GEARS

OBJECTIVE:

You will understand and demonstrate how gears transmit rotational power.

INTRODUCTION:

A gear is a toothed or grooved wheel or cylindrical shape used to transmit mechanical power. Combined in sets of two or more, gear wheels can be used to pass on a rotational force (called torque) from one gear to the next. Depending on the number, arrangement, and relative sizes of the gears, rotational movement can be speeded up or slowed down, the direction of movement can be changed, and a mechanical advantage (the amount by which a machine makes lifting easier) can be gained.

It is likely that by the first century AD all the major types of simple gear mechanism were known. The earliest ones were made of wood, with wooden teeth, and by the sixth century AD these were used extensively in windmills and waterwheels. Precision-made gear systems were in use surprisingly early—around 50 AD the Greek inventor Hero produced a "hodometer," a device incorporating ten gears. It reduced the speed of rotation and enabled the number of turns of a cart or chariot wheel to be measured, so distances traveled could be calculated. Around 1492 Leonardo da Vinci designed several types of gears, such as helical, conical, and trapezoidal.

Gears are not unlike pulleys (see 7.06) in that they are circular devices operating on the lever principle. They are used where large forces are being transmitted or where precise transfer of movement is required and no slippage is permissible. The flexibility and precision with which gears can transmit rotary power means that they have a very wide range of applications in machinery, from mechanical clocks to gearboxes, such as those found in automobiles, which couple the engine to the transmission. Here you will explore the various properties of simple gear systems.

TIME NEEDED:

1 hour

MATERIALS:

Note: You will need a partner for this investigation.

- gear kit (Legotechnic®, Meccano®, or similar) containing:
  - 3 gear wheels of differing size, but uniform tooth size
  - 3 shafts of uniform size to fit the gear wheels
  - mounting board with stand
- 2 100cm lengths of thread
- spring balance measuring to at least 2 kg
- 500g weight
- masking tape
- marker
- lubricating oil
- metric ruler
- calculator

Safety Precautions

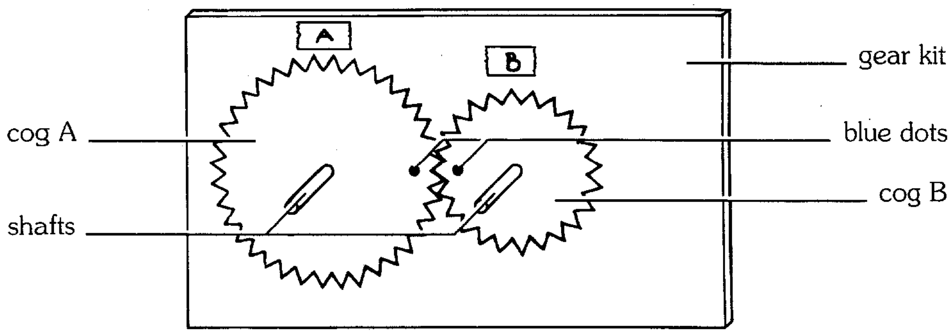
Please read the safety precautions at the beginning of this book..

PROCEDURE:

Part 1—Two cogs of different sizes

1. Mount the two larger gear wheels (cogs) and their shafts onto the mounting board. Leave enough space to the right of the smaller cog so that you can add the smallest cog in Part 2. Put a small piece of masking tape on the board above each wheel and label the larger cog "A" and the smaller cog "B". The teeth of the gear wheels should interlock, but still enable the cogs to turn easily (see figure 1). Make sure the shafts and cogs are well lubricated with oil to reduce friction.
2. Count the number of teeth on cog A and cog B and record these figures in the Data Table, in the column marked Number of Teeth.

