

How do Stirling Engines work?

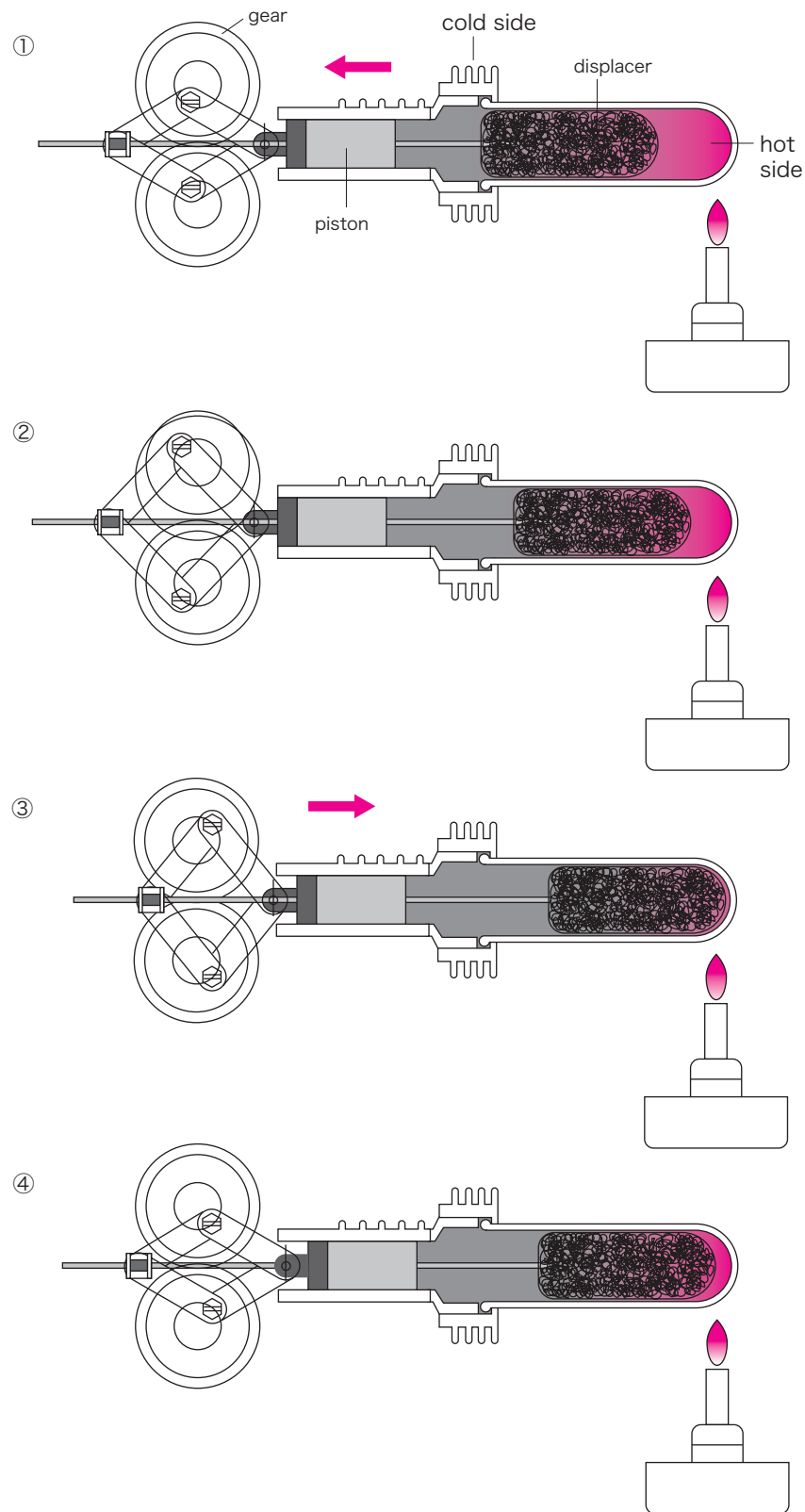
The following is the mechanism of Stirling engines.

①The thermal expansion of air pushes the piston to the gear side.

②When the piston reaches to the gear side, the hot air is pushed to the cold side and get cold.

③The contraction of air brings the piston back to the hot side.

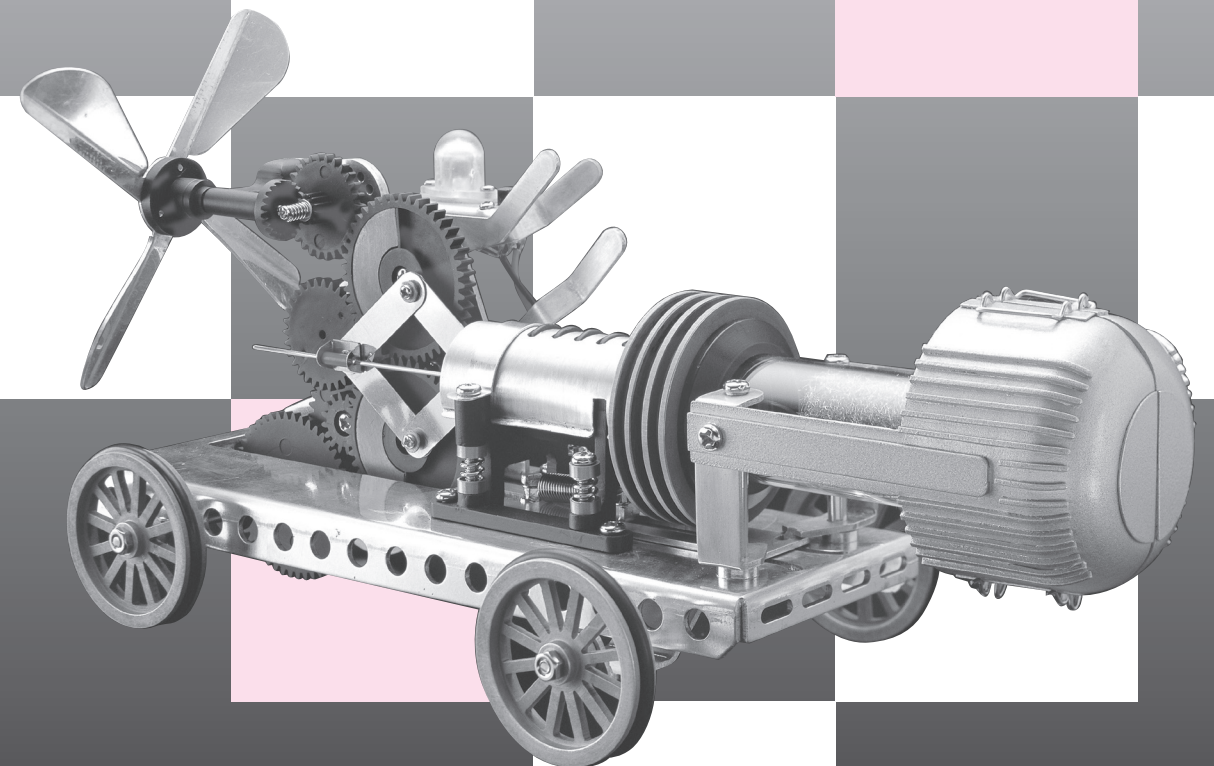
④Cool air is pushed by the piston to the hot side and expands.
(Return to ①)



大人の科学® Otona no Kagaku
The Sophisticated Science Kit for Adults

STIRLING ENGINE

Instructions for Assembling and Operating



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⚠ CAUTION! ★Please read the following instructions before using this kit.

- Use this kit for the original purpose only.
- Use caution when handling the glass cylinder. A piece of broken glass may cause injury.
- Fire is used for the experiment. Use great caution against a burn and fire.
- To avoid danger of a burn, never touch the glass cylinder while the engine is running.
- The glass cylinder remains hot for a while after the experiment. Do not touch it to avoid danger of a burn. When touching, make sure it gets cold enough.
- Use caution when handling any metallic parts. Improper use may cause injury.
- To avoid danger of suffocation, do not swallow small parts such as screws.
- To avoid danger of injury, do not point your hands and eyes with the screwdriver and the like in this kit.
- To avoid danger of traffic accident, do not operate the machine on the road.
- To avoid danger of electric shock, do not insert lead wires into an electric socket.

Two size AA batteries are required. Improper use of the batteries may cause the generation of heat, explosions or leaks. The following precautions should be taken:

- Do not use rechargeable batteries, such as nickel cadmium batteries, and oxyride batteries.
- Ensure that the positive and negative terminals on the batteries are facing the right way.
- Do not use used batteries and new batteries together and do not mingle more than two kinds of batteries.
- Do not short-circuit, recharge, break up or put the batteries in a fire.
- Remove the batteries when not using for a long time.

- ★ Please read the assembly instructions and cautions in this booklet carefully before using this kit. Do not use any materials that have become damaged or deformed while in use.
- ★ Keep the kit away from small children when not using.

Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

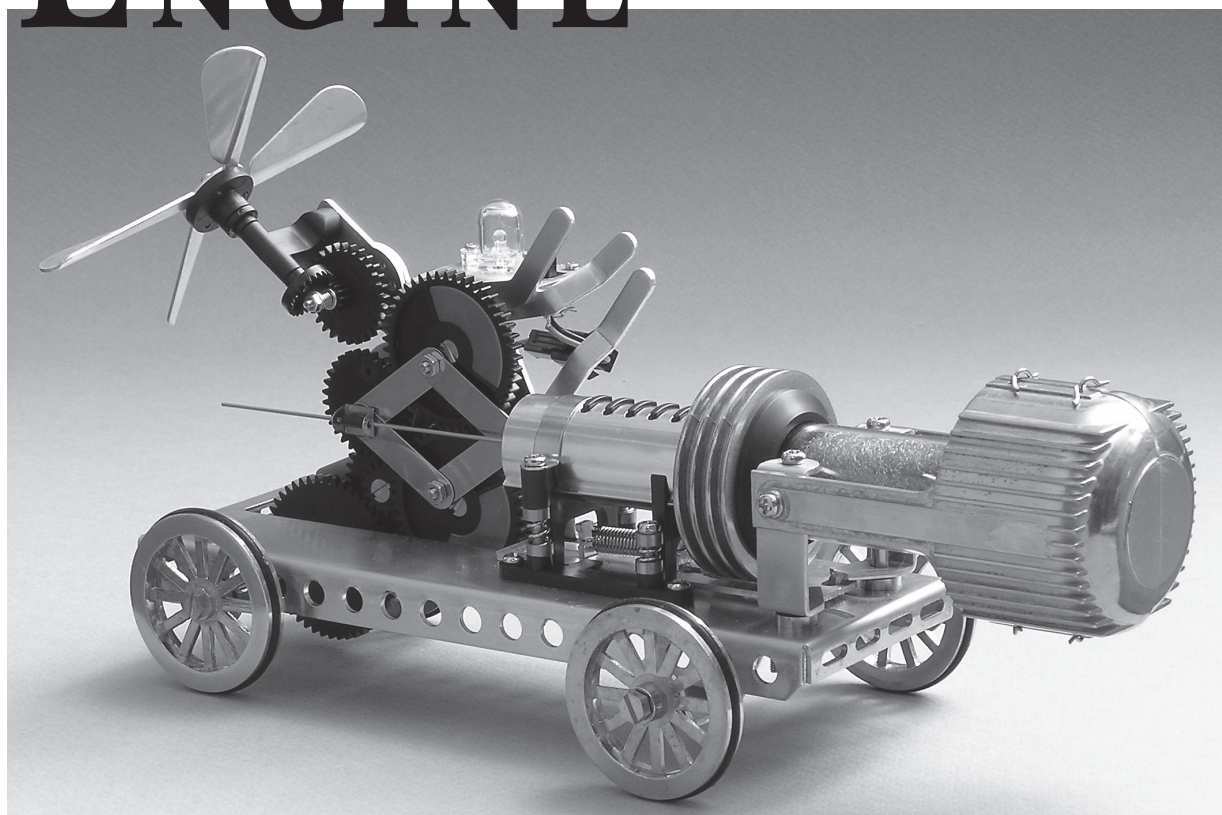
- The plastic materials used in this kit ●
gear (black) : POM piston cover, bearings, gauge (black) : ABS resin battery box (black) : polypropylene
screwdriver handle : polyethylene small bags : polyethylene
- The metallic materials used in this kit ●
main body parts and stand : aluminum displacer: iron pipes : brass flywheel and regenerator: copper
screws : nickel-plated iron

*Vinyl chloride resin is used for the covers of the lead wires.

*disposing of the kit, please follow the recycling regulations in your area.

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STIRLING ENGINE



The Stirling engine was invented by Robert Stirling (1790-1878) from Scotland, U.K who was an engineer and minister. He invented this external combustion engine in 1816 because the steam engine, which was in its heydays then, incur casualties repeatedly caused by the boiler explosion and he was pained at it. Around 1850, the Sterling engine was used for as many usages as the steam engine was used for. However, since the gasoline engine is invented and diffused rapidly, the Sterling engine faded out of the history. It is spotlighted again at the oil crisis in 1973. It attracts attention because of the high theoretical value of thermal efficiency and also because this external combustion engine has no limitation of heat source. As further research has done, it is aimed to be used practically in various fields such as usage in space with solar energy and so forth. Enjoy assembling and experiment to understand the basics of thermodynamics. You can try three kinds of experiments, namely, the generator, the fan, and the car.

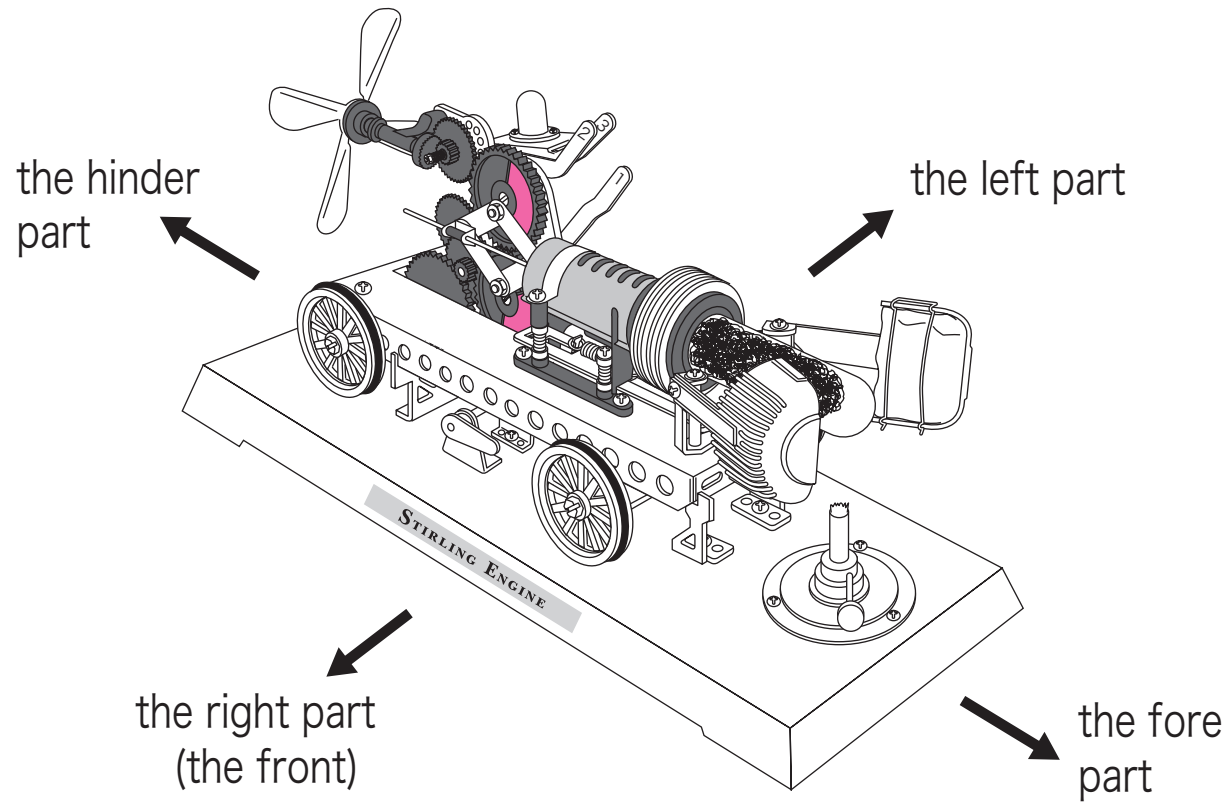
It takes about three hours to assemble. You don't need any special tool. (Size AA batteries to adjust the engine and alcohol fuel are not included in the kit.) Please follow this instruction booklet when you assemble.

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Before Assembling the Kit

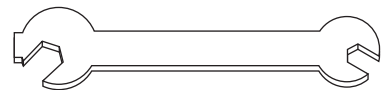
1. Understanding the right direction

The direction is mentioned in the instructions. Check the right direction with the picture below.



2. How to Use Supplied Tools

●wrench



The wrench can be used not only for tightening a nut but also for tightening screws as shown in the right figure.

●small nut wrench

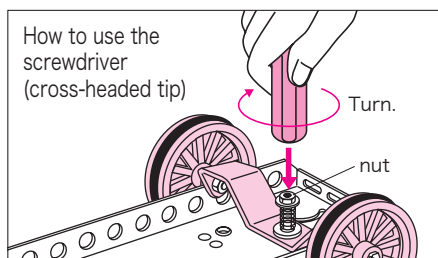
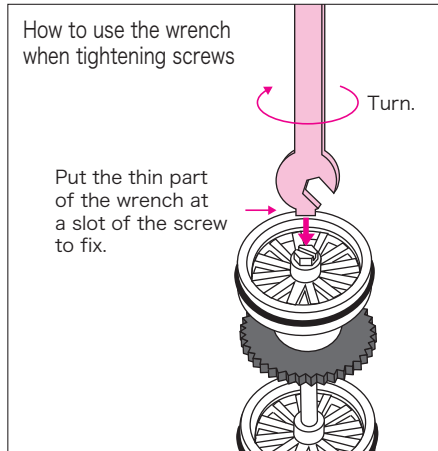


It is used to fasten the connecting rod at figure-18 on p.13.

●screwdriver (cross-headed tip)



The screwdriver can be used not only for tightening a screw but also for tightening a nut as shown in the right figure.



※ Please note that shapes and length of materials may appear slightly different from pictures and illustrations in this booklet.

1 Assembling the Stand

Parts to be used PARTS A ※ There may be more screws, washers, nuts and bushes than actually used for spare.

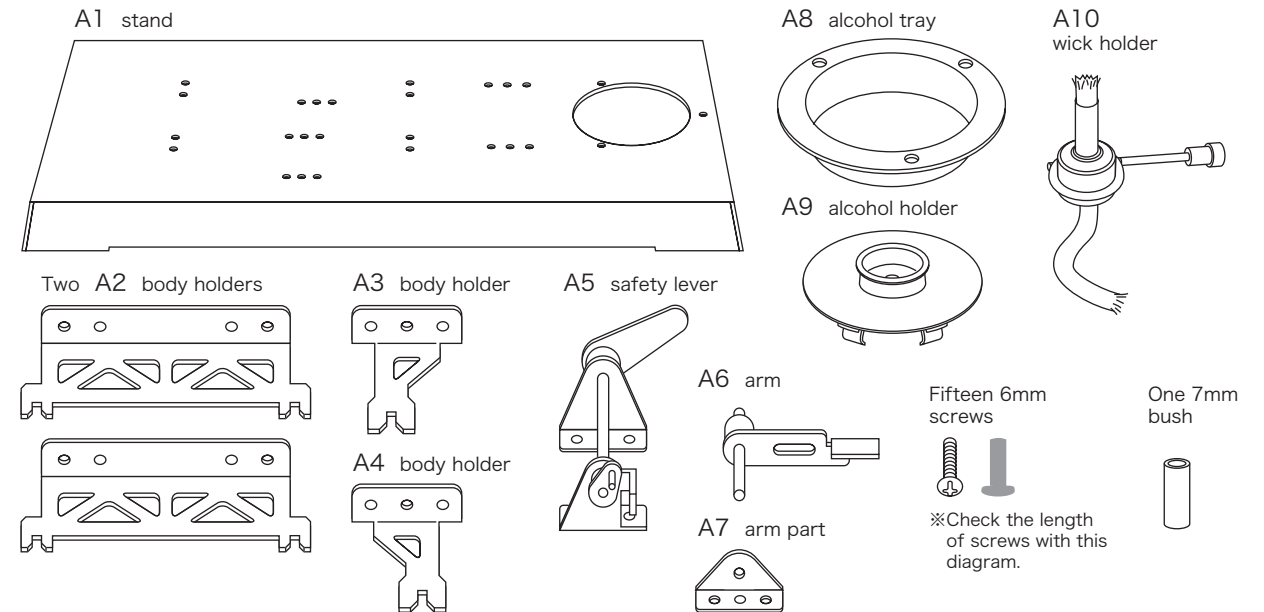
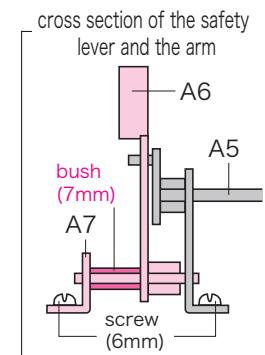
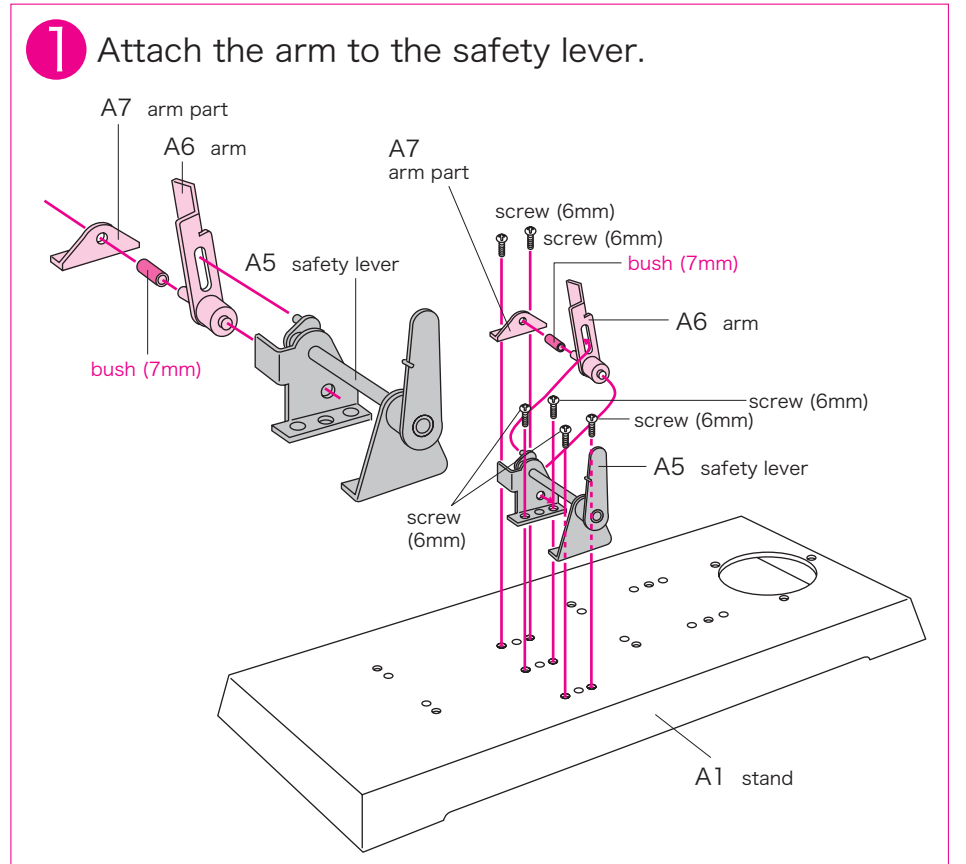


Figure — ❶
Attach the A5 safety lever to the A1 stand with 6mm screws. Then, attach the A6 arm to the A5 safety lever, put in the bush and fasten with the A7 arm part.



Full-scale ※Check the size with this.
screw (6mm)
bush (7mm)



Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

Figure — ②
Fasten the A2, the A3 and the A4 body holders with screws (6mm).

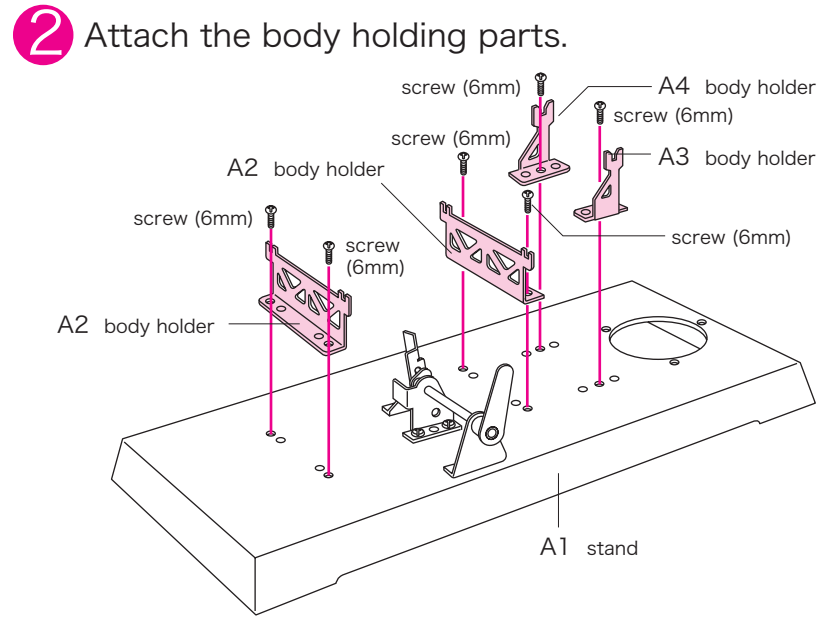
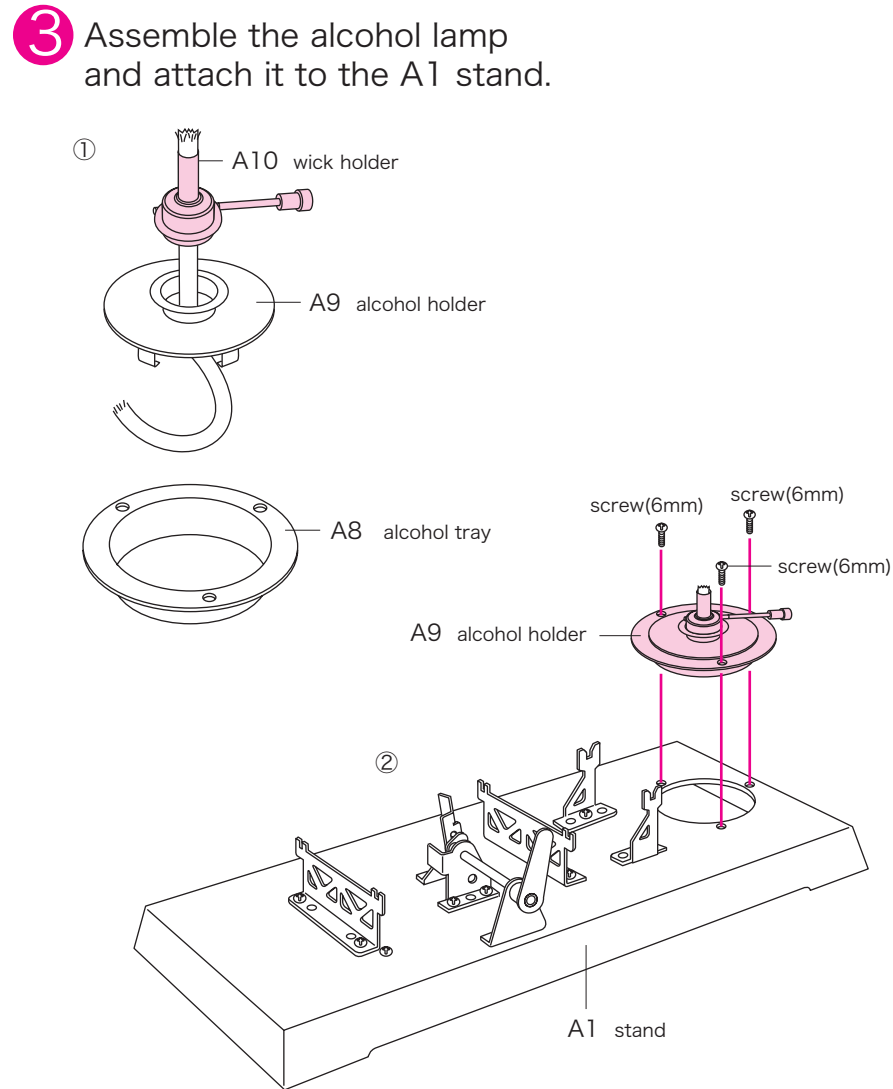
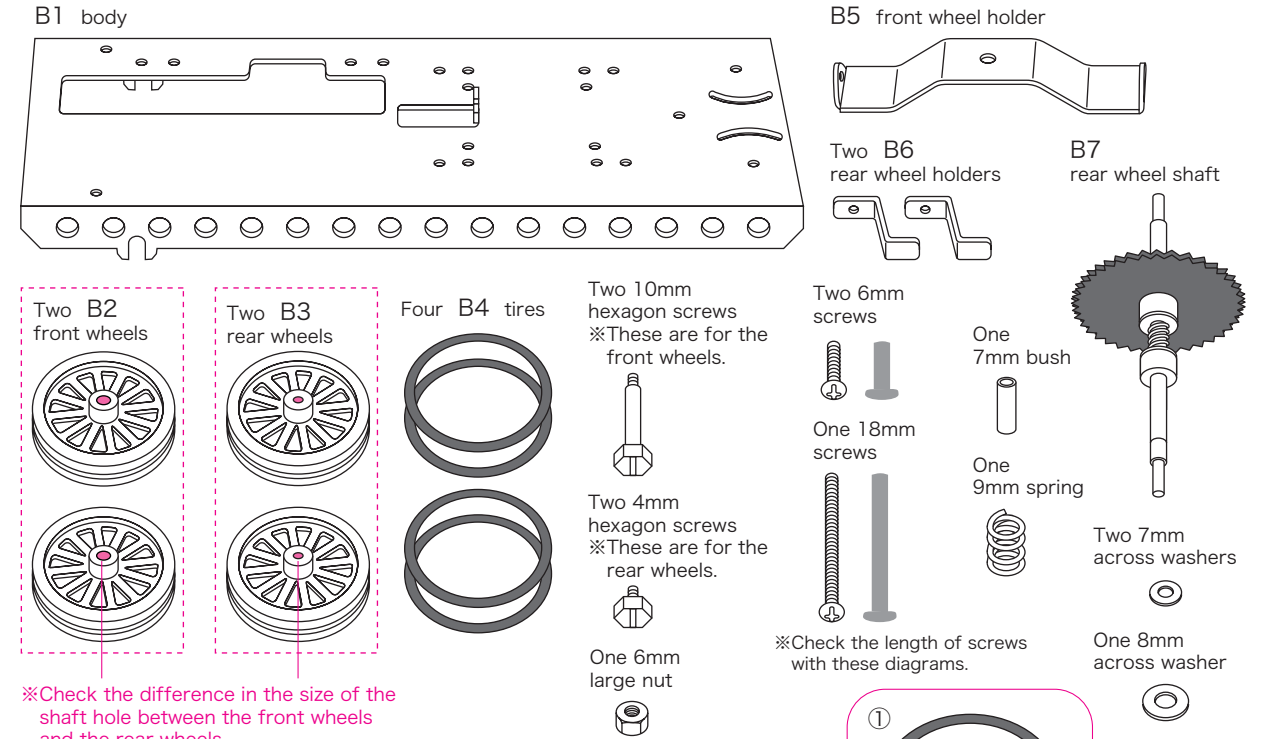


Figure — ③
① Attach the A10 wick holder to the A9 alcohol holder and set them on the A8 alcohol tray. (Roll the wick and put it in the alcohol tray. Do not fill the fuel alcohol until just before the experiment.)
② Fasten the alcohol lamp to the A1 stand with screws (6mm).



2 Attaching Wheels to the Body

Parts to be used **PARTS B** ※ There may be more screws, washers, nuts and bushes than actually used for spare.

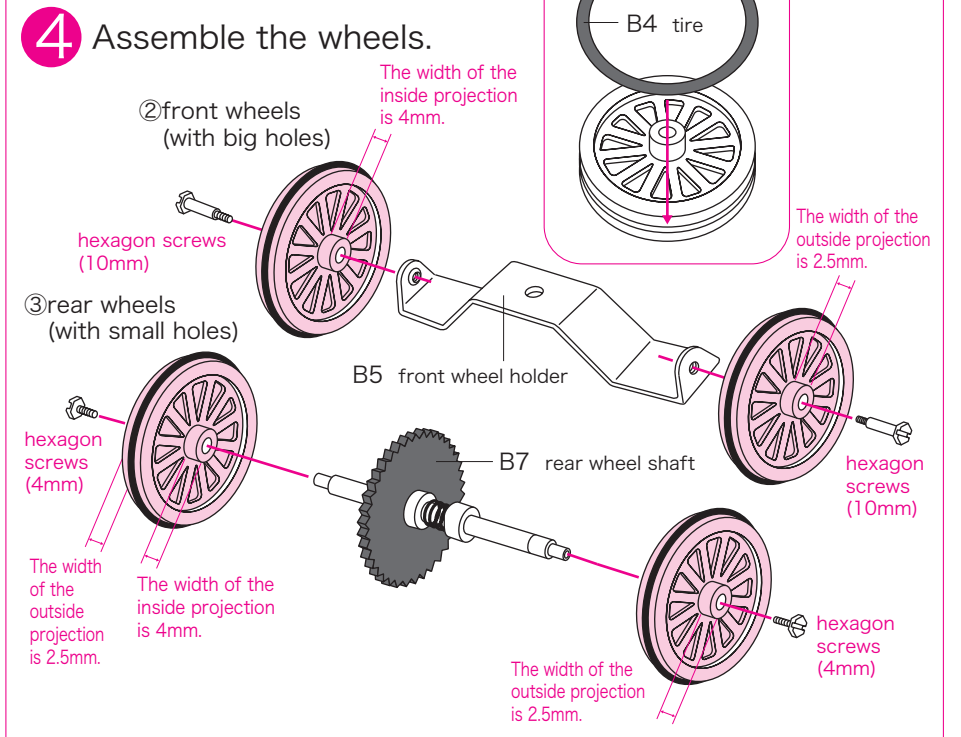


※Check the difference in the size of the shaft hole between the front wheels and the rear wheels.

Figure — ④
① Put four B4 tires on the B2 front wheels and the B3 rear wheels.
② Attach the front wheels to the B5 front wheel holder with hexagon screws (10mm).
③ Attach the rear wheels to the B7 rear wheel shaft with hexagon screws (4mm).

Full-scale ※Check the size with this.
10mm hexagon screws
※These are for the front wheels.

4mm hexagon screws
※These are for the rear wheels.



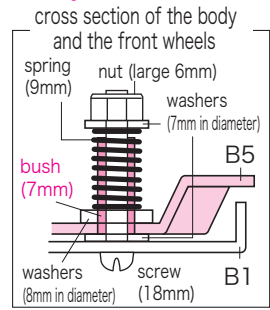
Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

Figure — 5
Overturn the B1 body and attach the rear wheels assembled at Figure — 4 with the B6 rear wheel holders. Attach the 18mm screw for the front wheels too.

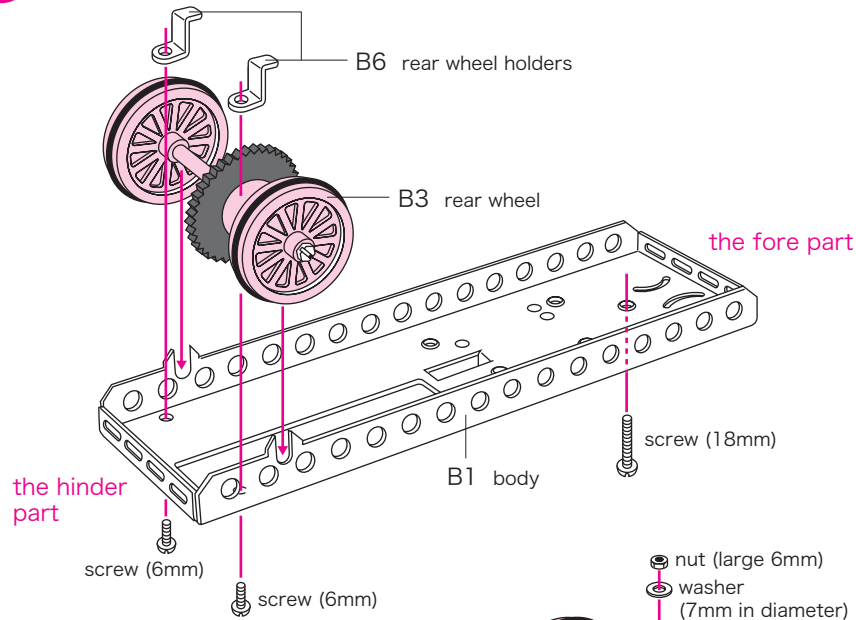
- Full-scale ※Check the size with this.
- screw (6mm)
 - screw (18mm)
 - bush (7mm)
 - spring (9mm)
 - washer (7mm in diameter)
 - washer (8mm in diameter)
 - nut (large 6mm)

Figure — 6
Attach the front wheels assembled at Figure — 4 in the following order.

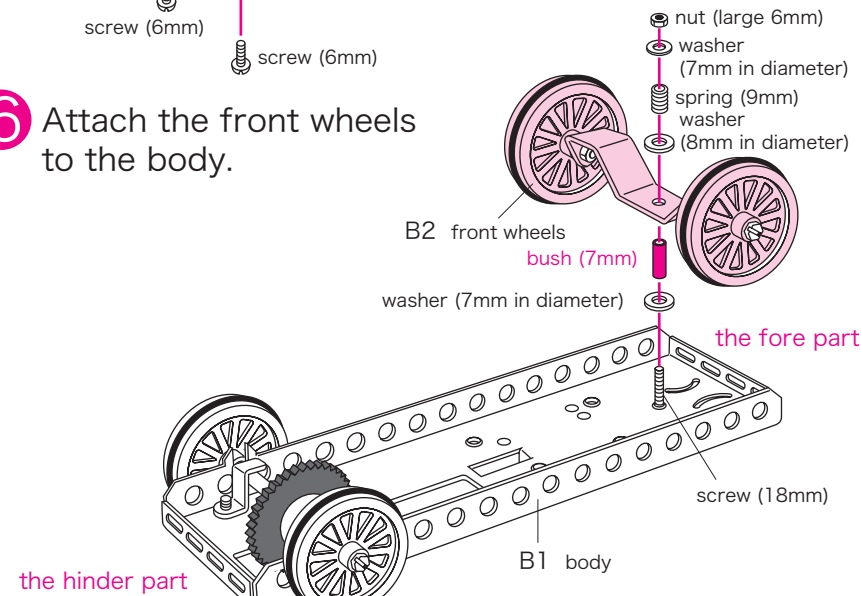
- washer (7mm in diameter)
- bush (7mm)
- front wheel holder
- washer (8mm in diameter)
- spring (9mm)
- washer (7mm in diameter)
- nut (large 6mm)



5 Attach the rear wheels to the body.



6 Attach the front wheels to the body.



3 Attaching the Cylinder to the Body

Parts to be used

PARTS

※ There may be more screws, washers, nuts and bushes than actually used for spare.

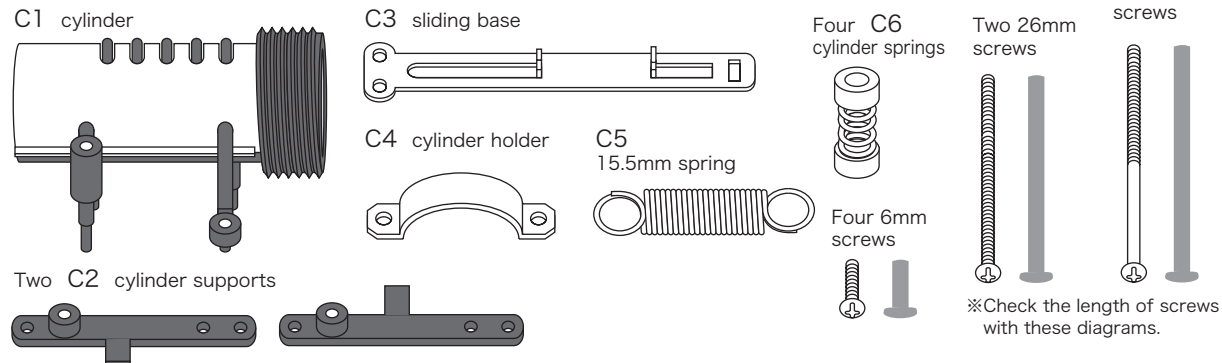


Figure — 7
Overturn the body up and attach the C3 sliding base to the front wheels side with the C5 spring.

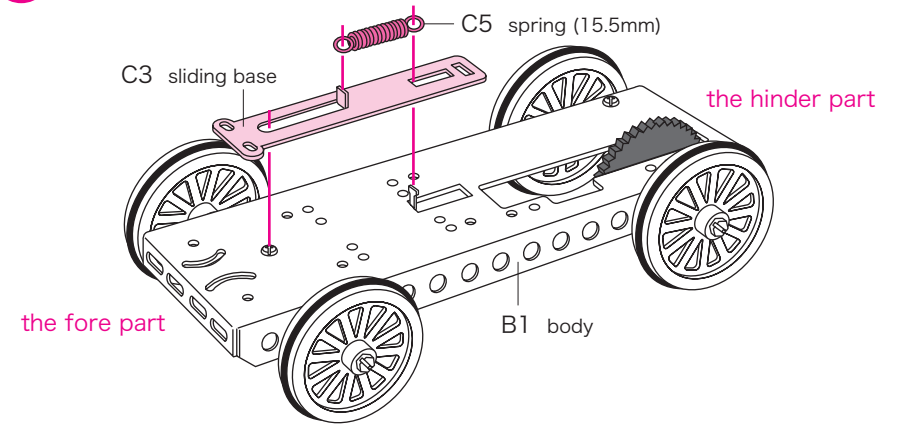
- Full-scale ※Check the size with this.
- C5 spring (15.5mm)

Figure — 8
Fasten C2 cylinder supports to the B1 body with 6mm screws.

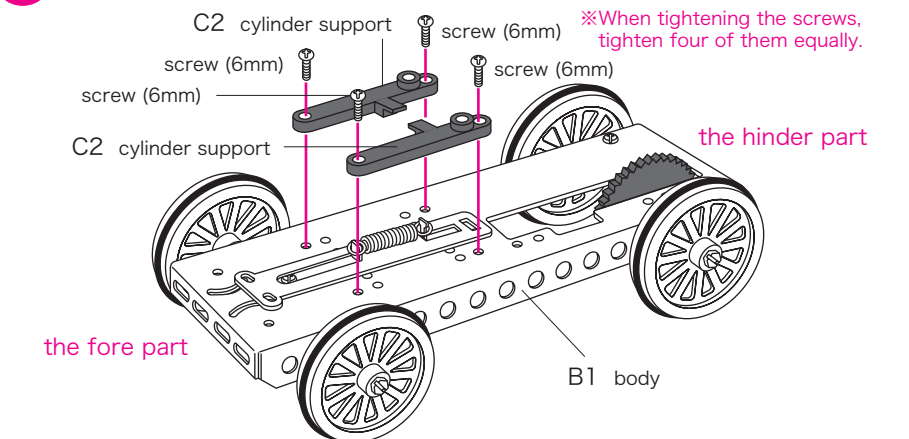
Figure — 9
Attach the C1 cylinder using the C6 cylinder springs. Be sure to fasten the C4 cylinder holder at the back part with 30mm screws.

- Full-scale ※Check the size with this.
- screw (6mm)
 - screw (26mm)
 - screw (30mm)
 - C6 cylinder spring
 - spring retaining bush (6mm in diameter)
 - 2.5mm in thickness spring (13mm)

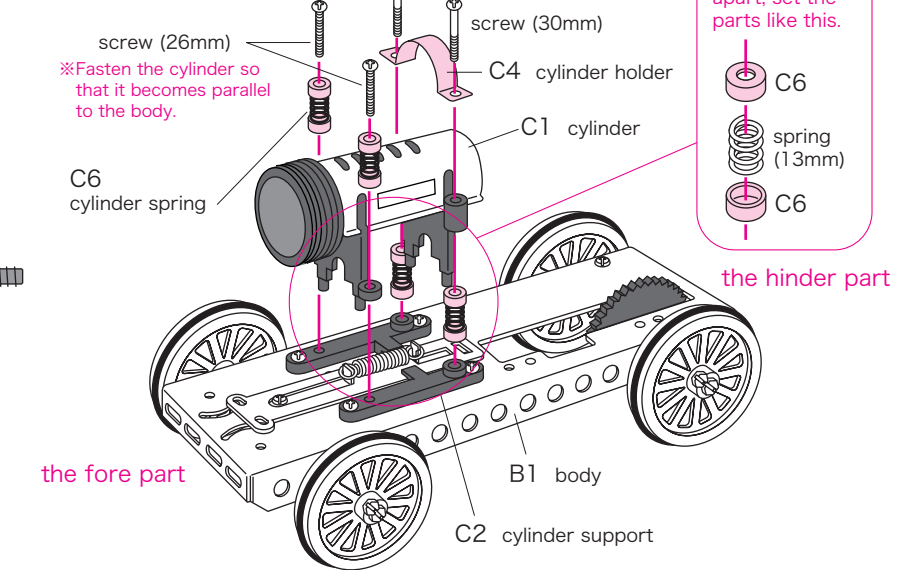
7 Attach the C3 sliding base.



8 Attach the C2 cylinder supports.



9 Attach the C1 cylinder.



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4 Assembling the Lever Part

Parts to be used

PARTS D ※ There may be more screws, washers, nuts and bushes than actually used for spare.

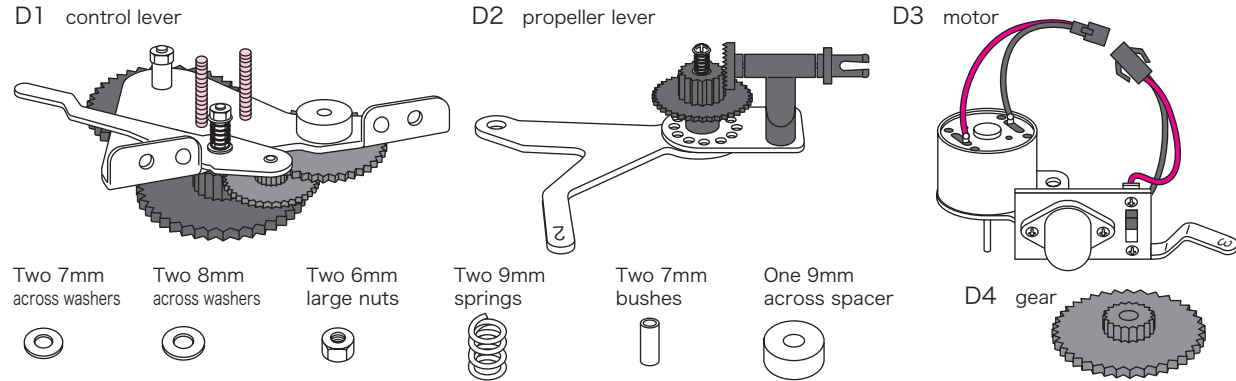


Figure — ⑩
Attach the D2 propeller lever to the D1 control lever.

⑩ Attach the propeller lever to the control lever.

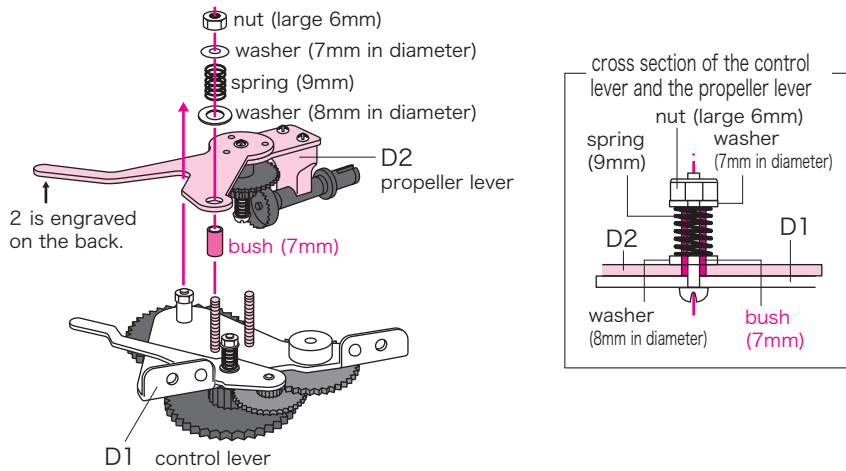


Figure — ⑪
Attach the motor to the screw at the D1 control lever.

⑪ Attach the motor.

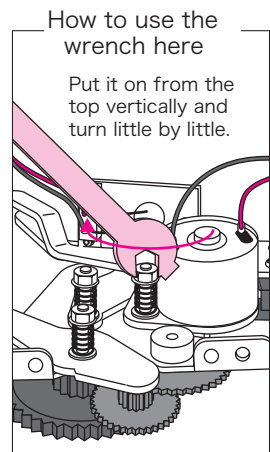
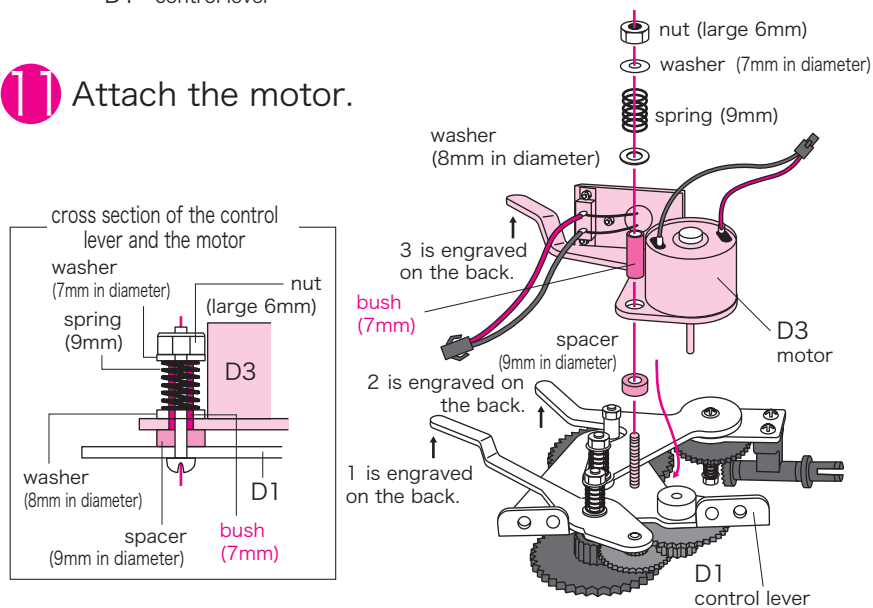
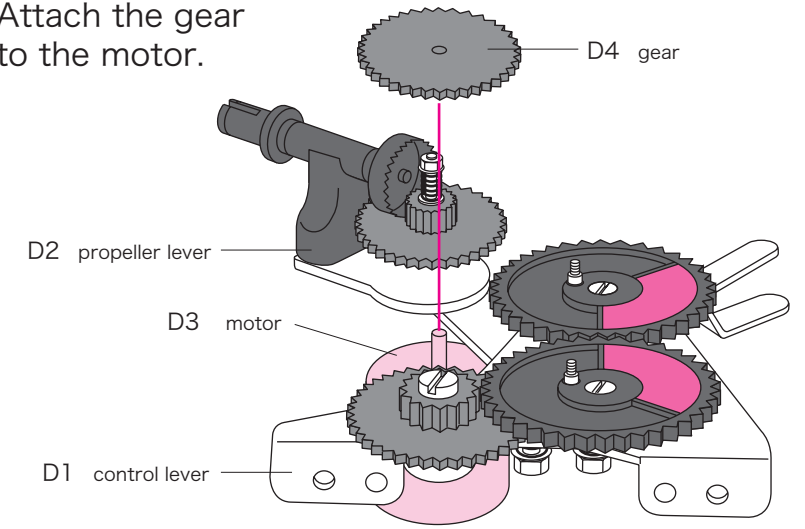


Figure — ⑫
Push the D4 gear on the motor assembled at Figure — ⑪.

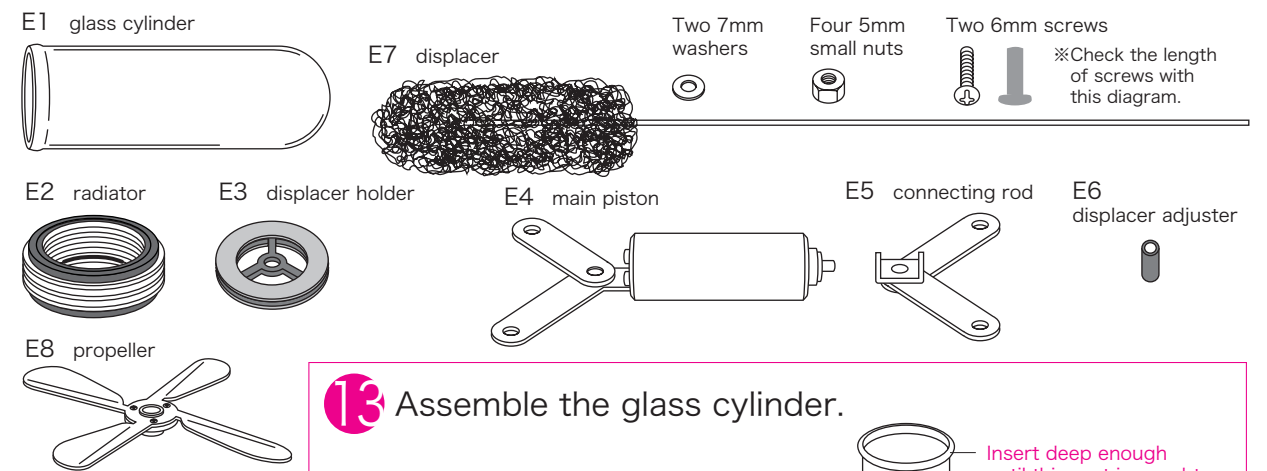
⑫ Attach the gear to the motor.



5 Assembling the Piston Part

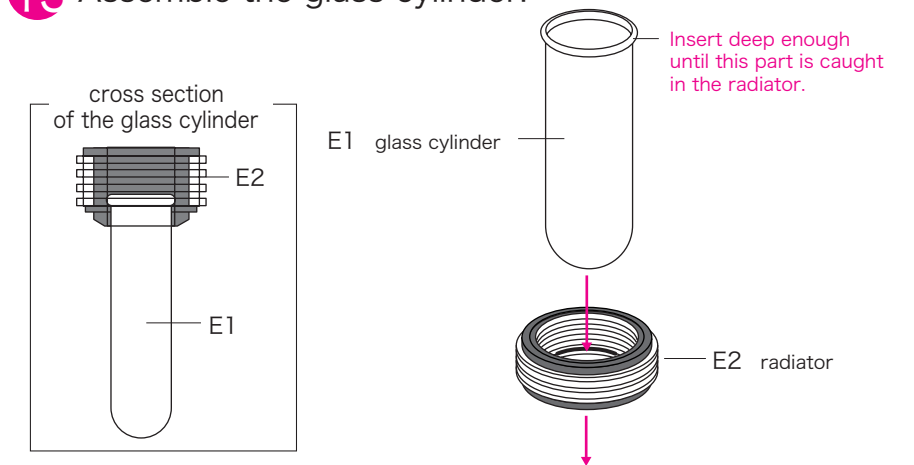
Parts to be used

PARTS E ※ There may be more screws, washers, nuts and bushes than actually used for spare.



⑬ Assemble the glass cylinder.

Figure — ⑬
Put E1 glass cylinder in the E2 radiator. (Put in the glass cylinder as deep as possible.)



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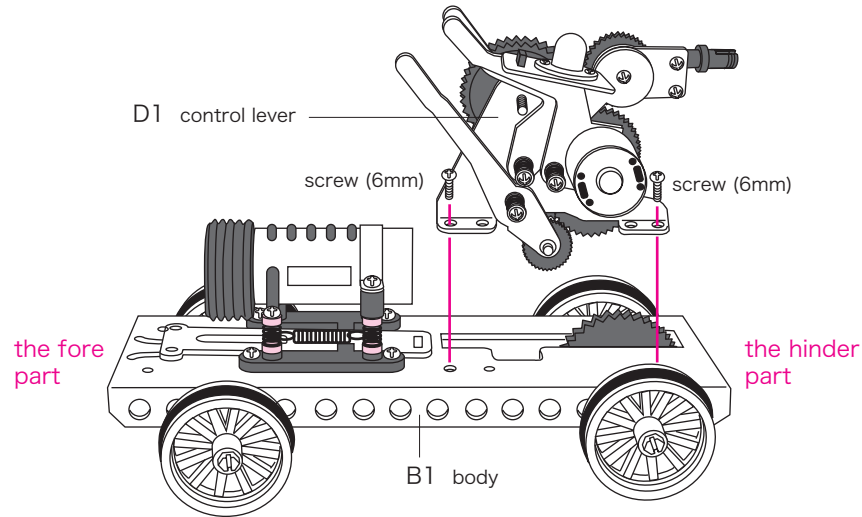
Figure — 14
Attach the control lever finished at Figure — 12, to the body finished at Figure — 9 with 6mm screws. Then, move each lever and check the operation. (If there are any loose levers, tighten the nut.)

Full-scale ※Check the size with this screw (6mm)

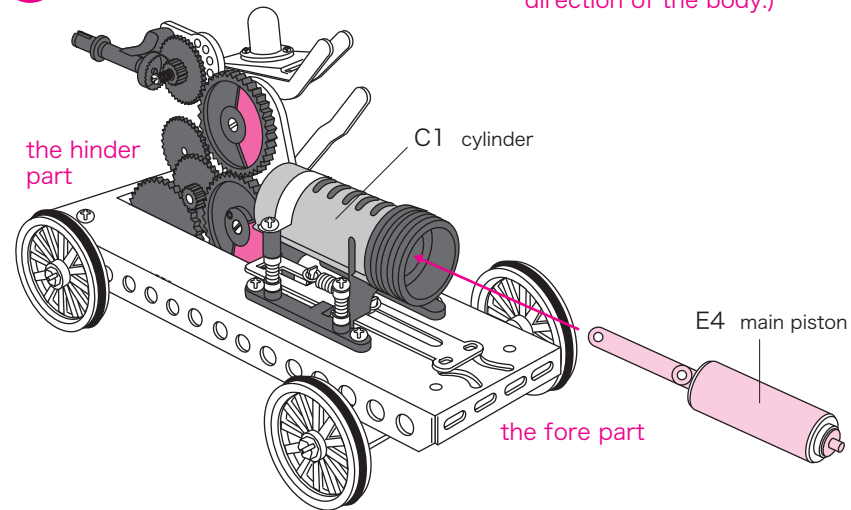
Figure — 15
Insert the E4 main piston into the C1 cylinder.

Figure — 16
Put the shaft of the E7 displacer through the E3 displacer holder and then into the center hole in the E4 main piston.

14 Attach the control lever.



15 Attach the E4 main piston. (Pay attention to the direction of the body.)



16 Attach the E7 displacer.

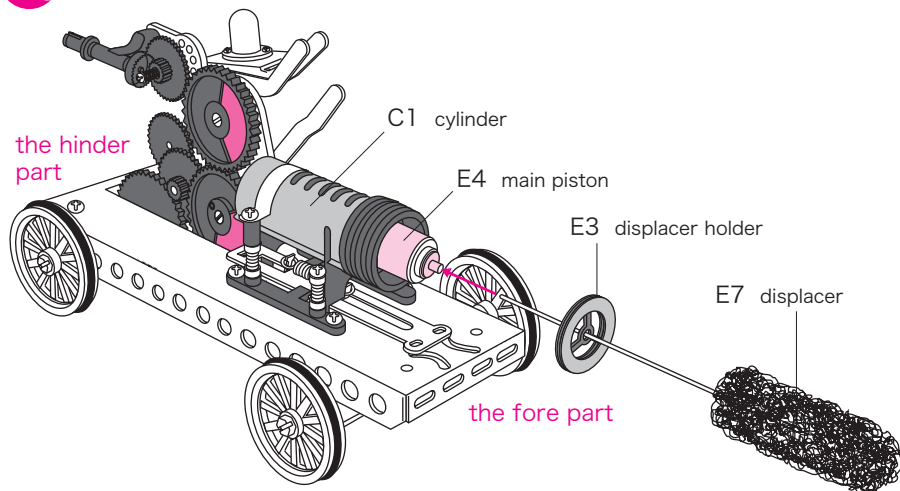
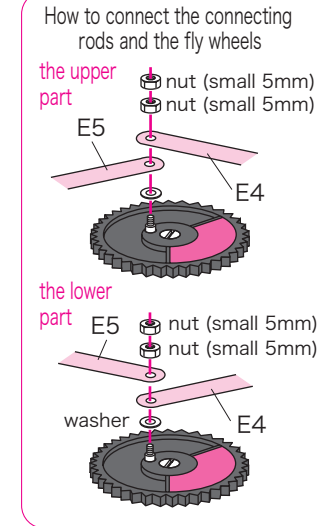


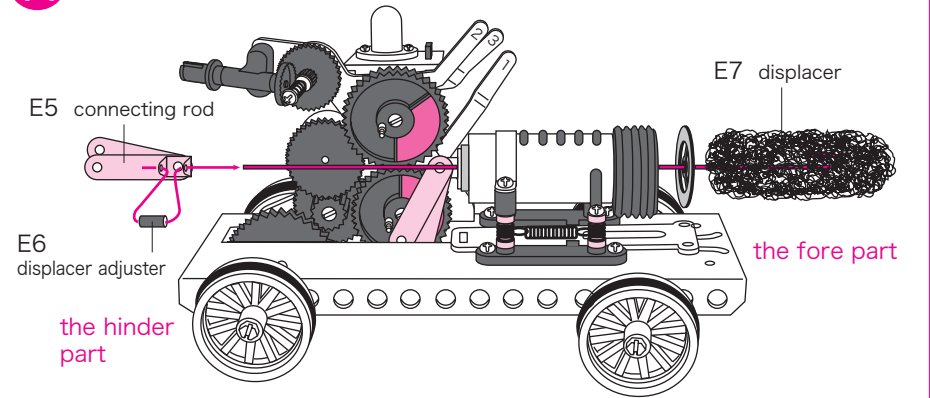
Figure — 17
Attach the E5 connecting rod to the shaft of the E7 displacer using the E6 displacer adjuster.

Figure — 18
Fasten the following parts in this order.
washer (7mm in diameter)
E5 connecting rod
the connecting rod of the E4 main piston
nut (small 5mm)
nut (small 5mm)

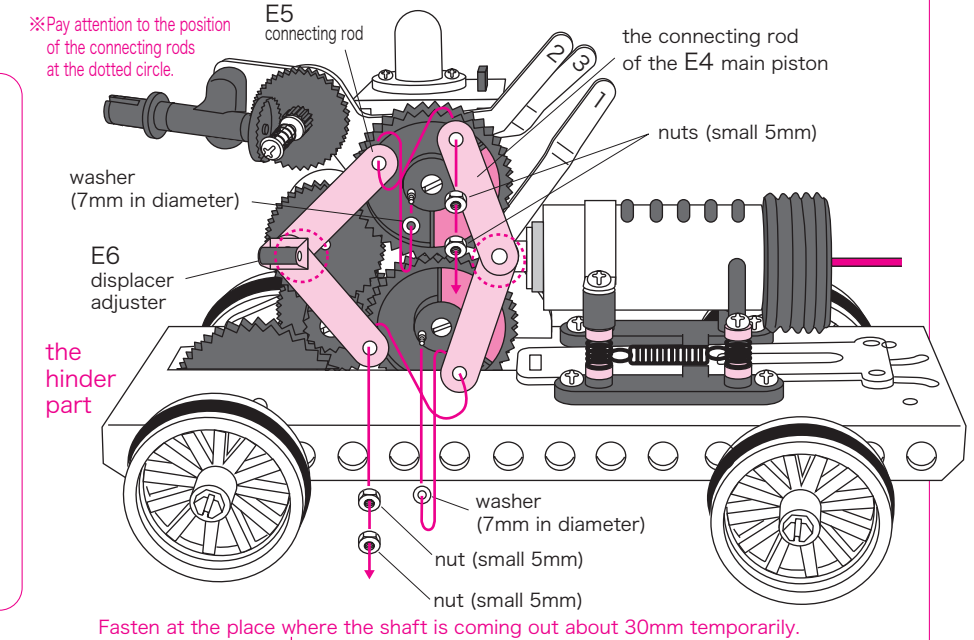


● How to screw two nuts at once.
Hold the inner nut with the wrench and screw the outer nut with the small nut wrench.

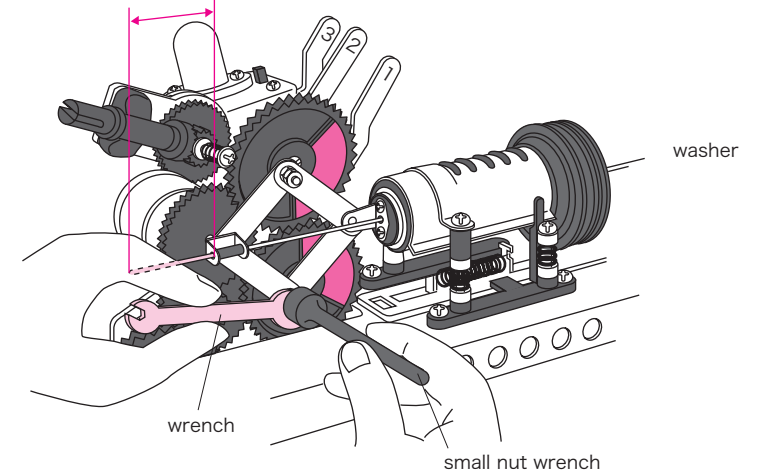
17 Attach the E5 connecting rod.



18 Attach two connecting rods to the fly wheels. (The shaft of the displacer is not illustrated to simplify the diagram.)



Fasten at the place where the shaft is coming out about 30mm temporarily.



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Figure — 19
Confirm the operation and switching of each lever with the right diagram.

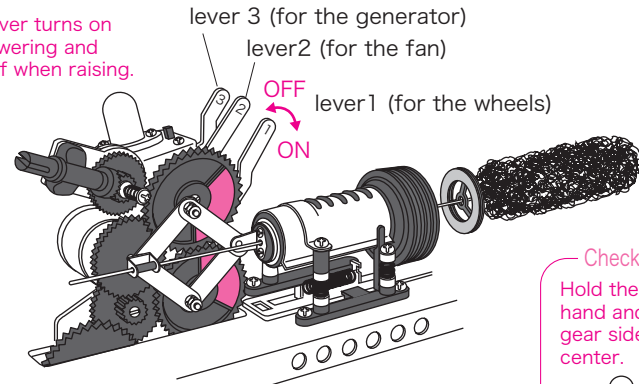
Every lever turns on when lowering and turns off when raising.

Figure — 20
Turn off the lever 1 and lever 2 and turn on the lever 3. Put the gauge to the piston part and adjust the height so that the tip of the gauge comes to the upper part of the piston (but not the cylinder). Turn the screws at both sides equally to adjust the height. Check the center at times looking from the gear side. Adjust the height so that the shaft comes straight from as near the center as possibly can.

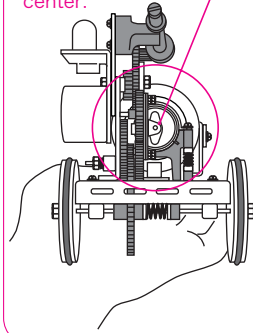
Figure — 21
Put two AA batteries in the battery box (pay attention to the direction!) and connect it with the motor connector. Check the condition by pushing forward the flywheel with a finger as shown in the Figure — 20. If it moves smoothly, the position is almost right. If it moves heavily, you need more adjustment. Find the right position until the displacer start moving automatically by turning the screws at both sides little by little. (Fine adjustment is needed. Turn the screws less than a round at a time.) The displacer moves faster in proportion as the shaft become level with the stand. Find the place where it moves as fast as possible.

19 How to turn on and off the control levers.

Every lever turns on when lowering and turns off when raising.

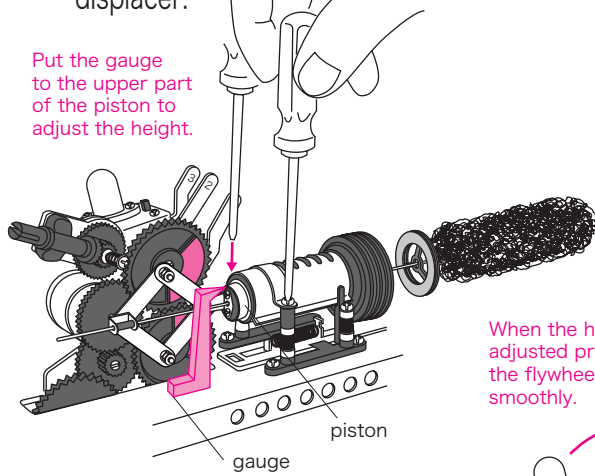


Check the center
Hold the engine in the hand and look from the gear side to check the center.

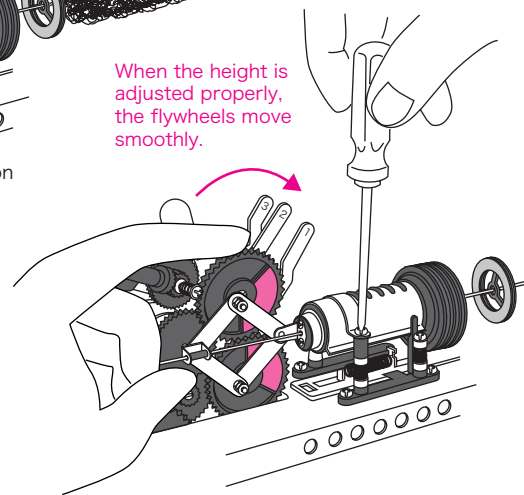
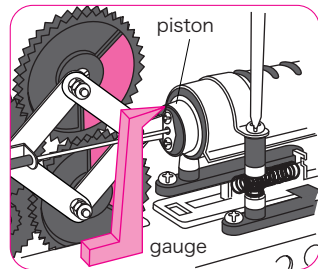


20 Adjustment of the height of the shaft of the displacer.

Put the gauge to the upper part of the piston to adjust the height.



When the height is adjusted properly, the flywheels move smoothly.



21 Adjustment of the displacer and the piston.

Adjust the height with this screw and the one at the other side.

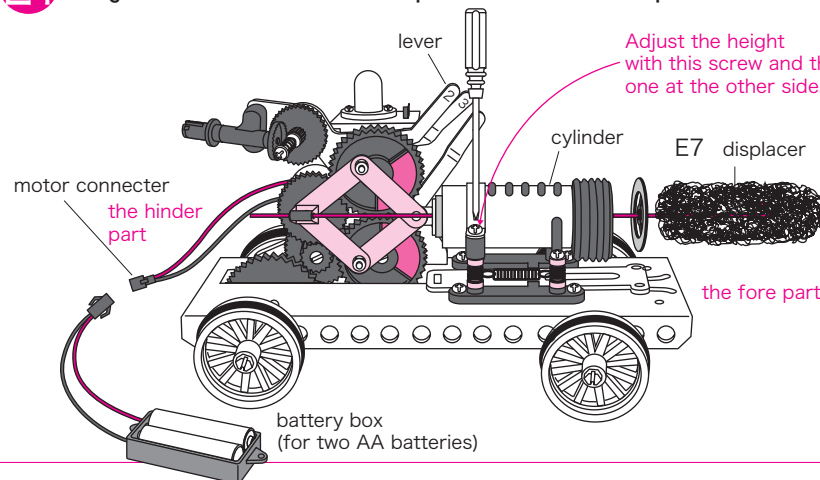


Figure — 22

After adjusting the position to move the displacer faster, disconnect the battery box from the motor connector and then connect the lamp connector and the motor connector. Then screw and set the glass cylinder paying attention not to break the displacer.

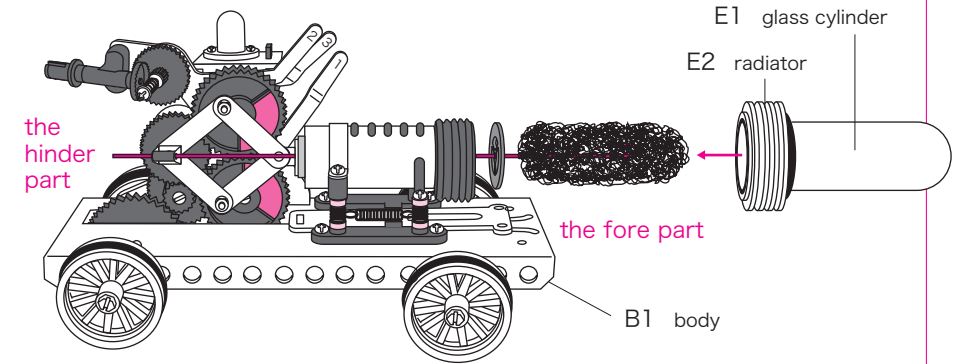
Figure — 23

Adjust the position of the shaft of the displacer while pushing forward the flywheel with a finger so that the metallic part at the end of the displacer slightly touches to the end of the glass cylinder.

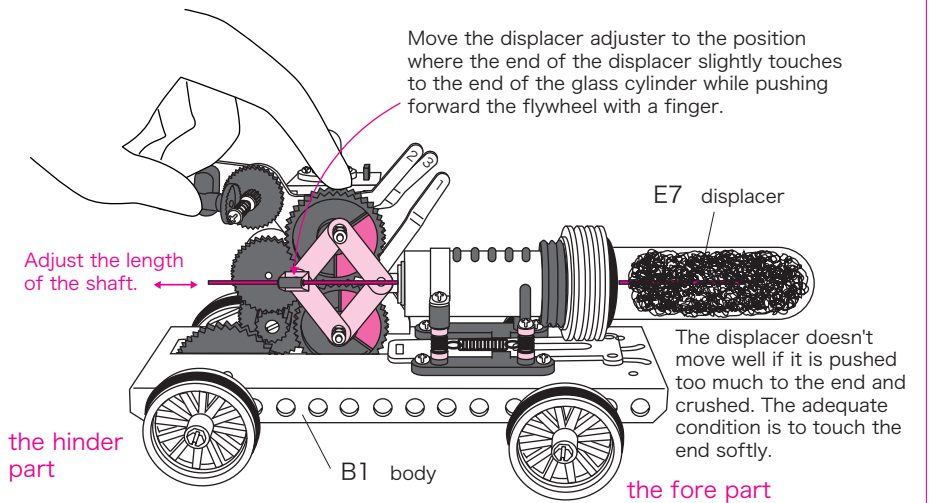
Figure — 24

Attach the E8 propeller to the D2 propeller lever.

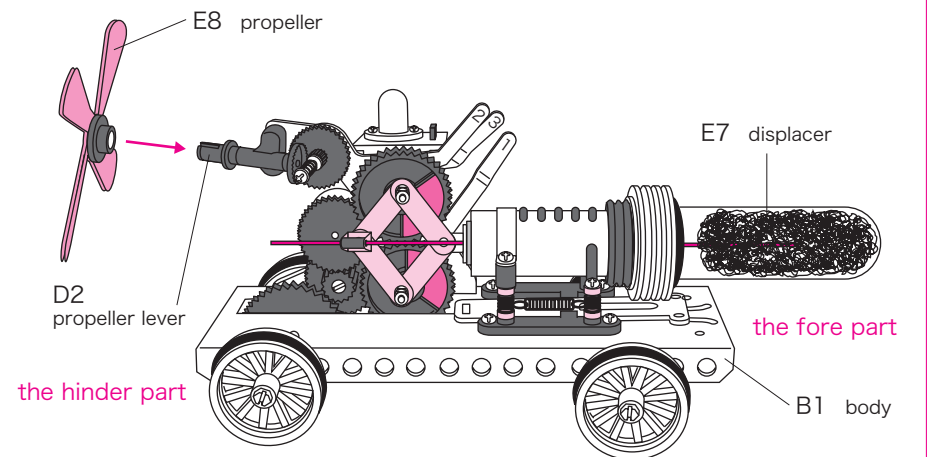
22 Attach the glass cylinder.



23 How to adjust the position of the displacer.



24 Attach the E8 propeller.



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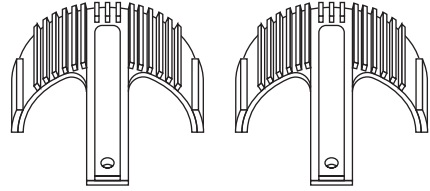
6 Attaching the Safety Covers

Parts to be used

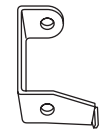
PARTS F

※ There may be more screws, washers, nuts and bushes than actually used for spare.

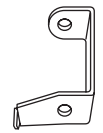
Two F1 safety covers



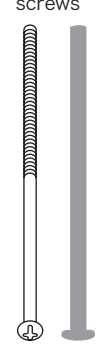
F2 hinge part



F3 hinge part



Two 40mm screws



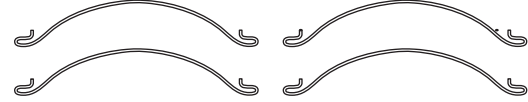
Two 6mm screws



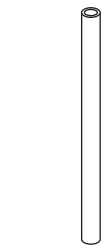
Two 9mm across spacer



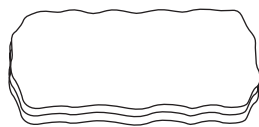
Four F4 thermal insulator hooks



Two F6 32mm pipes



F5 thermal insulator



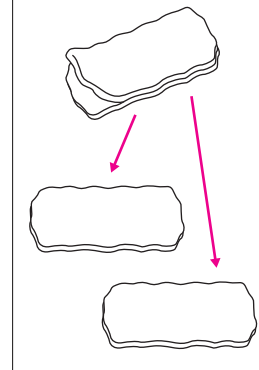
F7 sticker



※Check the length of screws with these diagrams.

Figure — 25 Assemble F1 safety cover symmetrically. (The F2 and the F3 are not the same.)

Strip off the E5 thermal insulator from the center into two sheets.



Full-scale ※Check the size with this screw (6mm)



25 Assemble the safety cover.

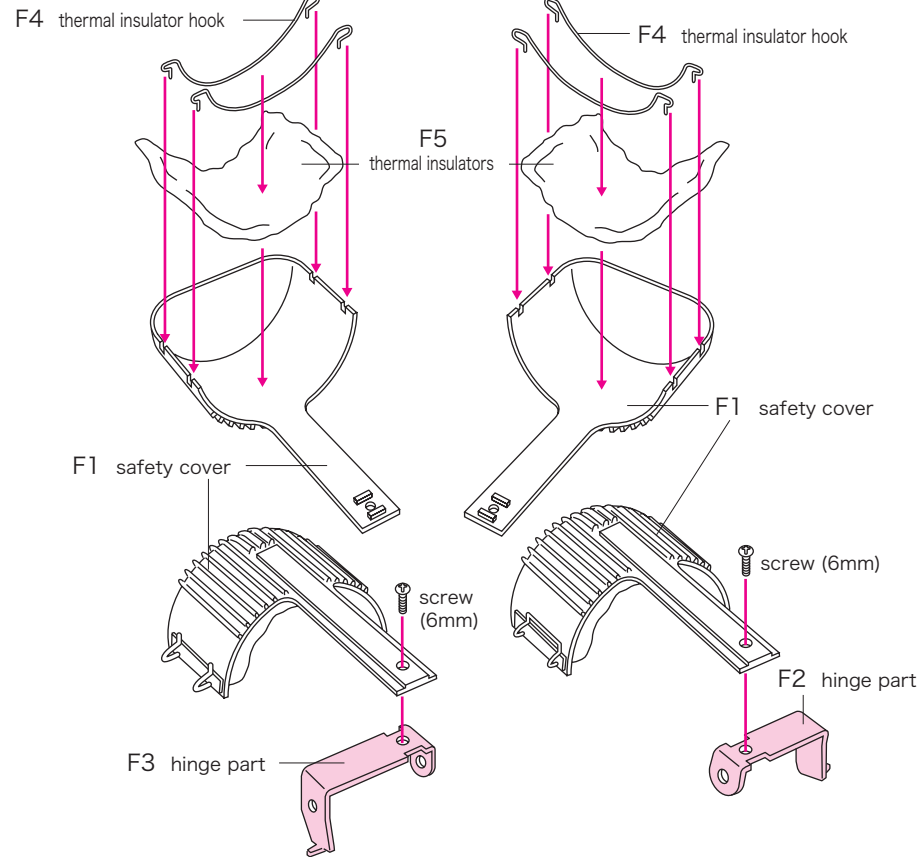


Figure — 26 Insert the hooks of the F2 and the F3 hinge parts into the holes in the sliding base to attach.

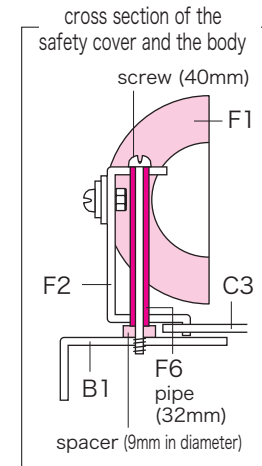
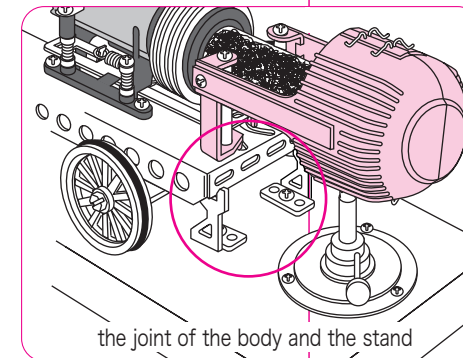


Figure — 27 Set the assembled body on the stand.



Full-scale ※Check the size with this spacer (9mm in diameter)



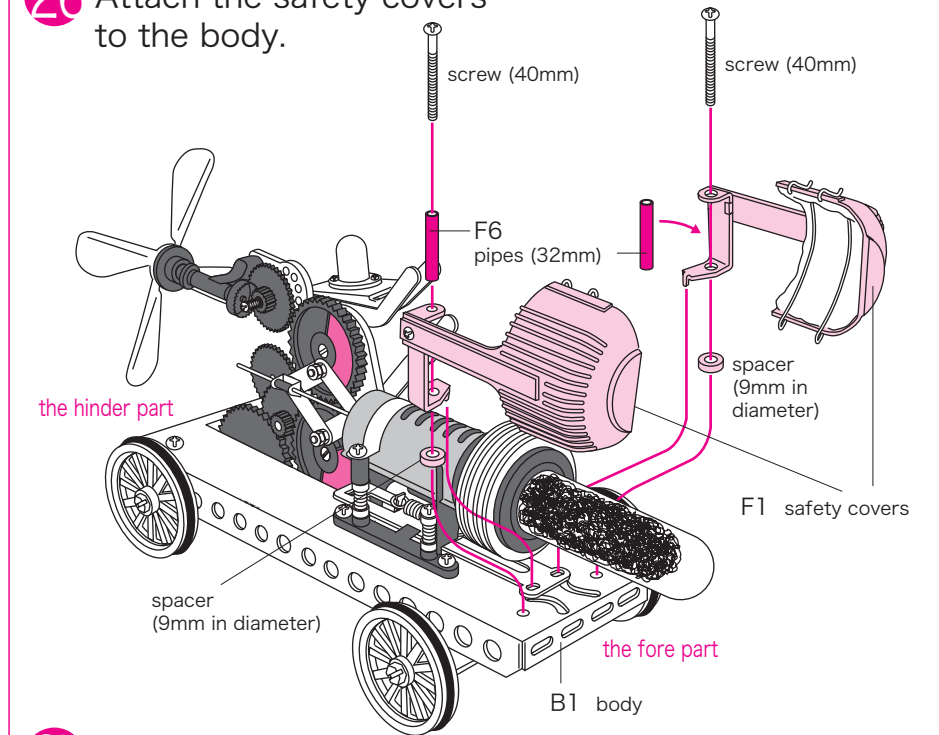
F6 pipe (32mm)



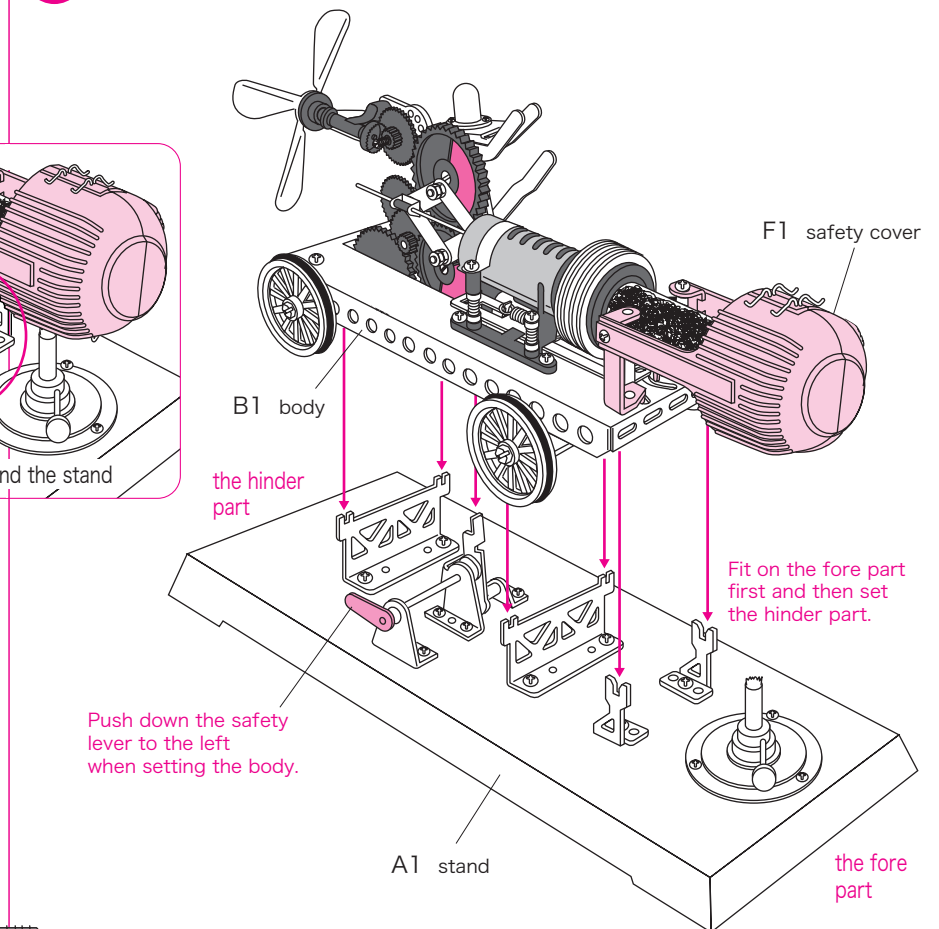
screw (40mm)



26 Attach the safety covers to the body.



27 Set it on the stand.



Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

Figure — 28
Put the F7 sticker to the stand.
The safety cover is opened by moving the safety lever.

28 Attach the sticker and the Stirling Engine is complete.

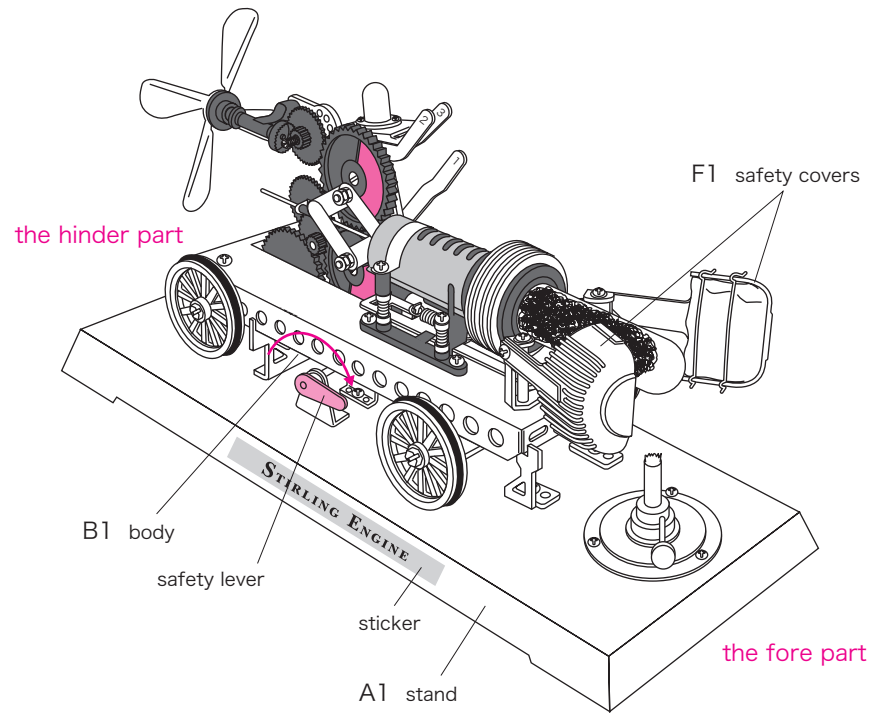


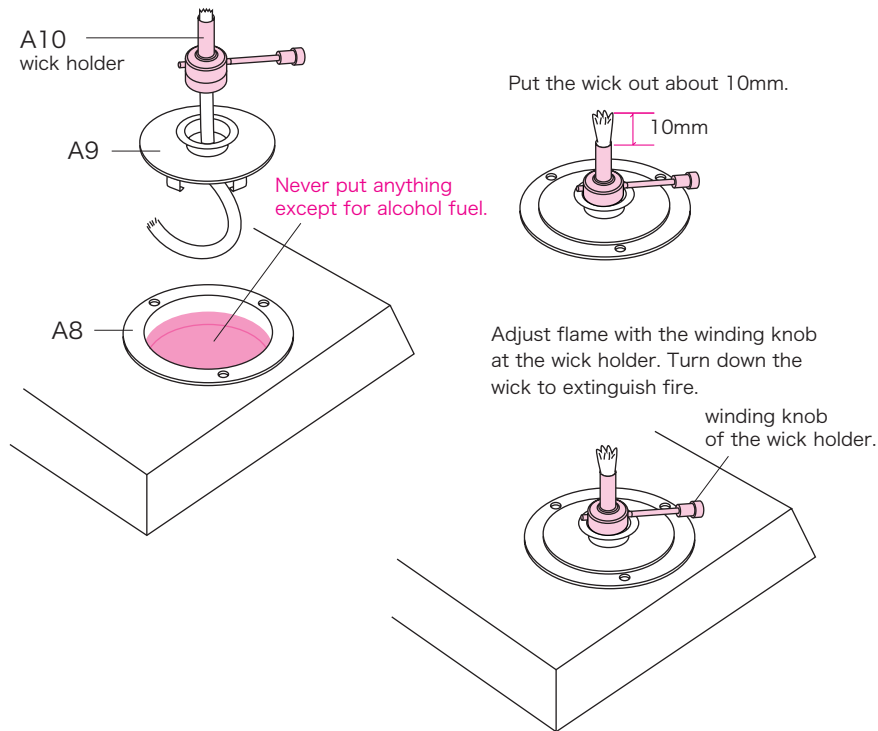
Figure — 29
Fill the alcohol tray by half with alcohol fuel.
Use great caution not to spill alcohol fuel when pouring. In case you spill the alcohol, be sure to wipe it up.

※Alcohol fuel is available at drugstores.

Fire is used. Please prepare wet towels against an emergency.



29 The explanation of the alcohol lamp.



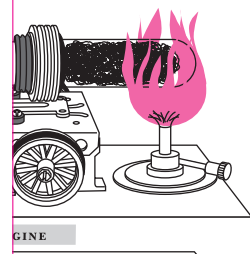
Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

7 Starting the Engine with the Alcohol lamp

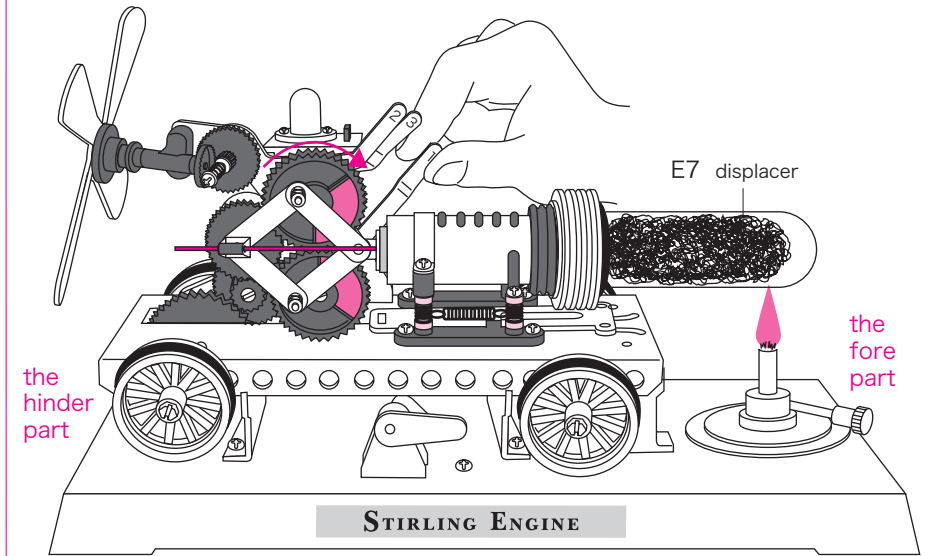
Figure — 30
Let's test the engine.
First, set the levers. Turn off three levers. Open the safety cover and light the alcohol lamp. After a while, turn the flywheel strongly in the direction of the arrow to start the engine.
(Use great caution to avoid a burn.)

Figure — 31
If it doesn't work well, adjust by turning the screws with screwdriver as shown in the right diagram to find a position where the piston moves fastest. (Turn the screws little by little. Less than a round will do.) If it still doesn't work well, try again the adjustment explained at Figure — 20.

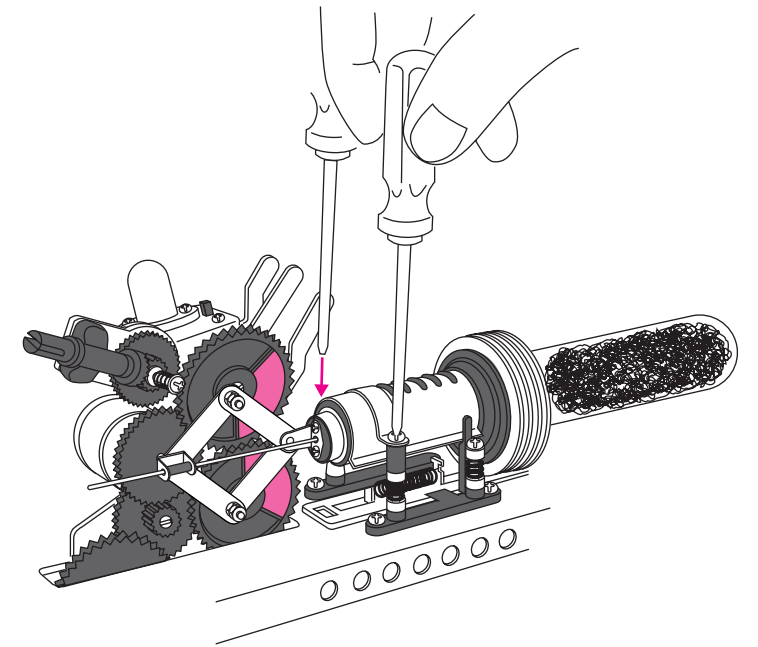
Adjust flame with the winding knob at the wick holder as shown in the figure below.



30 Start the engine with the alcohol lamp.
※The safety cover is not illustrated in this diagram to clarify the condition of the displacer.



31 How to adjust in case the piston doesn't move well.



8 Making Experiments of the Generator, the Fan and the Car

Figure — 32
<The generator experiment>

- ① Start the engine as shown on p.19.
 - ② Turn on the switch of the lamp of the generator.
 - ③ Turn on the lever 3 (for the generator) alone. (Keep the lever 1 and the lever 2 off.) Check if the lamp is lit.
- (Use great caution to avoid a burn.)

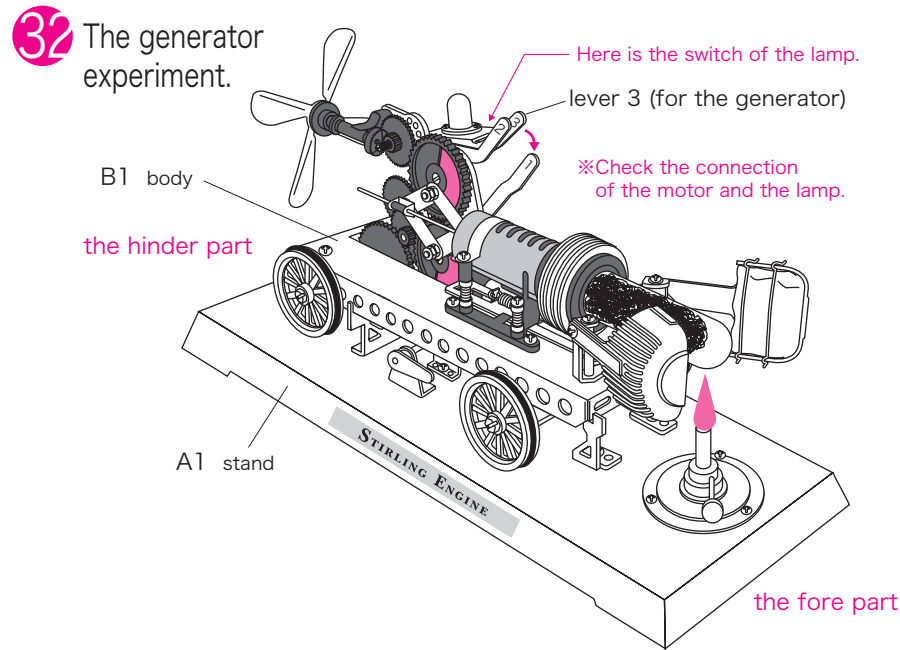
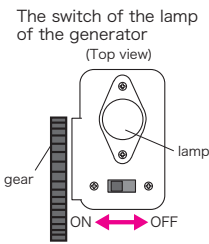


Figure — 33
<The fan experiment>

- ① Start the engine as shown on p.19.
 - ② Turn on the lever 2 (for the fan) alone. (Keep the lever 1 and the lever 3 off.) Check if the fan moves.
- (Use great caution to avoid a burn.)

Fire is used. Please prepare wet towels against an emergency.

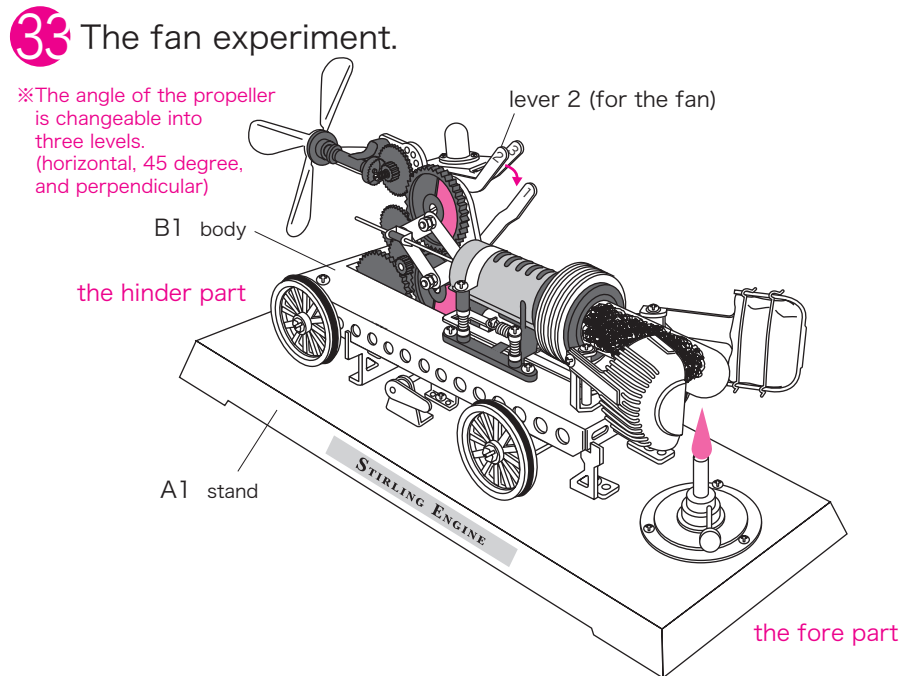


Figure — 34

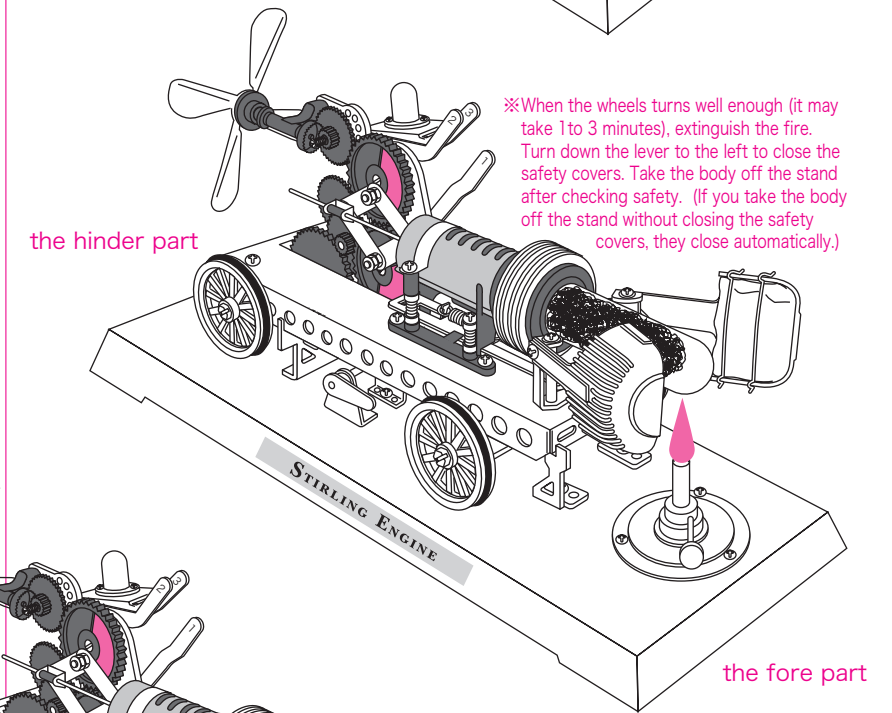
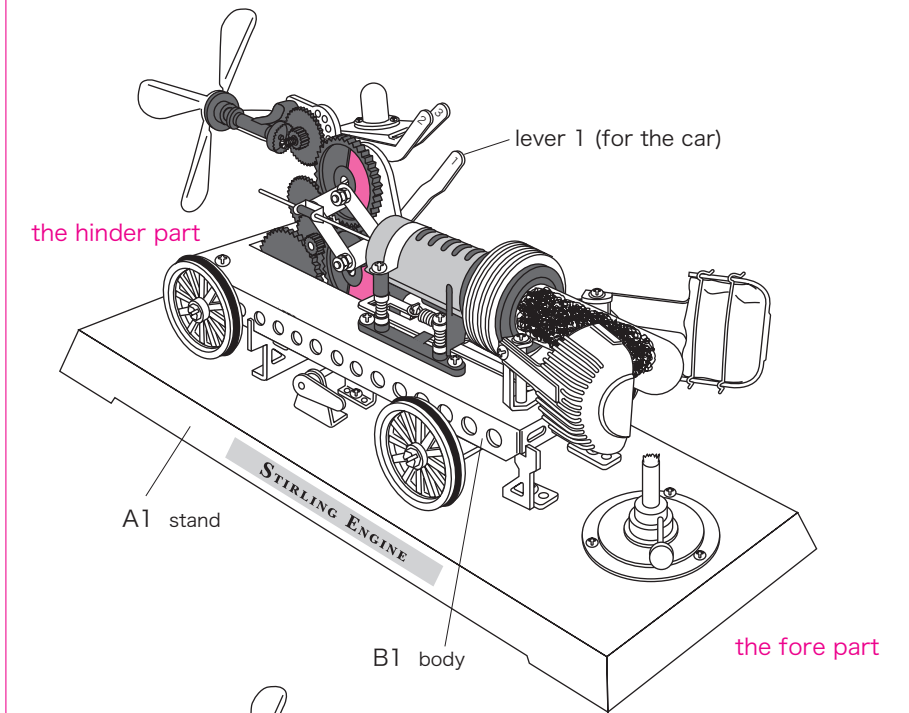
Caution : When you make this experiment continuously after the generator experiment or the fan experiment, extinguish the fire once, and wait until the glass cylinder gets cold. Start the experiment again after the cylinder gets cold enough and the safety is checked.

<The car experiment>

- ① Start the engine as shown on p.19.
- ② Turn on the lever 1 (for the car) alone. (Keep the lever 2 and the lever 3 off.) Check if the wheels turn.
- ③ When the wheels turn well enough, extinguish the fire. Turn down the safety lever to the left to close the safety covers.
- ④ Take the body off the stand and put the body on the ground. It starts moving slowly.

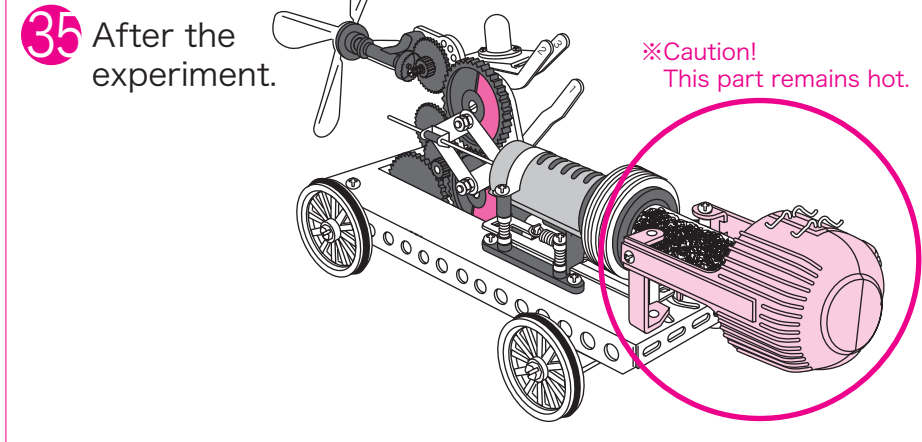
The glass cylinder remain hot after the fire is extinguished. Do not touch the car while moving to avoid danger of a burn.

34 The car operating experiment.



Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

Figure — 35
The end of the engine has remaining heat after the experiment. Make sure it becomes cold enough before you put it away.



Warning ★ Fire is used for the experiment. Use great caution to avoid a burn and fire. Do not let a 15 or less-year-old child experiment alone.

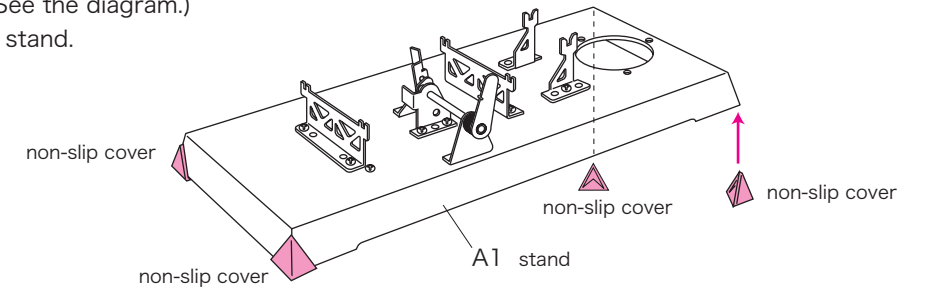
- ★ Caution with Fire and Heat ★**
- Do not leave the engine while the lamp is lit or heat remains.
 - Do not hold the body or the stand when the lamp is lit. It is very dangerous if the alcohol spill.
 - Do not put the stand on a slippery surface when making an experiment, or it may move.
 - Use great caution with small children when making the car experiment together.
 - Use great caution with remaining heat after the experiment.
 - Remove alcohol from the alcohol tray after the experiment when not using for a long time.
 - Use great caution to keep alcohol fuel after the experiment. Keep children away from the fuel and the machine.

Trouble Shooting STIRLING ENGINE

- Q: The displacer doesn't move even with batteries.**
A1. Are the batteries new? Are the positive and negative terminals on the batteries facing the right way? Are the motor and the batteries connected firmly?
A2. Have you adjusted the heights of the piston with a gauge accurately?
A3. Isn't the gear idling? (Ensure the lever 3 is turned on.)
- Q: The displacer moves with batteries but doesn't move with the alcohol lamp.**
A1. Do the displacer adjuster (the black rubber tube at the E5 connecting rod) and the metallic part at the end of the displacer move in the same rhythm? (If they don't, see p.15 and adjust the length of the shaft of the displacer.)
A2. Does the wick of the alcohol lamp come out enough? (Check with the diagram at p.18)
- Q: The fan experiment doesn't go well.**
A. Doesn't the nut at lever 2 loosen and the gear become out of mesh? (Tighten the nut of the lever 2.)
- Q: The engine becomes slow after several times of experiments.**
A. Dust may be produced by the friction wear of the metallic end. Remove the glass cylinder and clean out the dust.

Attaching Non-Slip Cover to the Four Corners of the Stand

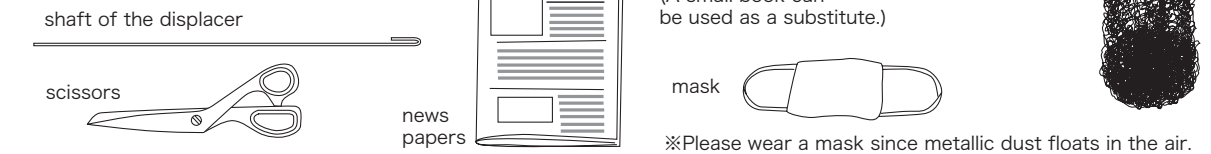
Set four non-slip covers (See the diagram.) to the four corners of the stand.



Making Your Own Displacer

You can make your own displacer using the shaft of the displacer in the kit. In case you make one, follow the instructions below. (It is not necessary to make one if the kit moves well in the first place. Try when the original one crumbles, or the metallic part has come off, or you really want to try.)

Things you need



- ① Cut the steel wool in half.
 - ② Spread the steel wool as this diagram.
 - ③ Cut it in 1/3 and 2/3.
 - ④ Put the 1/3 around the shaft to form a core.
 - ⑤ Wrap it tight.
 - ⑥ Wrap what is left around the core. Wrap the first half tight and the second half a little looser.
 - ⑦ Neaten the shape of the rolled steel wool with a board. Move it back and force in the glass cylinder to check the shape at times.
 - ⑧ After neatening it, cut it in the length shown in the diagram below. (Pay attention not to cut the shaft. Cut both ends.) Press it in the glass cylinder to fix the shape.
- It looks like this so far.
- about 15cm
- about 6cm