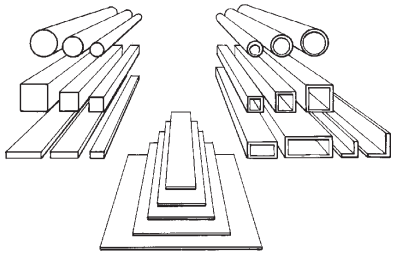
Pre-formed motor mounting plate



Drive belt



Pre-cut base plate



1 mm gauge aluminium sheet (half hard condition)

Selection of metal rods (different diameters)

NOTE

A complete paper feeder pack of components is available for this task.

WORKING OUT YOUR DESIGN

◀ DESIGN PROPOSALS

Now you know what materials and equipment are available to make the paper feeder, you need to think in more detail about the design:

- Set your ideas down on paper.
- Experiment with your ideas.
- Check your ideas against your specification.
- Decide which is the best design.
- Do a detailed drawing of the design.
- You need to end up with a working drawing which you or someone else can use to mark out, make and assemble the parts. It will be a good idea to draw full size the parts for your final design.

◀ NOTE

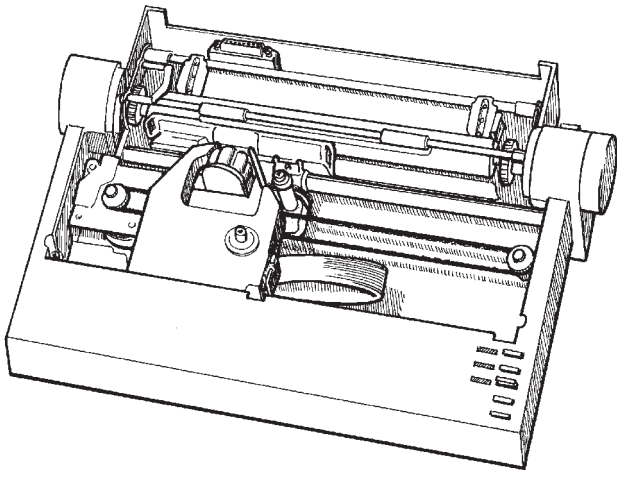
To find out about mechanical systems see Study File 2 (Communication)

GUIDELINES ON DESIGNING AND MAKING

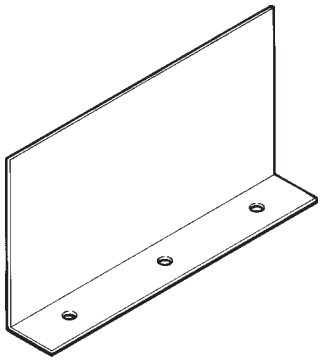
The following notes will give you some ideas about how the paper feeder could be designed and made. They do not give you an answer though ! You must make the important decisions and put all the 'ingredients' together so you end up with a working product.

What basic construction method will you use for making the feeder?

Paper feeding mechanisms in commercial products often use a combination of injection moulded plastic parts and metal pressings. It is very difficult to make complex parts by injection moulding but creating metal pressings is very easy.



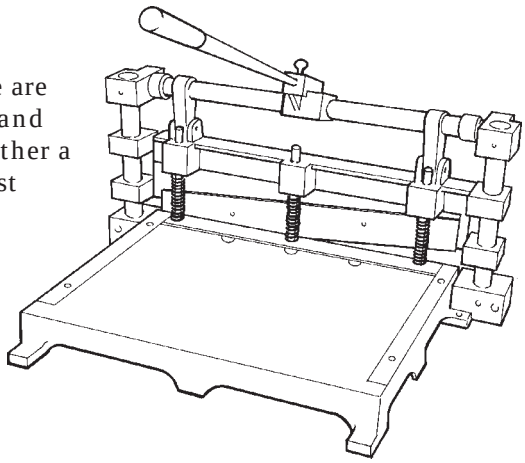
The basic framework for the feeder could be a flat metal base and two side plates fastened on with nuts and bolts. Suitable side plates can be bought ready formed and drilled. Alternatively, you can make your own.