Figure 1

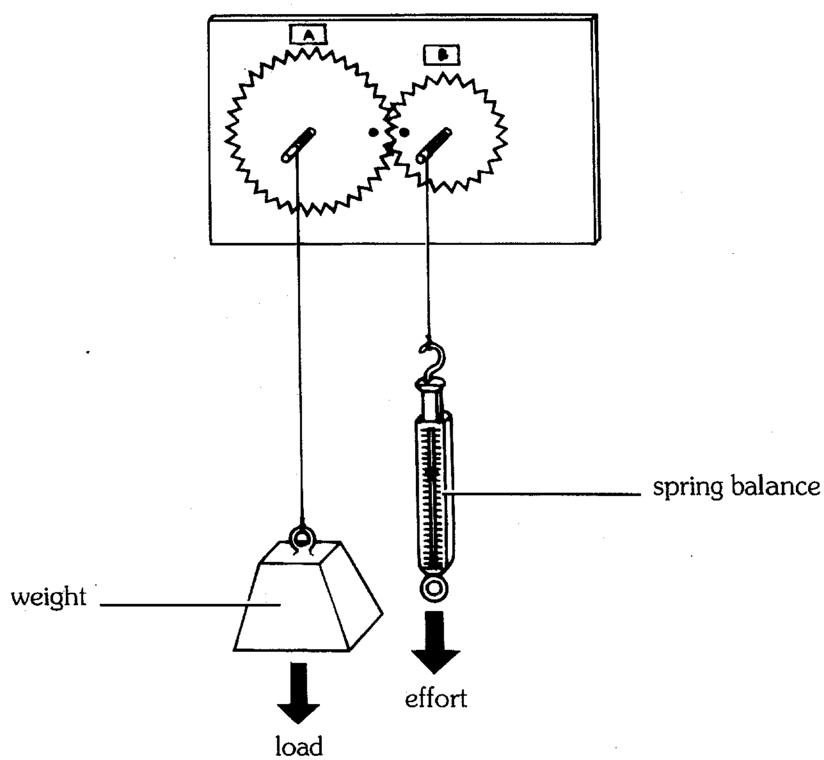


3. Put a small piece of masking tape on each cog where the teeth interlock, and mark a dot on each piece of tape. This will help you to keep track of the number of turns or part-turns of the cogs as they turn.

4. Turn cog A clockwise one complete turn, so that the dot returns to its former position. Note the direction of turn and number of turns of cog B. Record this information in Part 1 of the Data Table in row B, in the columns marked Direction of Rotation and Number of Turns.

5. Wrap a piece of thread once around shaft B and tape it in place. Turn cog B counter-clockwise to wind the thread around the shaft, leaving 20 cm hanging free. Tie the free end of the thread to the spring balance (see figure 2).

Figure 2



6. Wrap the other piece of thread once around shaft A and tape it in place. Tie the free end of the thread to a 500g weight (see figure 2). This is the load.

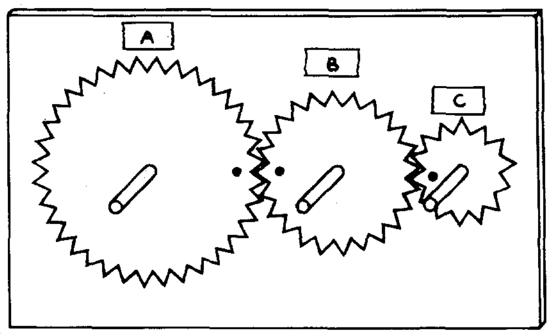
7. Pull on the end of the spring balance so that you are exerting a constant force and you are raising the weight on A at a constant speed. Note the reading on the balance when you do this. This is the effort. Record this in Part 1 of the Data Table in row B, in the column marked Torque.

Part 2—Three cogs of different sizes

8. Mount the third and smallest cog and its shaft on the mounting board so that its teeth interlock with those of cog B, as shown in figure 3. Put a small piece of masking tape above this cog and label it "C". Put another piece of masking tape on cog C where its teeth interlock cog B, and mark a dot on the tape.

9. Count the number of teeth on cog C and record this figure in Part 2 of the Data Table, in the column marked Number of teeth.

