

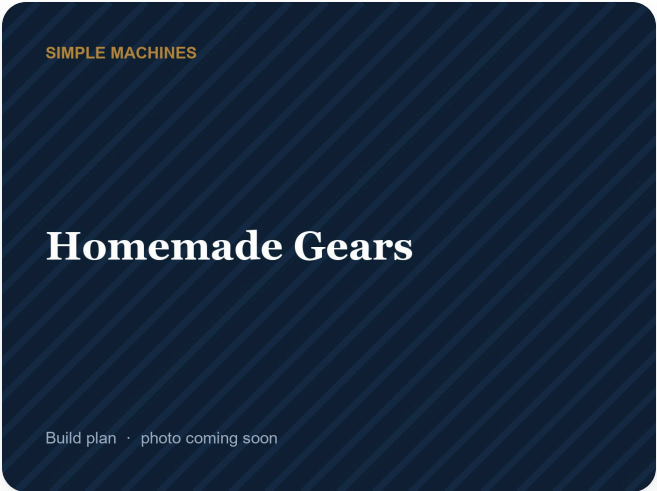
EQUIPMENT BUILD PLAN

SIMPLE MACHINES

Homemade Gears

Bruce's method for designing gears by hand: pick the number of teeth, turn that into a circumference and a diameter, and mark out the teeth with a compass. Matching gears made this way show how gears change direction, speed and force according to their tooth ratio.

Written from Bruce's original workshop handout. Bruce's final review of this plan is in progress.



DIFFICULTY	BUILD TIME
Intermediate	1-2 hours
COST	SAFETY
About \$5	Everyday care
GOOD FOR	
Teachers, Makers, Families	

What it shows

With a compass, a ruler and a little arithmetic you can make working gears from cardboard or wood and see exactly how they trade speed for force.

Key ideas: gears, gear ratio, mechanical advantage, circumference and diameter

Safety (Everyday care). Use care with craft knives. Cutting wood or plastic gears with a scroll saw or band saw should be done by an adult (or a shop teacher).

CONSTRUCTION

Build it

Materials

- ☐ **Stiff cardboard (several layers glued together), thin plywood or plastic sheet** · 1 sheet
- ☐ **White glue** · Small bottle
For laminating cardboard
- ☐ **Board for a base** · 1
- ☐ **Dowels, nails or bolts for axles** · 2-4

Tools

Compass
Ruler (metric)
Protractor
Pencil
Calculator
Craft knife or scissors (cardboard)
Scroll saw or coping saw (wood or plastic)
Drill or awl for axle holes

1

Choose the tooth size and count

Decide how many teeth each gear needs and how big each tooth step will be. All gears that mesh must use the same tooth step. Bruce's example: 30 teeth at 1 cm each.

2

Find the circumference

Multiply the number of teeth by the tooth step: 30 teeth x 1 cm = 30 cm around.

3

Find the diameter

Divide the circumference by 3.14: $30 \text{ cm} / 3.14 = \text{about } 9.55 \text{ cm}$. Set the compass to half of that (about 4.8 cm) and draw the circle on your material.

4

Draw the tooth-depth circle

Draw a second, smaller circle from the same center to set how deep the gaps between teeth will be (for 1 cm teeth, about 0.5 cm inside the first circle works well).

5

Mark the teeth

Divide the circle into equal parts: 360 degrees divided by the number of teeth (12 degrees for 30 teeth). Mark these points with a protractor, then sketch a tooth and a gap in each step, running from the outer circle down to the inner one.

6

Make a partner gear

Repeat with a different number of teeth but the same tooth step, for example 15 teeth, to get a 2-to-1 ratio.

7

Cut out the gears

Cut cardboard with a craft knife; cut wood or plastic on a scroll saw. Round off the tips of the teeth slightly so they mesh more smoothly, and drill a hole at the exact center.

8

Mount and test

Fix axles in a base board so the gears' centers are apart by the sum of their two radii, adjusting slightly until the teeth mesh without binding. Mark one tooth on each gear and turn them to count rotations.

THE PHYSICS**How it works**

Meshing teeth force both gear edges to move the same distance. A gear with twice as many teeth has twice the circumference, so it turns only half as fast as its smaller partner.

What a gear gives up in speed it gains in turning force (torque), and vice versa. Driving a big gear with a small one trades speed for force; driving a small gear with a big one trades force for speed.

Two meshing gears always turn in opposite directions. Adding a third gear in between (an idler) makes the first and last turn the same way without changing the ratio.

Using it

- Count turns: if the 15-tooth gear turns 10 times, how many times does the 30-tooth gear turn?
- Use the gears in student machine projects that need to slow down a motor or change direction.
- Add an idler gear and predict the direction of the last gear before turning.
- Relate the math to real machines: bicycle gears, hand drills and clocks.

GO FURTHER

Variations

- Bruce's students have made gears from several layers of glued cardboard, plastic and wood. A school shop class can help with power-tool cutting.
- Make a gear train of three or more gears and calculate the overall ratio.

IF IT DOESN'T WORK

Troubleshooting

IF THIS HAPPENS

Gears jam.

TRY THIS

Move the axles slightly farther apart and round off the tooth tips.

IF THIS HAPPENS

Gears slip.

TRY THIS

Move the axles closer together, or make the teeth a little deeper.

IF THIS HAPPENS

The teeth don't divide evenly around the circle.

TRY THIS

Use the protractor (360 degrees divided by the tooth count) rather than measuring along the curve.

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