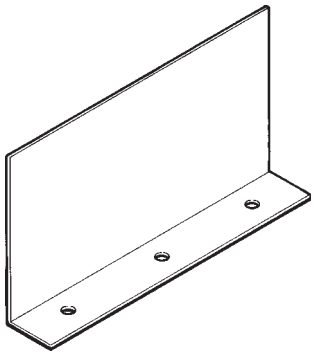
QUALITY CHECK

Opportunity to use surface plate or equivalent

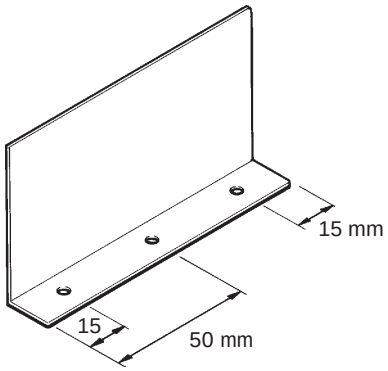
The side plates and base are first marked out to size and then cut to size using either a metal guillotine (the best method) or tinsnips.



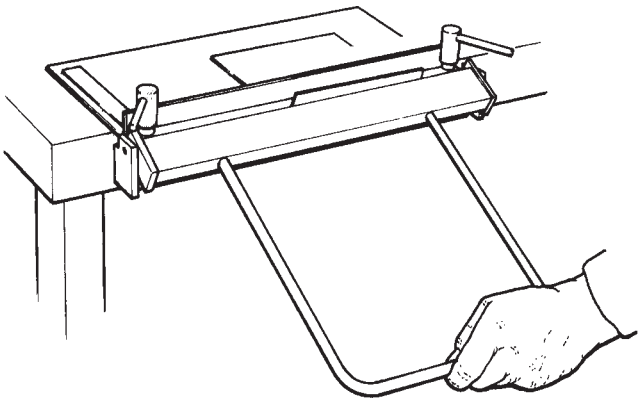
Mark out and drill the side plates while they are flat. You can use a surface gauge to rule lines parallel to the edge of the plates and then measure along to centre punch for drilling.



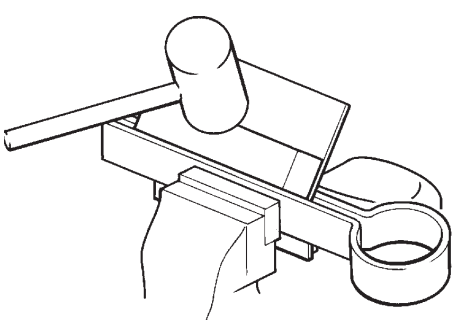
The drawing shows the hole measurements on ready-formed side plates. If you use these side plates, you need to mark out the same hole spacings onto both sides of your base plate.

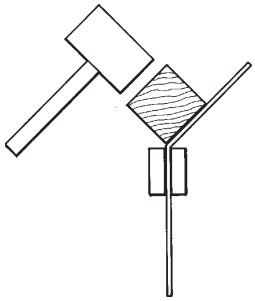


You can fold sheet material with the TEP metal folding unit. Test your work for a 90° angle using a try square on a flat surface.



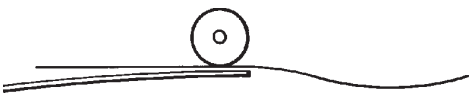
Sheet metal can also be folded using vice tongs in a vice. Lay a strip of wood or metal alongside the sheet and then tap it with a lead mallet or equivalent to bend the metal.

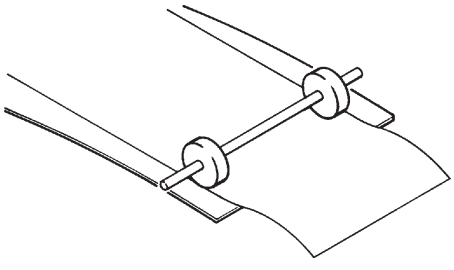




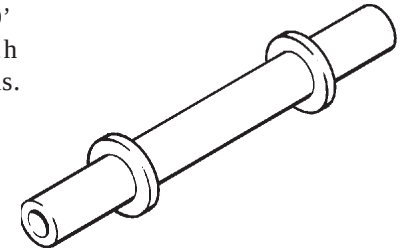
HOW WILL YOU FEED THE PAPER?

The most straightforward way of feeding paper is the wheel and pressure plate method. This is because the springy pressure plate always keeps the paper trapped against the wheels even if the roller is slightly crooked in its frame. (How would you fix the pressure plate?)

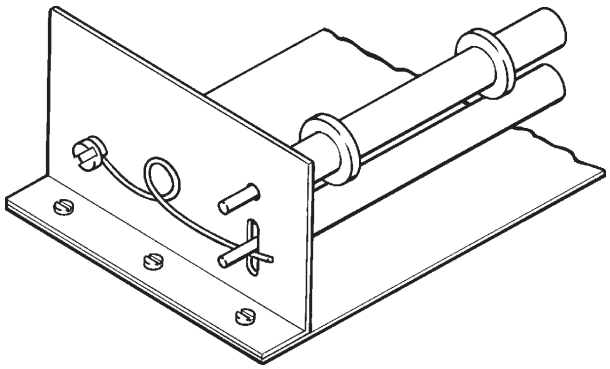




The illustration shows two 'O' ring seals slipped over a length of plastic tube to act as wheels. 'O' ring seals are very accurately made and inexpensive.

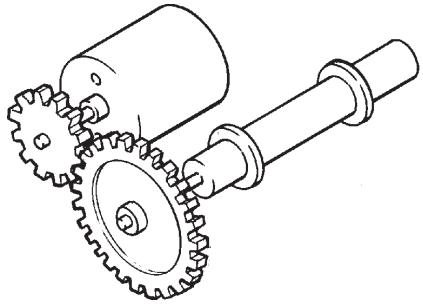


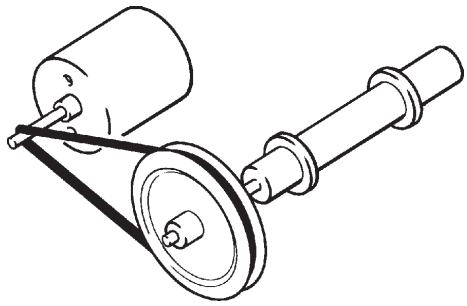
If you decide to use two rollers to feed the paper, they must be positioned very accurately to avoid gaps between them. Use rubber laboratory tubing for the outer covering of the two rollers to make this a little easier. An alternative - but more difficult - method is to spring load one of the rollers so it is always firmly in contact with the other. For example, you could make the ends of the bottom roller move up and down in slots but keep it sprung upwards by the kind of spring used in clothes pegs.



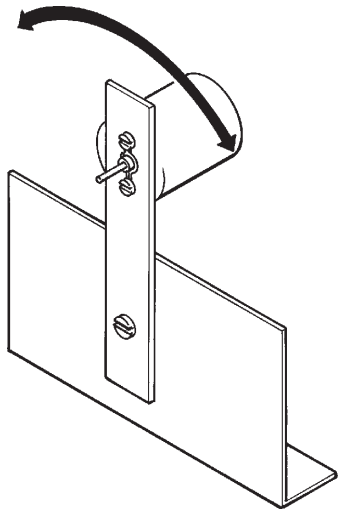
HOW WILL YOU DRIVE THE ROLLERS WITH THE MOTOR?

Only one roller needs to be driven to feed the paper either using the pressure plate method or two rollers. This can be done using a belt drive or gears as shown.



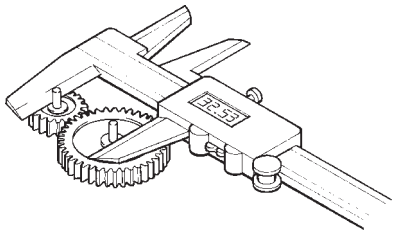


The belt drive is the most straightforward option because the distance between the motor spindle and the pulley wheel is not too critical; if the belt rests directly on the motor spindle, it will also give a very good speed reduction but may slip off. If you use two gears, they must mesh correctly; they must not be too tight or too loose. Getting the meshing right is called depthing. A very easy solution to the problem (which also works for tensioning a drive belt) is to mount the motor on a swinging arm so that its position can be adjusted by undoing the fastening screw.



QUALITY CHECK/MATHS OPPORTUNITY

Measuring distance between centres and working out hole centres.



NOTE

The swinging arm system allows for a high degree of adjustment. Alternatively, for gear depth use over-size holes to fix the arm.

The brief asks you to make the paper feeder work within certain speed limits. To work out the paper feed speed, you need to know:

MOTOR SPEED - This will be on average 2,500 revolutions per minute (rpm) when the motor is free running.

SPINDLE DIAMETER (if the belt method is used) - This is likely to be 2 mm diameter.

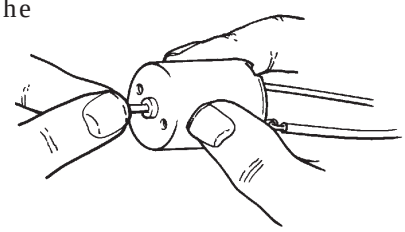
PULLEY DIAMETER or NUMBER OF TEETH ON GEARS

DRIVING WHEEL OR ROLLER DIAMETER.

MATHS/SCIENCE OPPORTUNITY

See Study File 21 (Uses of Pi)

The following are example calculations for either the pulley or two-gear method of driving a shaft. The motor speed quoted is for a small motor that runs at 3000 r.p.m. with no load. When it is driving a mechanism, it will be slowed down. If you take a small motor in your hand and grasp the rotating spindle between two fingers, you will hear it slow down. It is being made to do work in overcoming friction with your skin. As it does this work, your skin and the spindle heat up!



To get a more realistic figure for the calculations, you should derate the motor speed by - say - 50%. In other words, you assume that the motor will lose half of its speed when it is driving the mechanism. (The word 'derate' is used by engineers to describe this kind of down-rating.)

CALCULATION FOR A PULLEY DRIVE

Assume a 2 mm diameter motor spindle, 40 mm diameter driven pulley, 8 mm diameter wheels on the driving shaft.

Motor speed = 3000 r.p.m.. × 0.5 = 1500 r.p.m.

$$\frac{\text{Speed of driven pulley}}{\text{Speed of driver pulley}} = \frac{\text{diameter of driver pulley}}{\text{diameter of driven pulley}}$$

$$\frac{\text{Speed of driven pulley}}{1500 \text{ r.p.m.}} = \frac{2 \text{ mm}}{40 \text{ mm}}$$

$$\text{Speed of driven pulley} = \frac{2 \times 1500}{40} = 75 \text{ r.p.m.}$$

The driving wheels also rotate at 75 r.p.m. The paper feed speed is therefore:

75 r.p.m. × circumference of the 8 mm diameter drive wheels.

Circumference = $\pi d = 3.142 \times 8 = 25.1$ mm.
Paper feed speed is therefore $25.1 \times 75 = 1882.5$ mm/min.
This equals approximately 1.9 m/minute or 31 mm/s.

CALCULATION FOR A GEAR DRIVE

Assume a 10 tooth pinion gear on the motor spindle, a 60 tooth driven gear and 8 mm diameter wheels on the driving shaft.

$$\frac{\text{Speed of driven gear}}{\text{Speed of driver gear}} = \frac{\text{number of teeth on driver gear}}{\text{number of teeth on driven gear}}$$

$$\frac{\text{Speed of driven gear}}{1500 \text{ r.p.m.}} = \frac{10}{60}$$

$$\text{Speed of driven gear} = \frac{10 \times 1{,}500}{60} = 250 \text{ r.p.m.}$$

The driving wheels also rotate at 250 r.p.m. The paper feed speed is therefore:

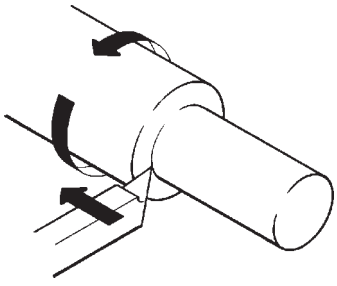
250 × circumference of the 8 mm diameter drive wheels.

Circumference = πd = 3.142 × 8 = 25.1 mm.
Paper feed speed is therefore 25.1 × 250 = 6275 mm/min.
This equals approximately 6.3 m/min or 105 mm/s.

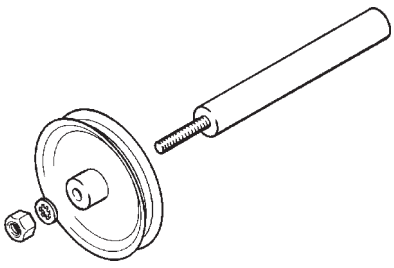
HOW WILL YOU MAKE UP THE FEED SHAFT(S)?

The feedshafts can be made from metal or plastics. The first thing to decide is whether you want to mount the driven pulley or gear inside or outside the frame. It is easier to mount it inside, if you can. The gear or pulley has to be fixed tightly to the shaft and you can do this using any of the following three methods:

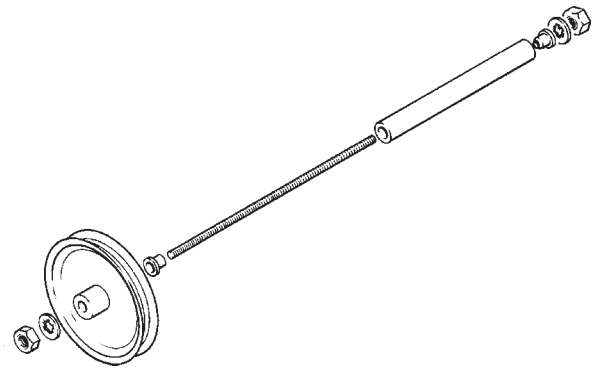
1. Turn down the end of the shaft on a lathe so the pulley or gear fits tightly onto the shaft.



2. Turn down the end of the shaft so the pulley or gear fits on - and then make a screwthread on the end so a nut can be tightened against it.



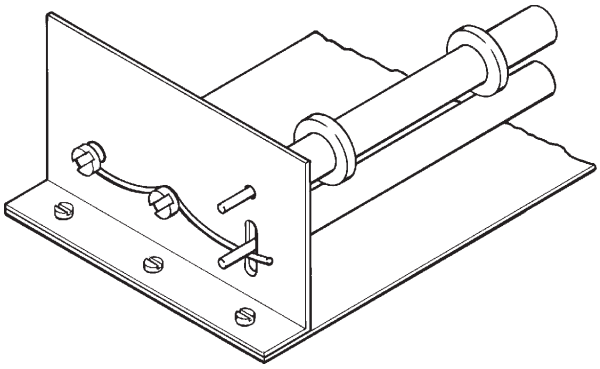
3. Use a length of plastic tubing (with the ends faced off on a lathe if possible) and pass a length of metal studding through the centre as shown. This is a very easy method.



The shaft(s) can be turned into rollers by covering them with rubber laboratory tubing. Alternatively, 'O' ring seals can be placed over the shaft(s) to act as wheels. The 'O' ring method is easier and neater.

◀ NOTE

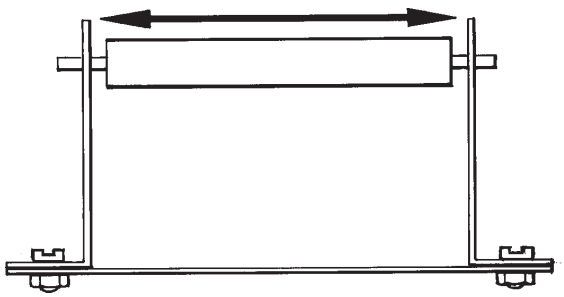
See Study File 14 (Machining)



◀ QUALITY CHECK

Opportunity to use lathe dials and/or Vernier callipers

Finally, remember that the feed shaft(s) must be of the correct length to fit within the frame. They must not be too tight or they will not turn properly and there must not be too much end-float. 'End-float' is the name given to the movement when a shaft moves either way along its length.

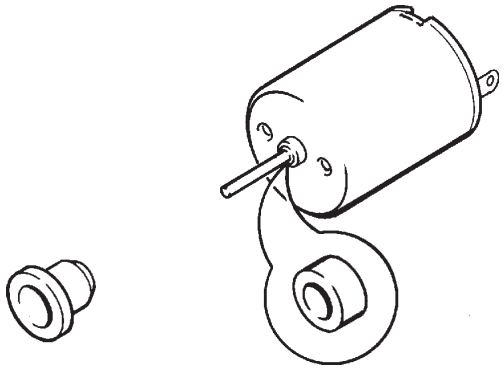


◀ QUALITY CHECK

Tolerances of fitted parts.

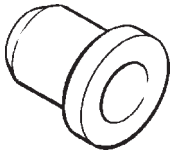
HOW WILL YOU MOUNT THE FEED SHAFT(S)?

Any rotating shaft must rotate as freely as possible. Normally, they rotate in bearings. A plain bearing is normally made of metal (e.g. brass like the one on the front of your motor) and takes the form of a small tube.



Some bearings are porous and contain oil for lubrication. Many very small plain bearings are now made from plastic materials which have lubricating properties (i.e. they are made from 'slippery' plastics).

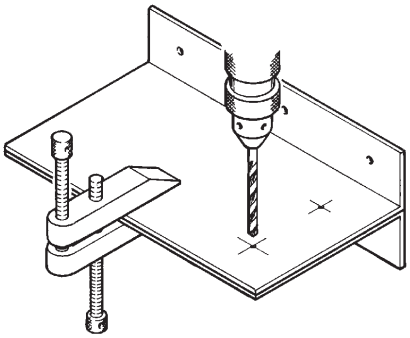
A cheap and inexpensive plastic bearing is shown; this is pushed tightly into a hole of 4 mm diameter.



Plastic bearing

If you choose not to use a bearing for your prototype, you must drill a hole only slightly larger in diameter than the shaft. (Please remember it is not normally good practice to have a shaft rubbing on aluminium or an ordinary plastic rubbing on metal!)

Because the bearing holes for your shafts will be in the same position on both side plates, you need only mark them out on one plate. The two plates are then fastened together with a tool maker's clamp (or small 'G' clamp) for drilling. This is an important method for making identical parts.

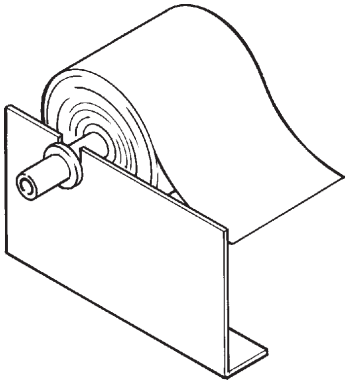


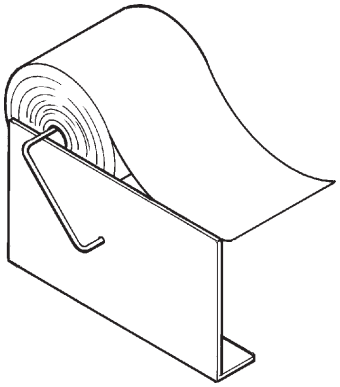
NOTE

Parts can be held together with double sided tape but high bonding strength may result in damage unless care is taken when separating plates.

HOW WILL YOU MOUNT THE PAPER ROLL?

The paper roll could be mounted by passing a plastic or metal rod (or tube) through its centre and resting this in two cut-outs in the frame sides. Alternatively, it could, for example, be mounted on a piece of folded wire.



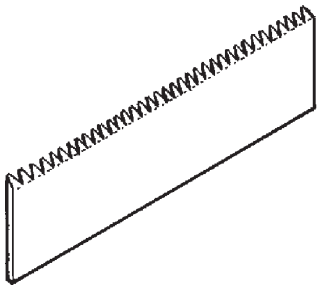


MATHS OPPORTUNITY

What is the relationship between diameter of roll and length of paper?

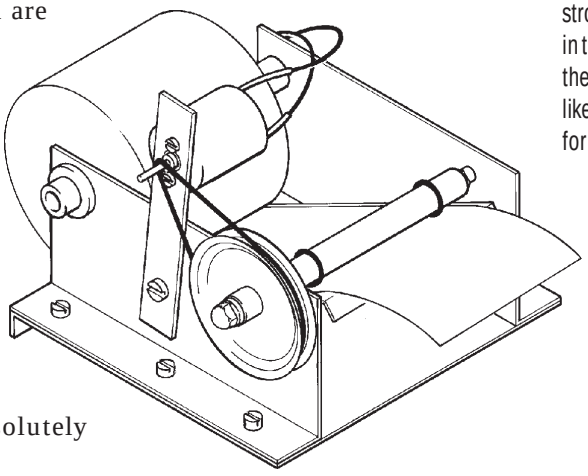
HOW WILL YOU ENABLE THE PAPER TO BE CUT?

If you look at the point where the till receipt comes from the cash register, you normally see a serrated metal edge against which the paper is torn. Could you make such an edge from thin sheet? How would it be mounted onto the frame?



PUTTING IT ALL TOGETHER

If all the parts have been marked out and cut out accurately, it should be easy to assemble the parts of the paper feeder. A number of adjustments can be made at this stage if you are not happy with the outcome. For example, washers can be inserted between the frame sides and the shaft(s) if there is too much end float; the pressure plate, if used, can be bent to give the correct 'spring'; bearing holes can even be re-drilled in different positions if absolutely necessary.



NOTE

A possible solution where overall form is strongly suggested by components provided in the paper feeder pack. Techniques such as the spring pressure plate make success more likely than not but there are many decisions for pupils or students to make.

HOW WELL DOES YOUR PAPER FEEDER WORK?

To evaluate the success of your paper feeder, you must ask whether it meets the firm's requirements and your specification. You need to carry out several tests to find out:

- When the paper feeder is set up and turned on, does the motor run properly and turn the driven pulley or gear? If the answer is 'no', check the wiring to the motor and check that all parts of the mechanism are free to run.

- When the driven pulley or gear is turning, does it turn the shaft? If the answer is 'no', one of these must be slipping on the shaft.

- If the feed shaft is turning, is paper fed through? If the answer is 'no', is there a gap between the two things that should pinch together either side of the paper e.g. between the rubber wheels and the pressure plate? If these are tight together the paper roll may not be able to turn.

- Is paper fed out each time the motor is switched on? If the answer is 'no', it is likely that one of the possible faults listed above is causing an intermittent ('every now and then') problem.

If your paper feeder moves paper out each time it is switched on, you can complete your evaluation by:

- Measuring the paper feed speed with a stop watch.

- Asking others to evaluate how easy it is to change a roll of paper and to tear off the paper that has been dispensed.