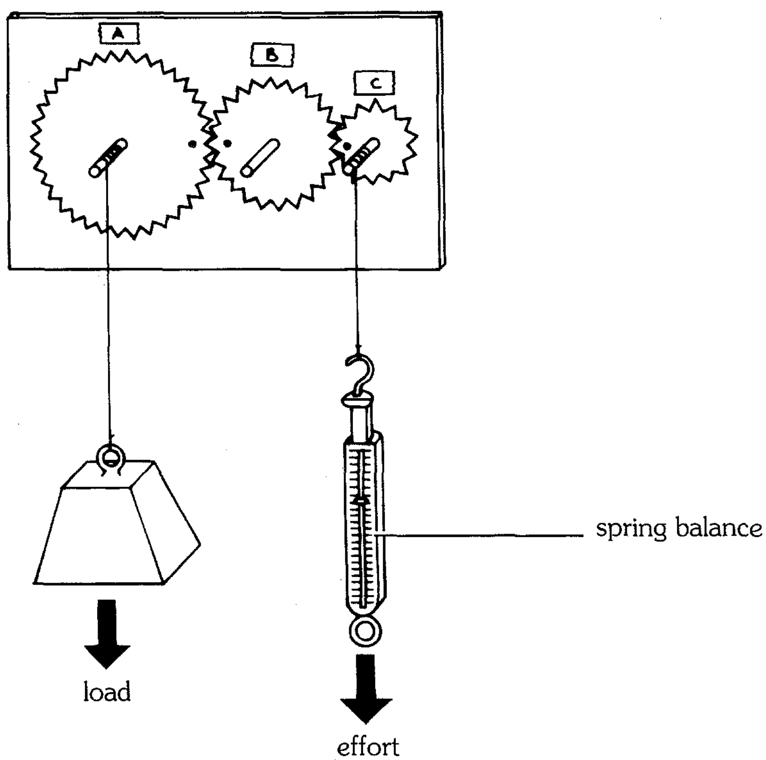
Figure 3



10. As in step 4, work out the direction and number of revolutions of each cog. To do this, turn cog A clockwise one complete turn. Note the direction of turn and number of turns of cog B and cog C. Record this information in Part 2 of the Data Table in rows B and C respectively, in the columns marked Direction of rotation and Number of turns.

11. Remove the spring balance and thread from shaft B and attach them to shaft C, repeating step 5 (see figure 4).

Figure 4



12. As in step 7, pull on the end of the spring balance so that you are exerting a constant force and you are raising the weight on A at a constant speed. Note the reading on the balance when you do this. Record this in Part 2 of the Data Table in rows B and C, in the column marked Torque.

DATA TABLE

Cog	Number of teeth	Direction of rotation	Number of turns	Torque (load or effort about the shaft) (g)
Part 1				
A		clockwise	1	500 g
B				
Part 2				
A		clockwise	1	500 g
B				
C				

ANALYSIS:

1. From your findings in Part 1 and 2, what conclusions can you draw about:

a) changes in number of turns of the cog going from a large cog to a smaller one? What can you deduce about changes in speed of rotation of the shaft going from a large cog to a smaller one?

b) changes in torque (load or effort about the shaft) going from a large cog to a smaller one?

2. Gear wheels operate on the principle of levers (see 7.01). The greater the radius of the cog, the greater the torque that is exerted. In an ideal system (one in which there is no friction) torque or turning power is transmitted with 100 percent efficiency between gear wheels. The mechanical advantage (MA) for such a system is calculated as follows:

$$MA = \frac{\text{load torque}}{\text{effort torque}} = \frac{\text{load force x radius of wheel}}{\text{effort force x radius of wheel}} = \frac{\text{radius of driven (load) gear wheel}}{\text{radius of driver (effort) gear wheel}}$$

We do not need to measure the radius of the cog. Because the teeth of one gear are at the same spacing as the teeth of the gear it is meshed with, the radius of the cog is proportional to the number of teeth the cog has. In this case, we can calculate the mechanical advantage as follows:

$$MA = \frac{\text{no. of teeth in driven (load) gear}}{\text{no. of teeth in driver (effort) gear}}$$

a) Calculate the theoretical MA (i.e. assuming no friction) for your gear system in Part 1.

b) Compare your value in a) with the actual value of MA calculated from your results using:

$$MA = \frac{\text{load torque}}{\text{effort torque}}$$

In Part 2, the MA for the gear system is given by:

$$MA = \frac{\text{no. of teeth in gear B}}{\text{no. of teeth in gear C}} \times \frac{\text{no. of teeth in gear A}}{\text{no. of teeth in gear B}}$$

For example, if A had 54 teeth, B had 36 teeth, and C had 18 teeth:

$$MA = \frac{36}{18} \times \frac{54}{36} = \frac{54}{18} = 3$$

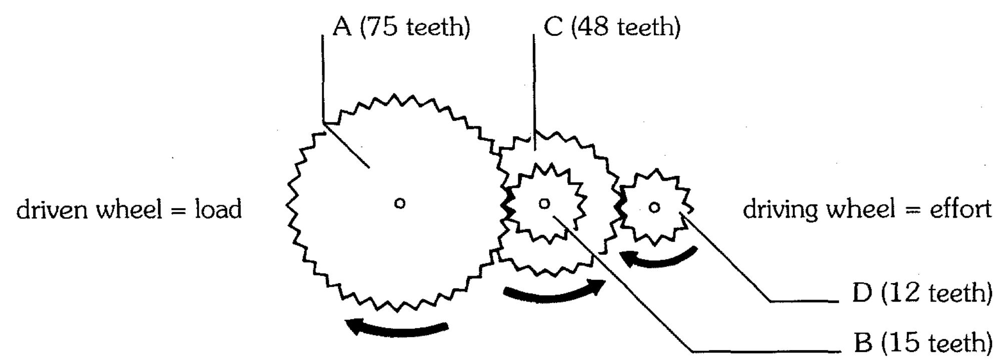
c) Calculate the theoretical MA (i.e. assuming no friction) for your gear system in Part 2.
d) Compare your value in c) with the actual value calculated from your results using:

$$MA = \frac{\text{load torque}}{\text{effort torque}}$$

How do you account for the difference in the values?
e) Calculate the percentage difference of your figures in b) and those in d). Which system—the two-gear or three-gear one—is most efficient? In other words, calculated as a percentage, which is nearest to its theoretical mechanical advantage?

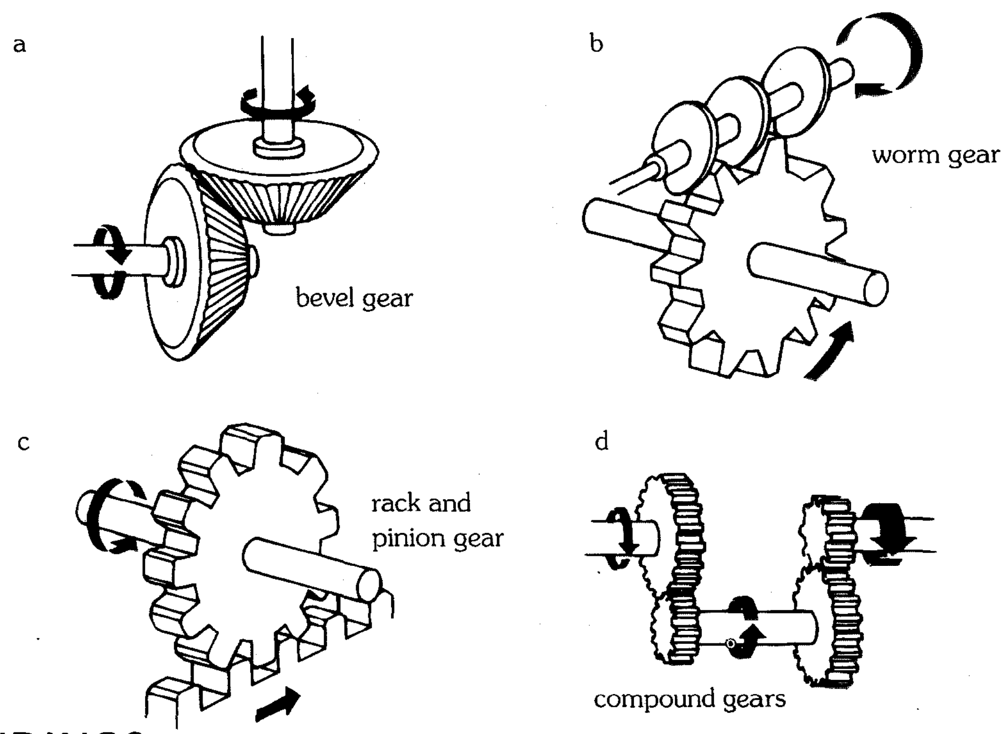
3. In figure 5, what is the effort on shaft D required to move a load of 1 kg on shaft A (assume there is no loss of effort due to friction)? (Hint: B and C are mounted on the same shaft. A meshes with B and C meshes with D. There are two MAs to calculate: D to C and B to A.)

Figure 5



4. Figure 6 shows four kinds of gear mechanism. Do some research. What do these gear mechanisms do, and where are examples of these found?

Figure 6



OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES