

# How do Stirling Engines work?

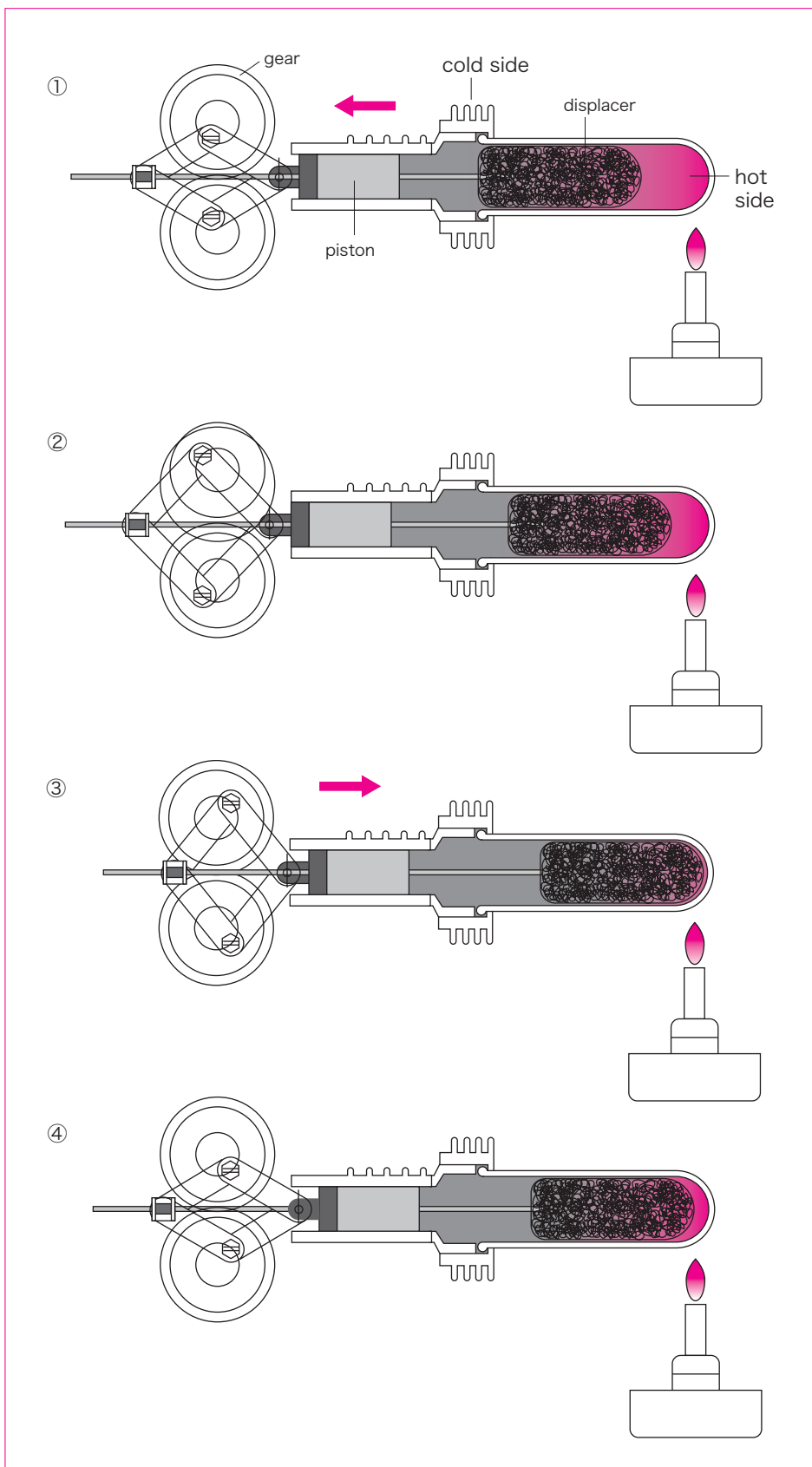
The following is the mechanism of Stirling engines.

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

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

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

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

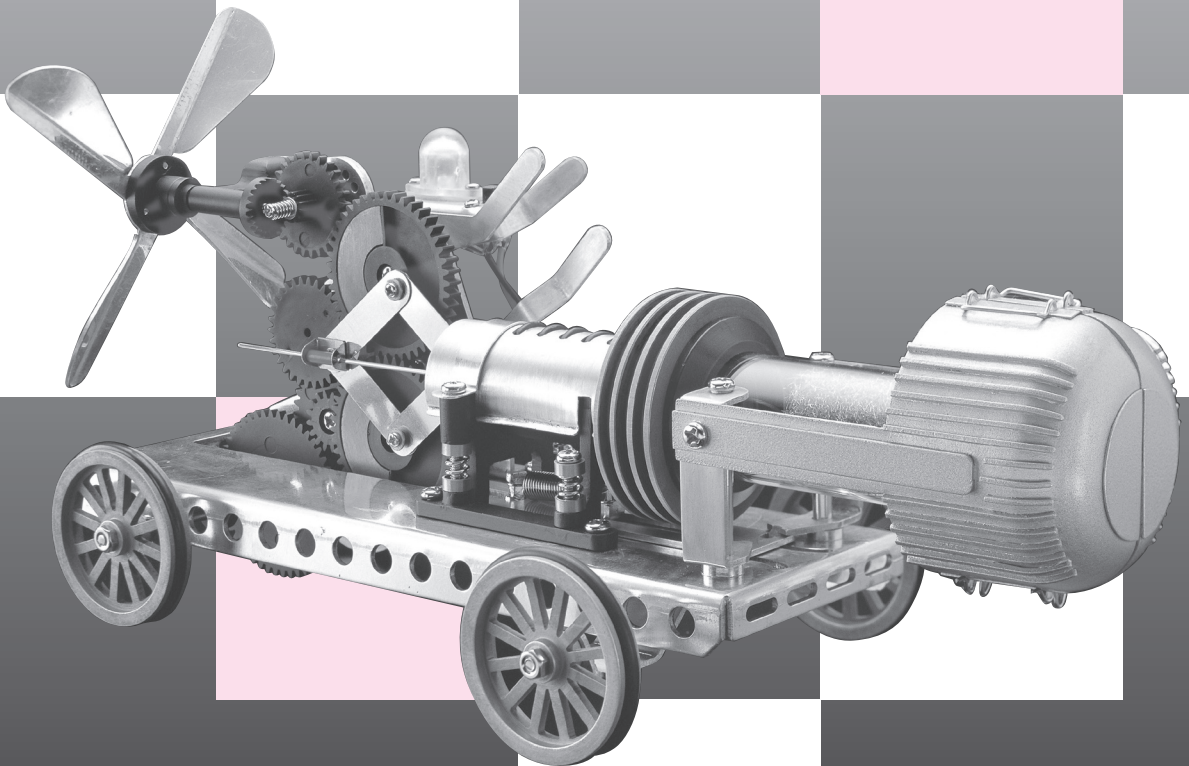


大人の科学® Otona no Kagaku  
The Sophisticated Science Kit for Adults

# STIRLING ENGINE

STIRLING ENGINE

Instructions for Assembling and Operating



Gakken

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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

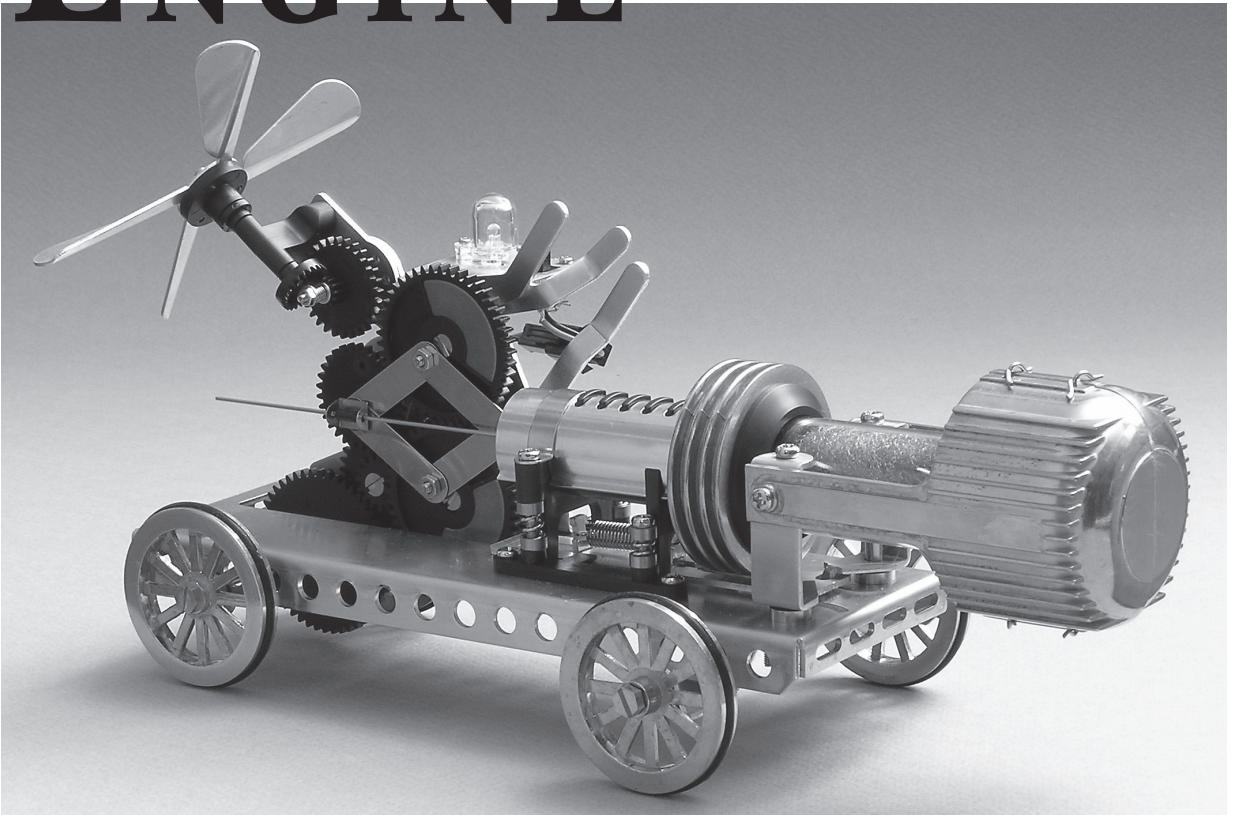
\*Vinyl chloride resin is used for the covers of the lead wires.

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

大人の科学® Otona no Kagaku

# STIRLING ENGINE

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.

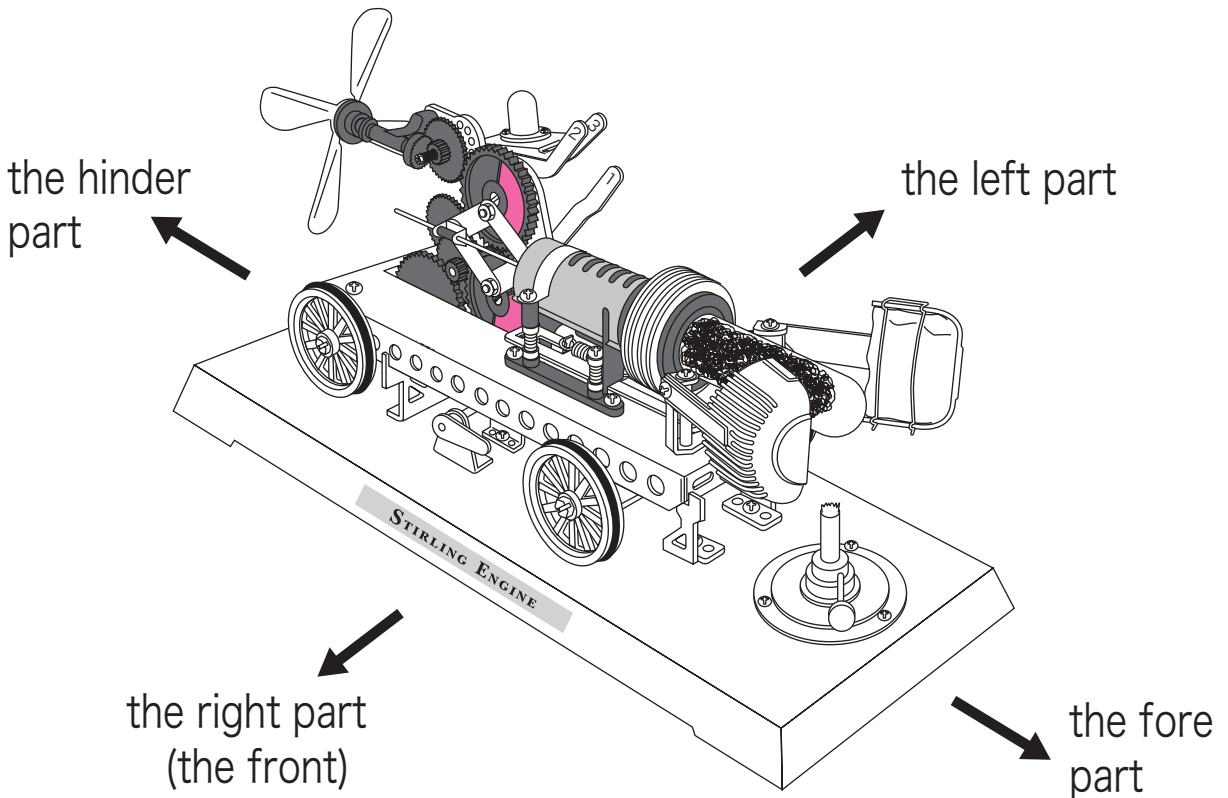
It takes about three hours to assemble. You don't need any special tool. (Size AA batteries to adjust the engine and alcohol fuel are not included in the kit.) Please follow this instruction booklet when you assemble.

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.

# Before Assembling the Kit

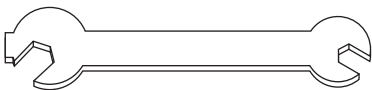
## 1. Understanding the right direction

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.

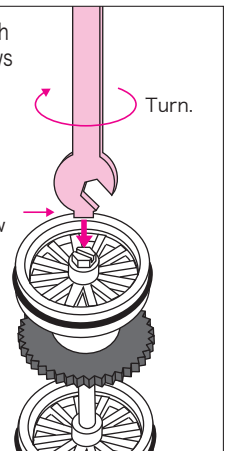
### ●screwdriver (cross-headed tip)



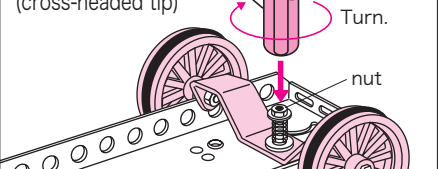
The screwdriver can be used not only for tightening a screw but also for tightening a nut as shown in the right figure.

How to use the wrench when tightening screws

Put the thin part of the wrench at a slot of the screw to fix.



How to use the screwdriver (cross-headed tip)



※ 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.

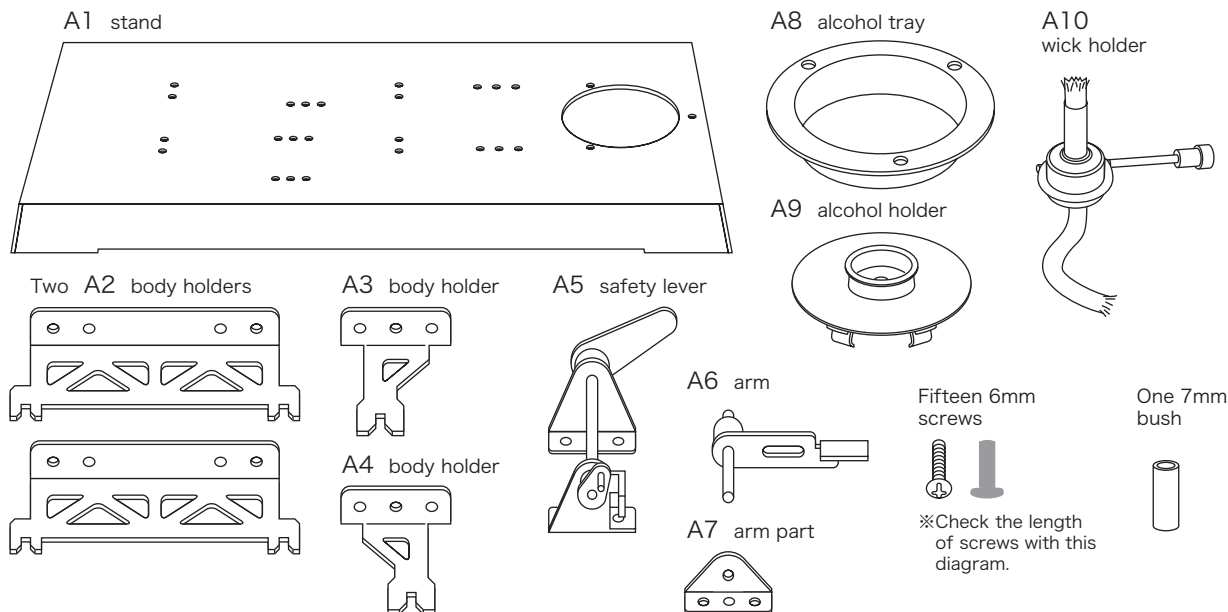
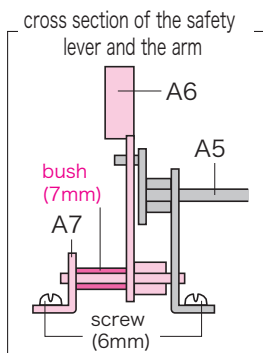


Figure — ①  
 Attach the A5 safety lever to the A1 stand with 6mm screws. Then, attach the A6 arm to the A5 safety lever, put in the bush and fasten with the A7 arm part.



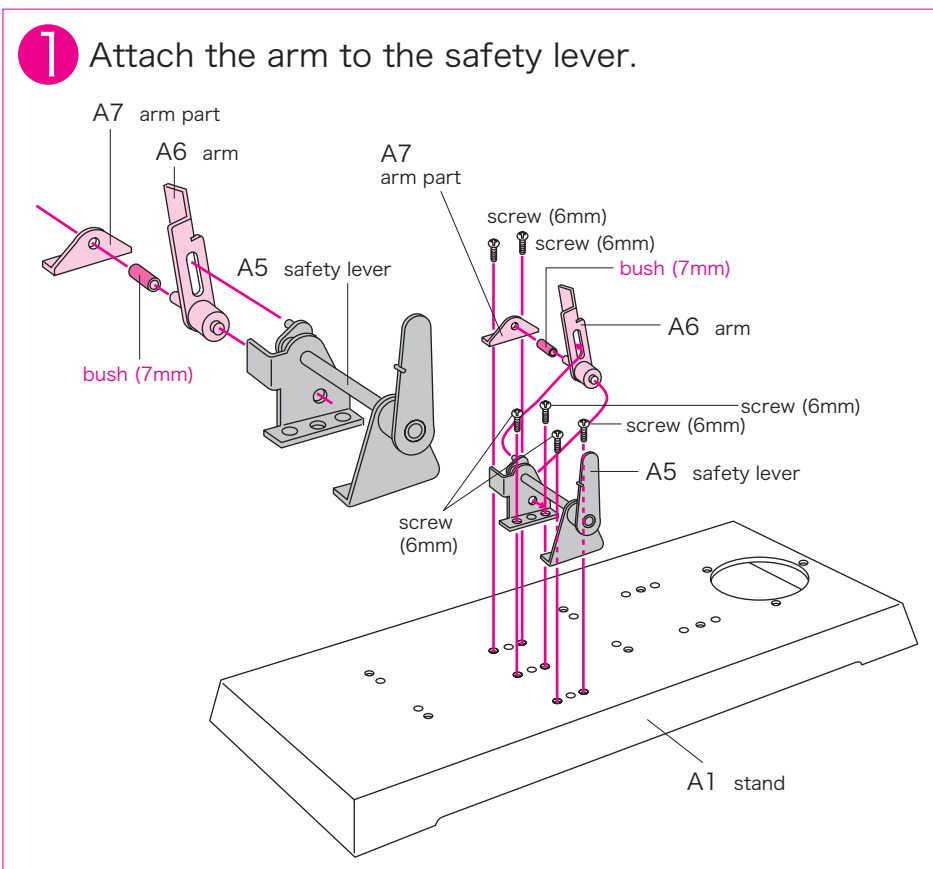
Full-scale ※Check the size with this.



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).

## ② Attach the body holding parts.

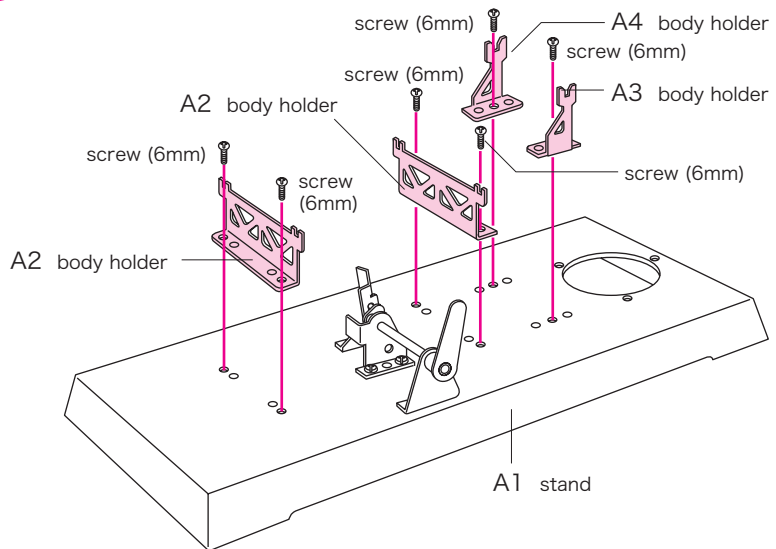
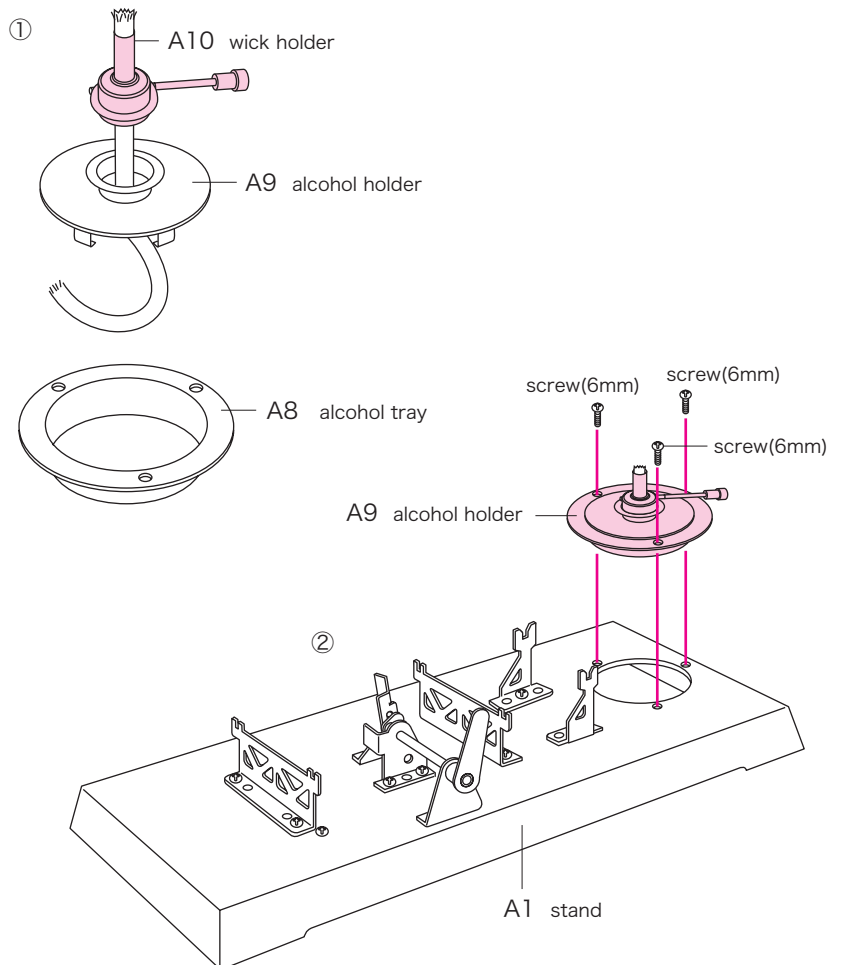


Figure — ③

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.)

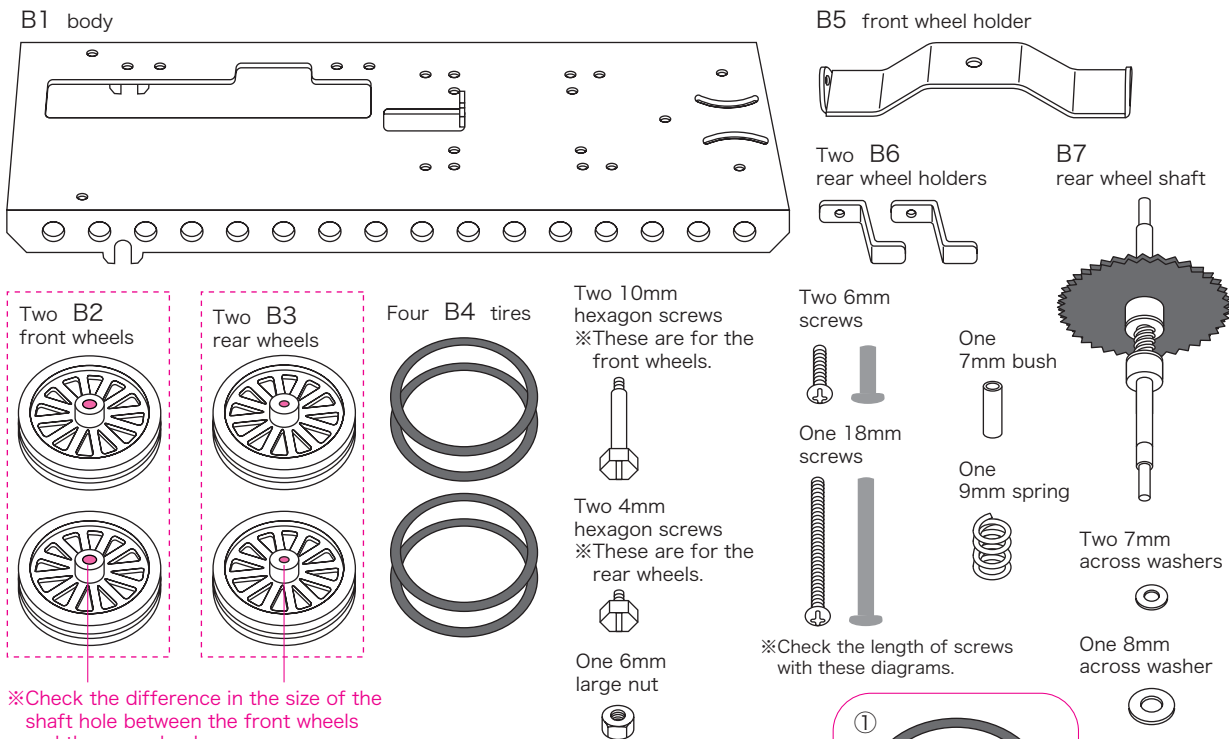
② Fasten the alcohol lamp to the A1 stand with screws (6mm).

## ③ Assemble the alcohol lamp and attach it to the A1 stand.



# 2 Attaching Wheels to the Body

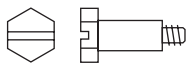
**Parts to be used** PARTS B ※ There may be more screws, washers, nuts and bushes than actually used for spare.



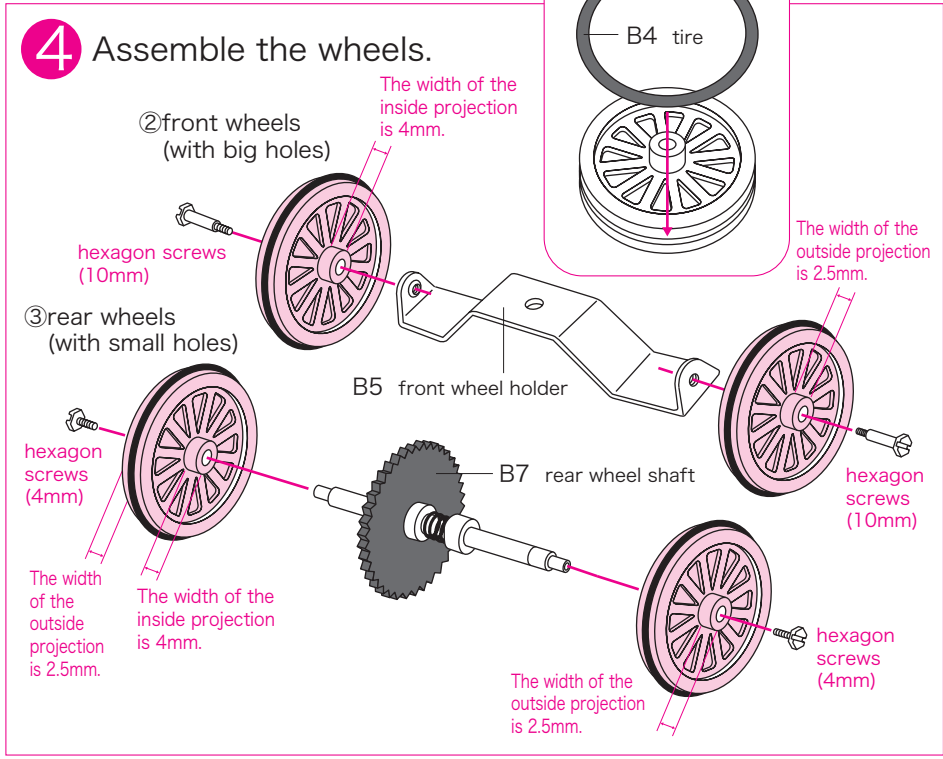
※Check the difference in the size of the shaft hole between the front wheels and the rear wheels.

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



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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.

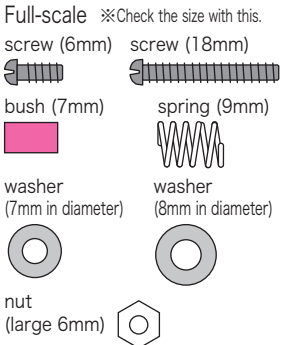
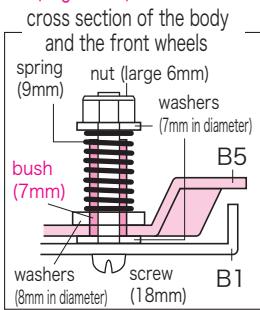


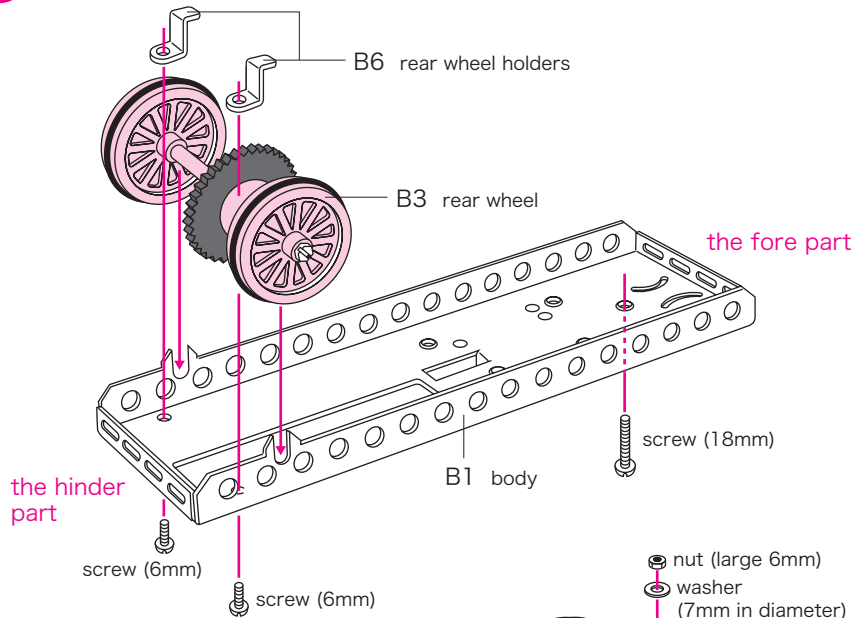
Figure — 6

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

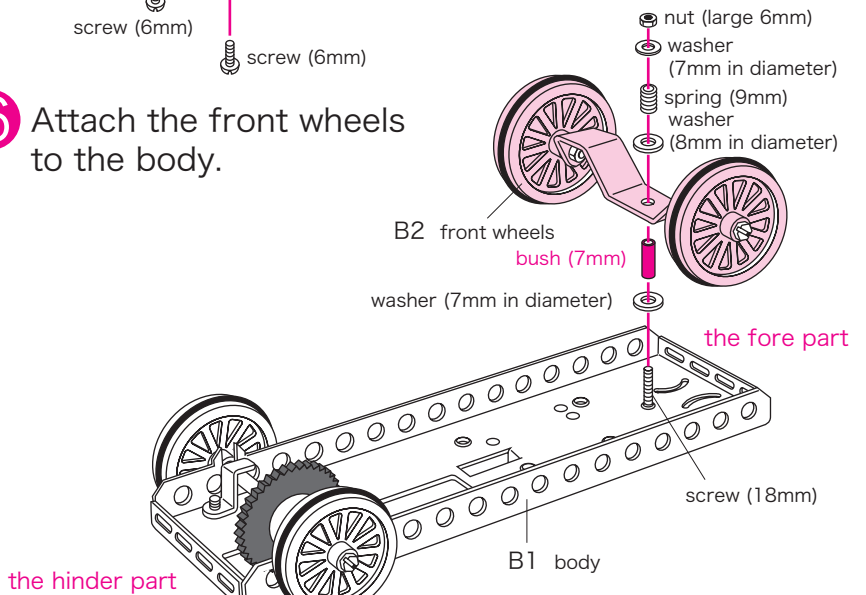
- washer (7mm in diameter)
- bush (7mm)
- front wheel holder
- washer (8mm in diameter)
- spring (9mm)
- washer (7mm in diameter)
- nut (large 6mm)



## 5 Attach the rear wheels to the body.



## 6 Attach the front wheels to the body.

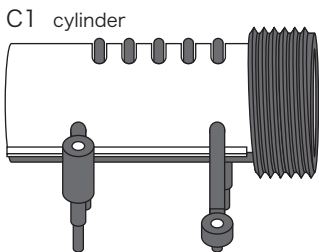


# 3 Attaching the Cylinder to the Body

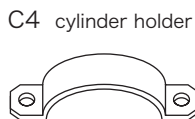
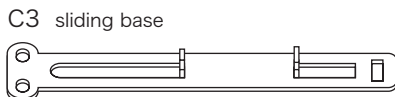
Parts to be used

**PARTS**

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



Two C2 cylinder supports



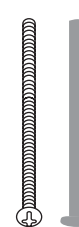
Four C6 cylinder springs



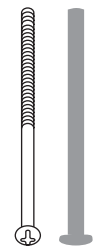
Four 6mm screws



Two 26mm screws



Two 30mm screws



※Check the length of screws with these diagrams.

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)



7 Attach the C3 sliding base.

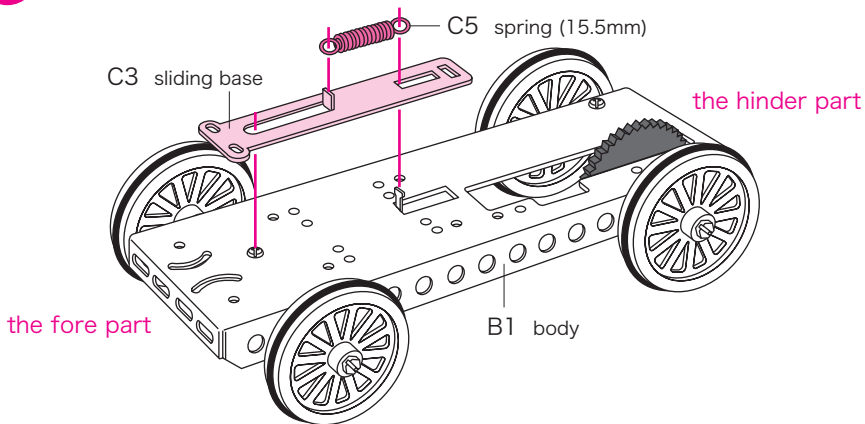


Figure — 8

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

8 Attach the C2 cylinder supports.

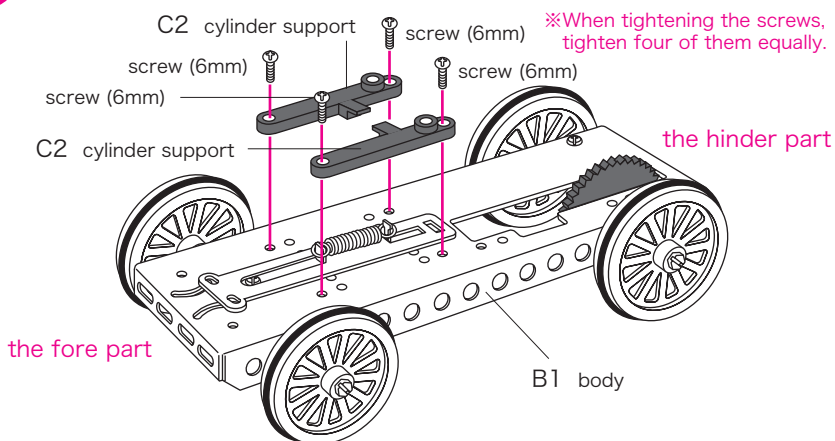


Figure — 9

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)

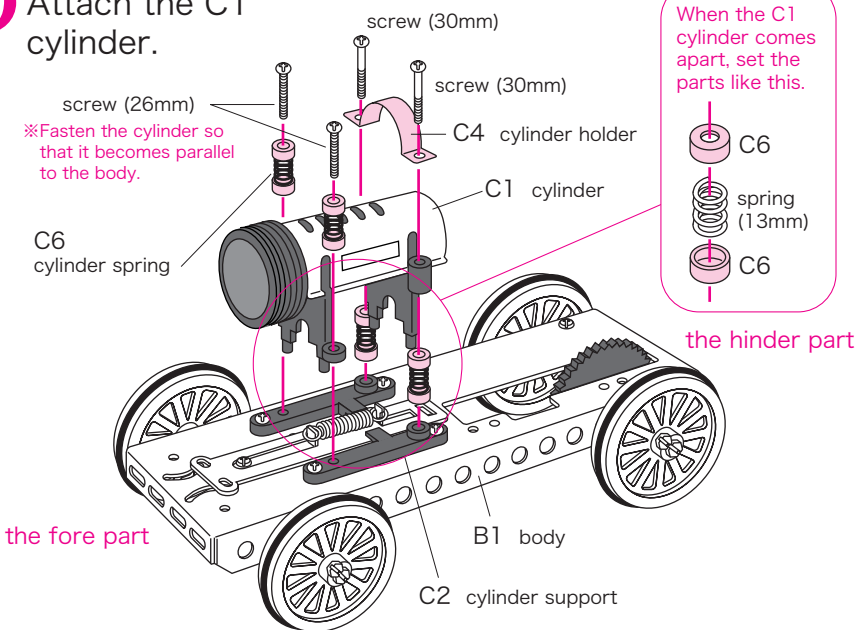


2.5mm in thickness

spring (13mm)



9 Attach the C1 cylinder.



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.

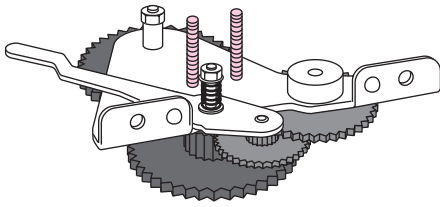
# 4 Assembling the Lever Part

## Parts to be used

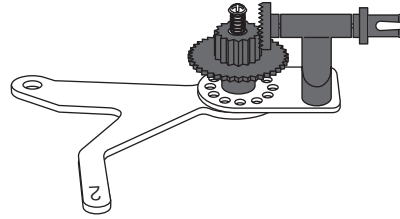
## PARTS D

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

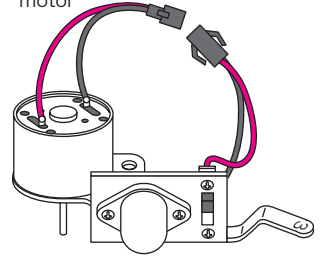
D1 control lever



D2 propeller lever



D3 motor



Two 7mm  
across washers



Two 8mm  
across washers



Two 6mm  
large nuts



Two 9mm  
springs



Two 7mm  
bushes



One 9mm  
across spacer



D4 gear

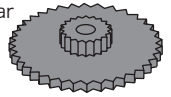


Figure — 10  
Attach the D2  
propeller lever to the  
D1 control lever.

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

Full-scale ※Check the size with this.

washer  
(7mm in diameter)



washer  
(8mm in diameter)



spacer  
(9mm in diameter)



nut  
(large 6mm)



bush (7mm)

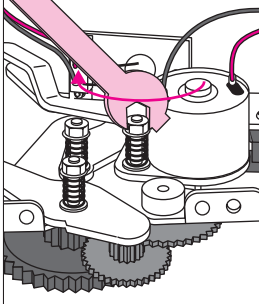


spring (9mm)

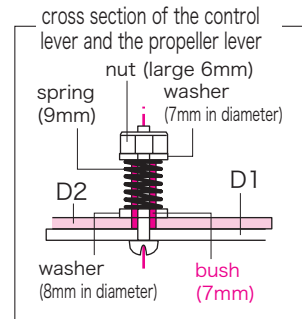
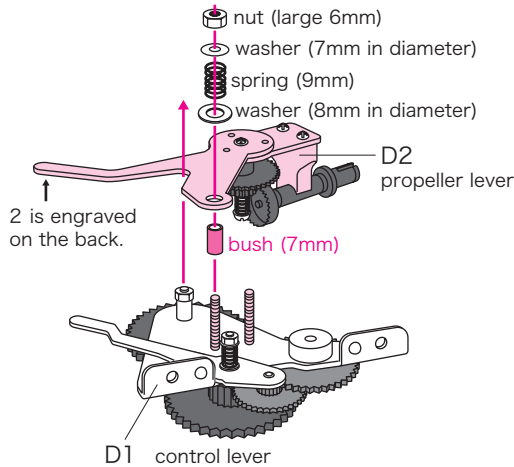


How to use the  
wrench here

Put it on from the  
top vertically and  
turn little by little.



10 Attach the propeller lever to the control lever.



11 Attach the motor.

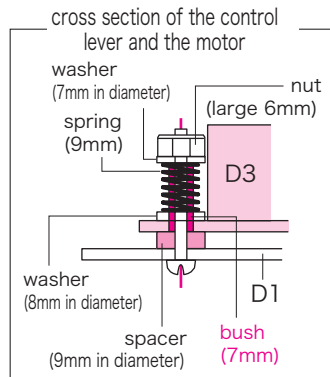
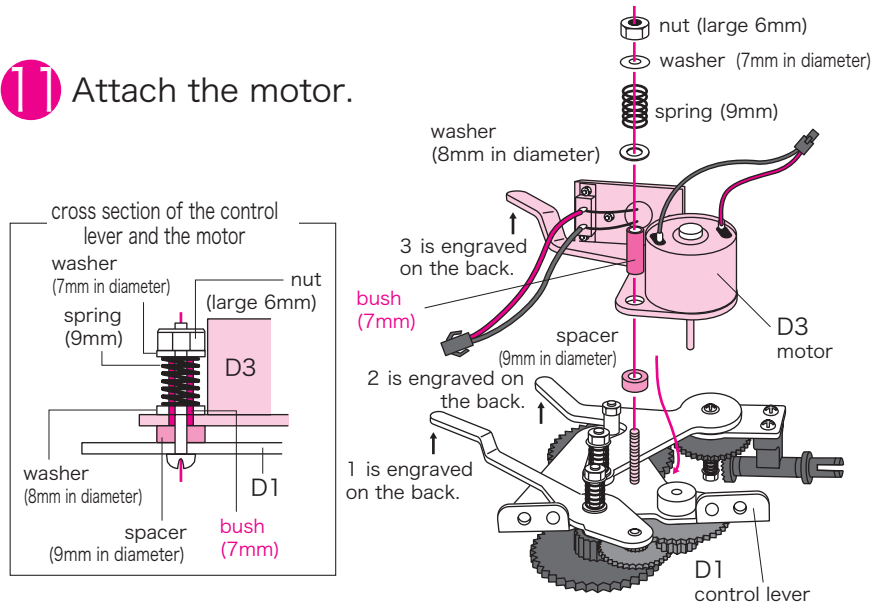
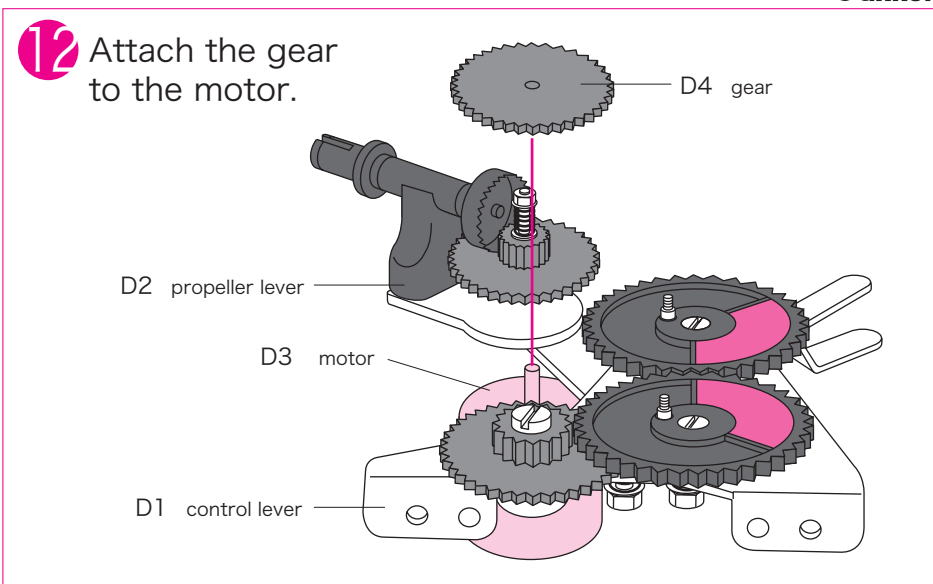


Figure — 12  
Push the D4 gear on the motor assembled at Figure — 11.



## 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.

E1 glass cylinder



E7 displacer



Two 7mm washers



Four 5mm small nuts



Two 6mm screws



※ Check the length of screws with this diagram.

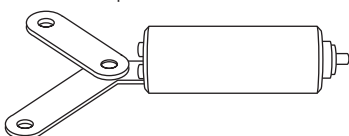
E2 radiator



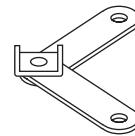
E3 displacer holder



E4 main piston



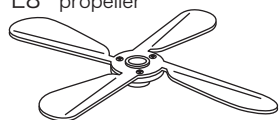
E5 connecting rod



E6 displacer adjuster

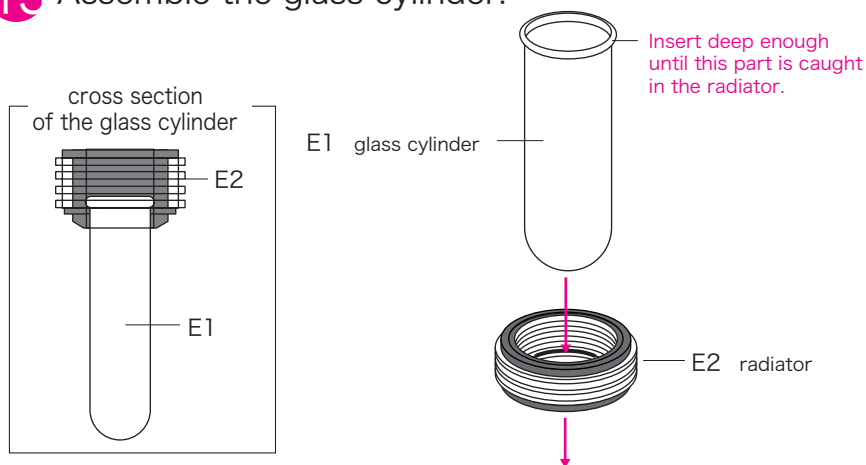


E8 propeller



**13** Assemble the glass cylinder.

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



**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 — 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.)

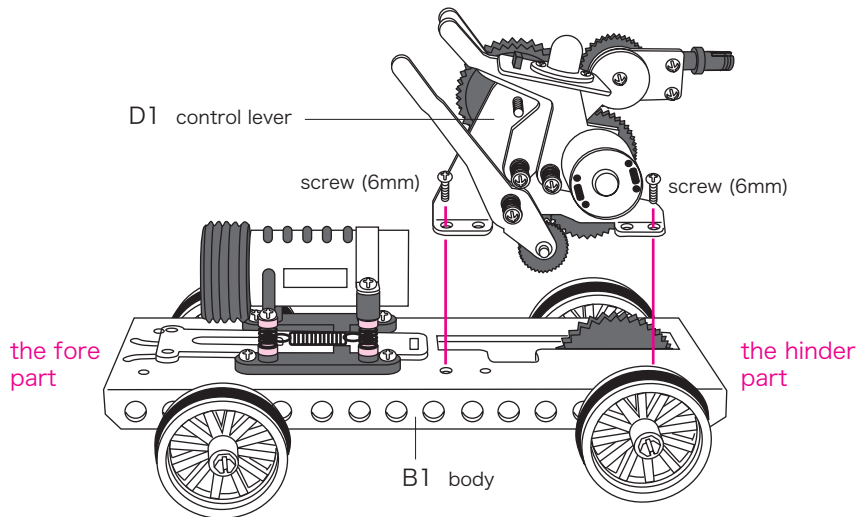
Full-scale ※Check the size with this screw (6mm)



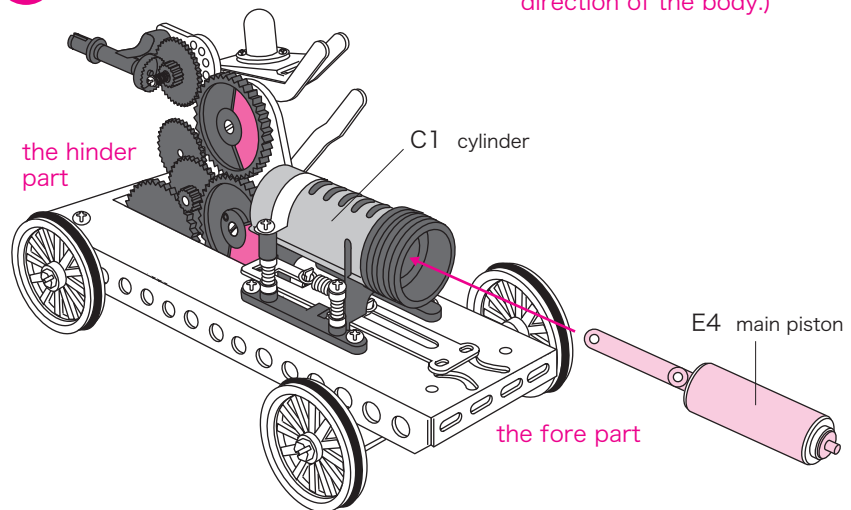
Figure — 15  
 Insert the E4 main piston into the C1 cylinder.

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.

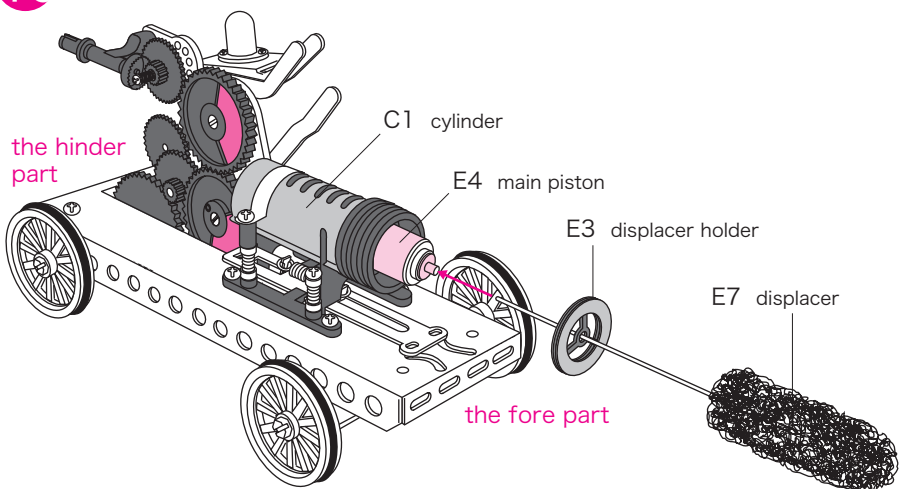


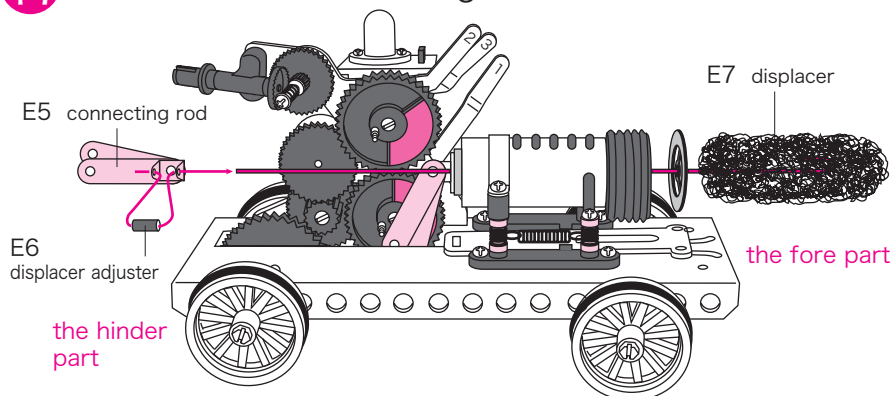


Figure — 17  
 Attach the E5 connecting rod to the shaft of the E7 displacer using the E6 displacer adjuster.

Figure — 18  
 Fasten the following parts in this order.

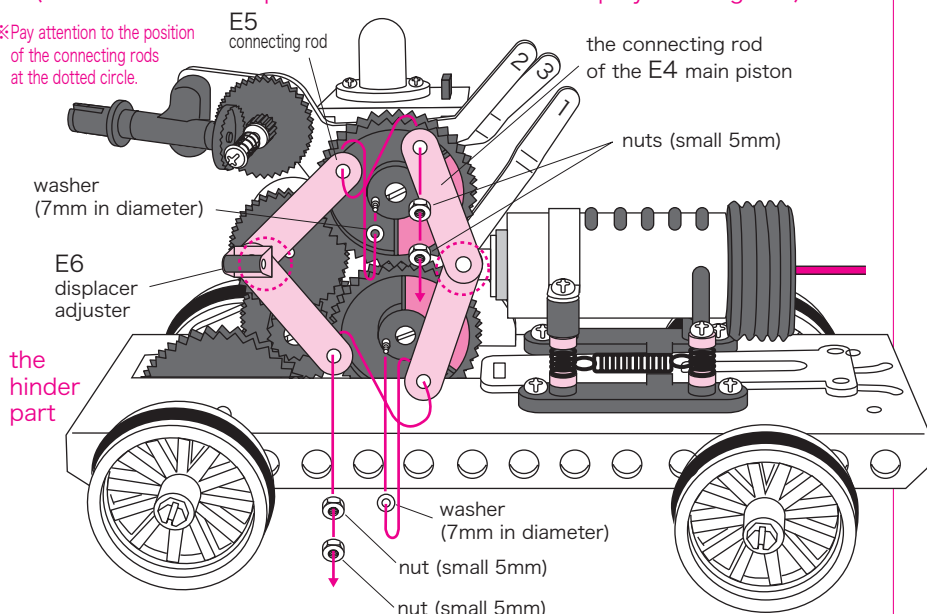
- washer (7mm in diameter)
- E5 connecting rod
- the connecting rod of the E4 main piston
- nut (small 5mm)
- nut (small 5mm)

17 Attach the E5 connecting rod.

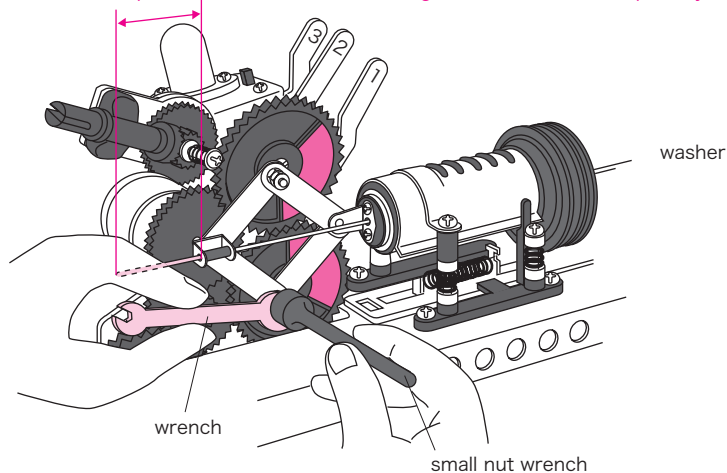


18 Attach two connecting rods to the fly wheels.  
 (The shaft of the displacer is not illustrated to simplify the diagram.)

※Pay attention to the position of the connecting rods at the dotted circle.

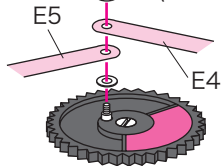


Fasten at the place where the shaft is coming out about 30mm temporarily.

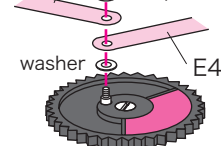


How to connect the connecting rods and the fly wheels

the upper part  
 nut (small 5mm)  
 nut (small 5mm)



the lower part  
 E5 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.

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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

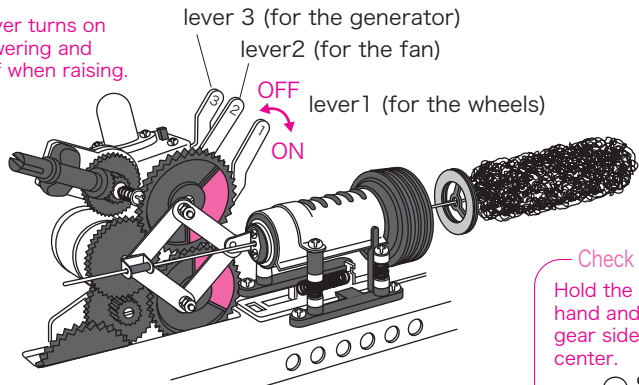
Turn off the lever 1 and lever 2 and turn on the lever 3. Put the gauge to the piston part and adjust the height so that the tip of the gauge comes to the upper part of the piston (but not the cylinder). Turn the screws at both sides equally to adjust the height. Check the center at times looking from 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.

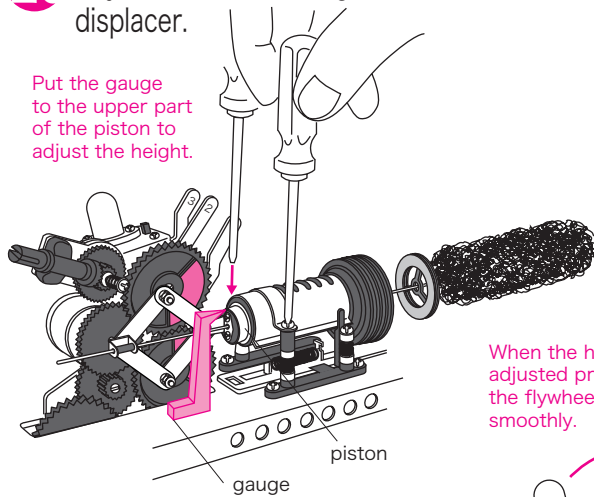
## 19 How to turn on and off the control levers.

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

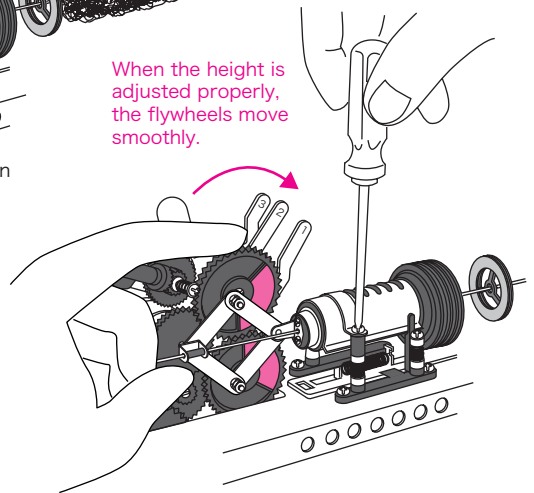
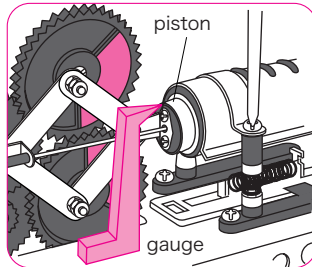


## 20 Adjustment of the height of the shaft of the displacer.

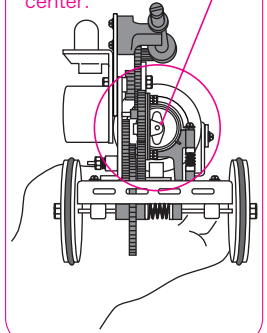
Put the gauge to the upper part of the piston to adjust the height.



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

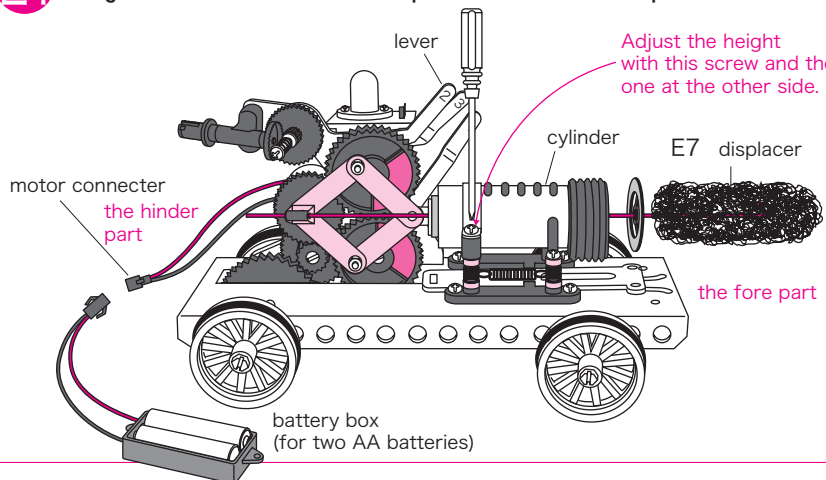


Check the center. Hold the engine in the hand and look from the gear side to check the center.



## 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.

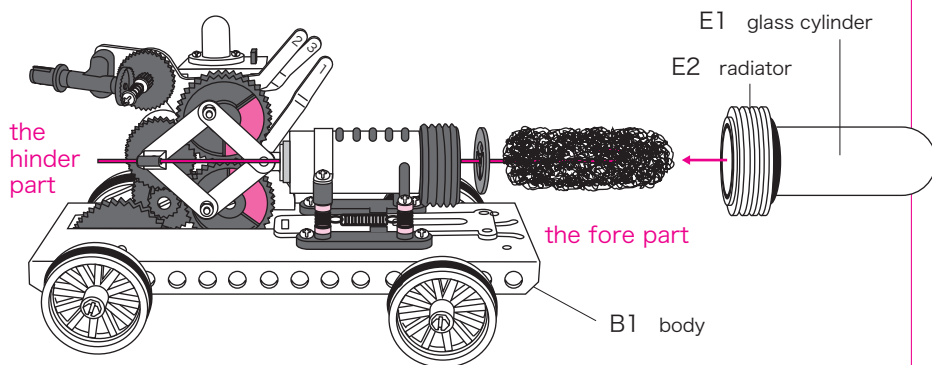
## Figure — 23

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.

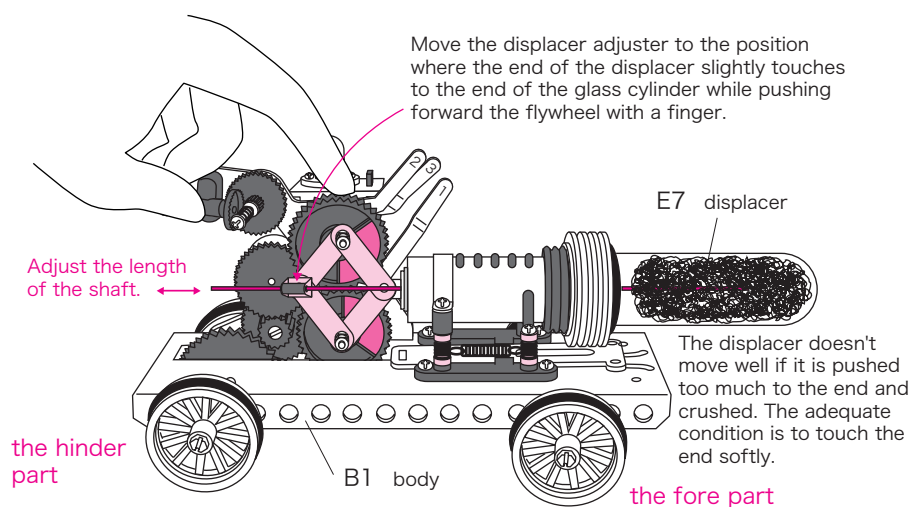
## Figure — 24

Attach the E8 propeller to the D2 propeller lever.

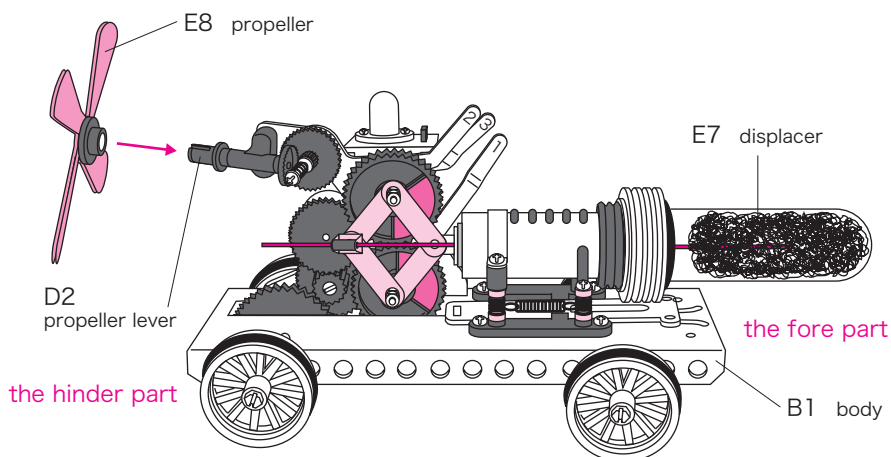
## 22 Attach the glass cylinder.



## 23 How to adjust the position of the displacer.



## 24 Attach the E8 propeller.



**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.

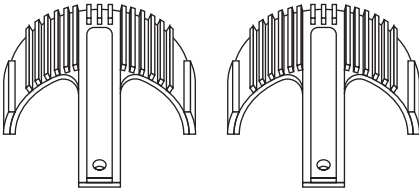
# 6 Attaching the Safety Covers

## Parts to be used

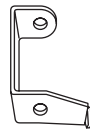
## PARTS F

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

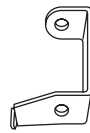
Two F1 safety covers



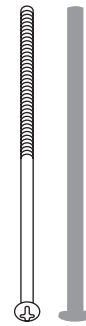
F2 hinge part



F3 hinge part



Two 40mm screws



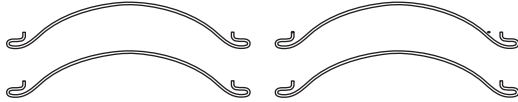
Two 6mm screws



Two 9mm across spacer



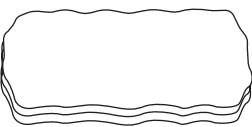
Four F4 thermal insulator hooks



Two F6 32mm pipes



F5 thermal insulator



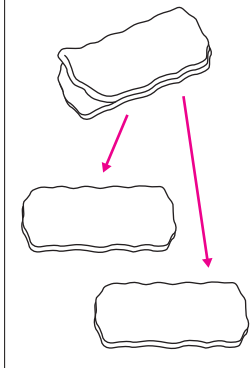
F7 sticker

STIRLING ENGINE

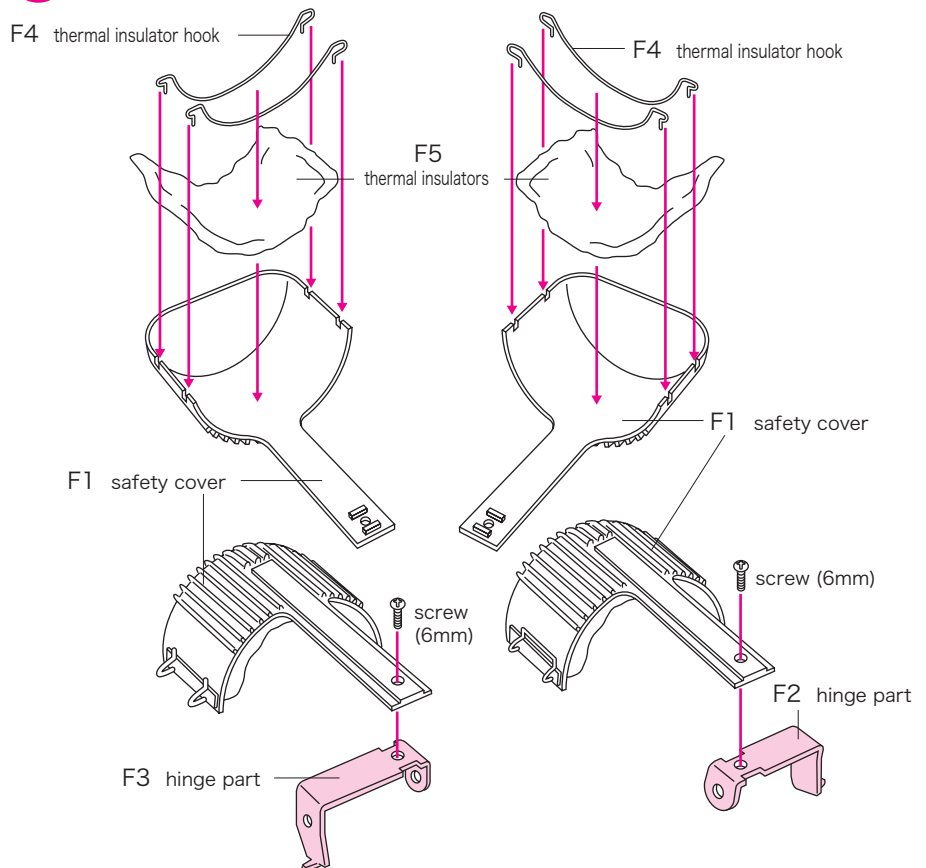
※Check the length of screws with these diagrams.

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.



## 25 Assemble the safety cover.

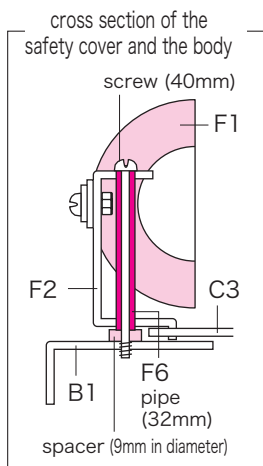


Full-scale ※Check the size with this.  
screw (6mm)



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



26 Attach the safety covers to the body.

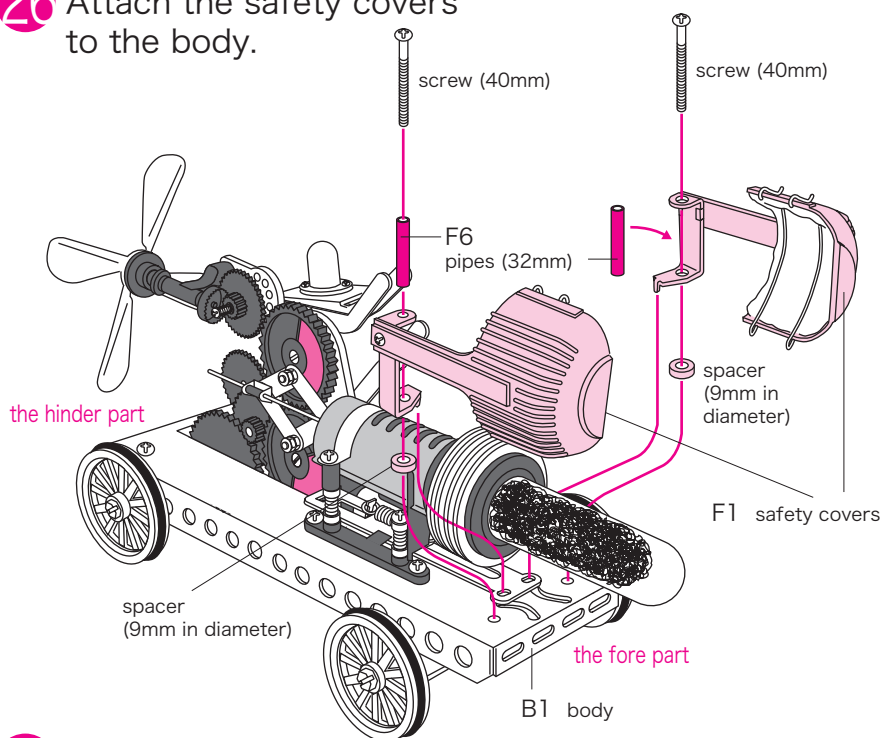
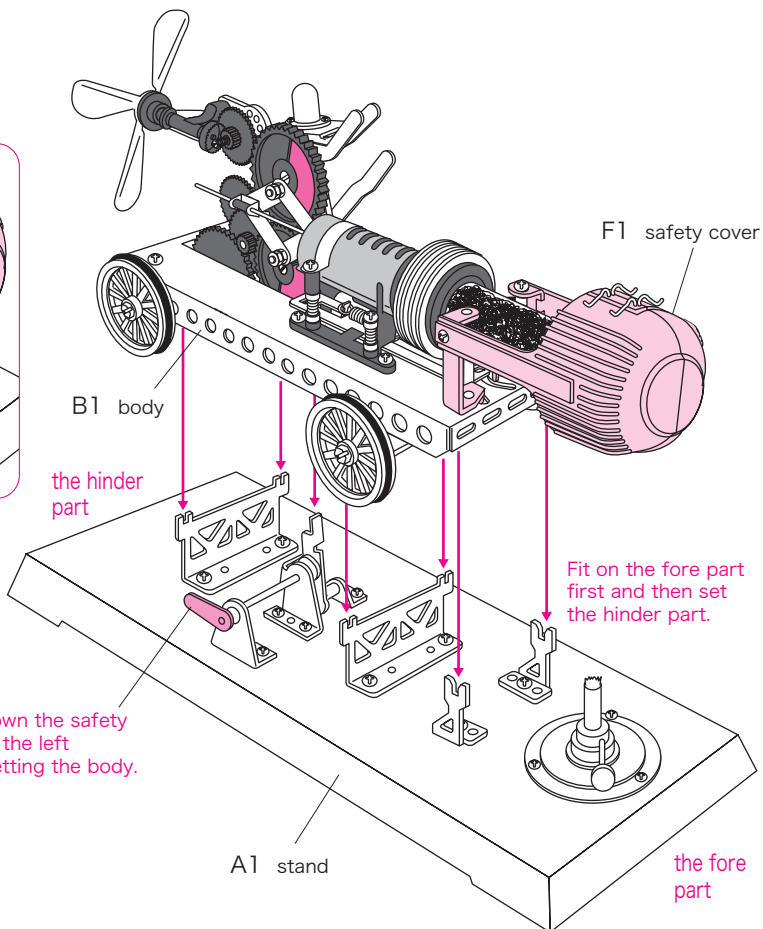
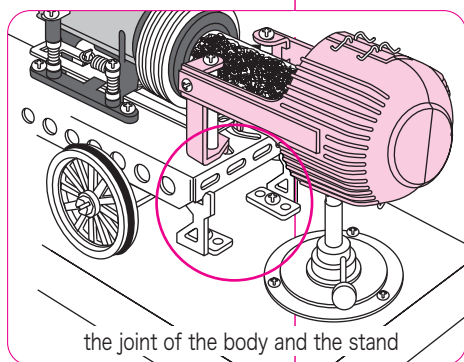


Figure — 27  
Set the assembled body on the stand.

27 Set it on the stand.



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



F6 pipe (32mm)



screw (40mm)



Figure — 27  
 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.

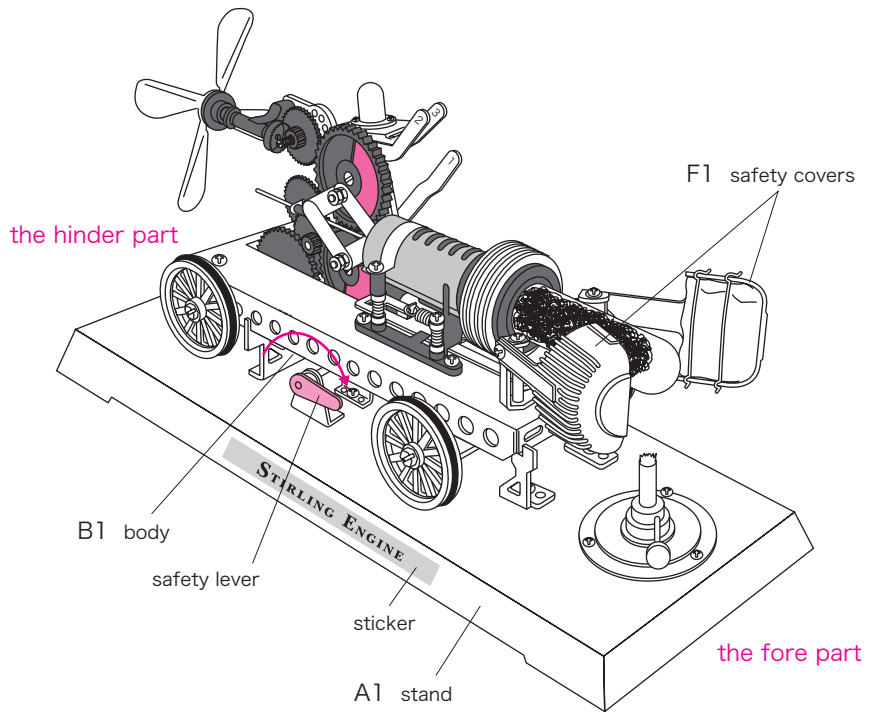
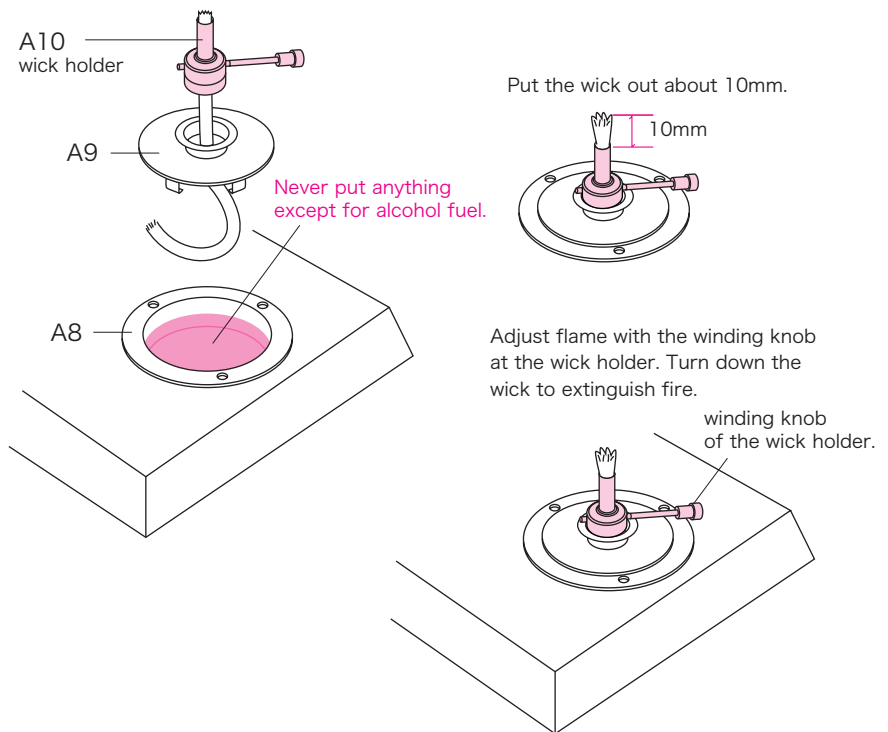


Figure — 29  
 Fill the alcohol tray by half with alcohol fuel.  
 Use great caution not to spill alcohol fuel when pouring. In case you spill the alcohol, be sure to wipe it up.

※Alcohol fuel is available at drugstores.

29 The explanation of the alcohol lamp.



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



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.)

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

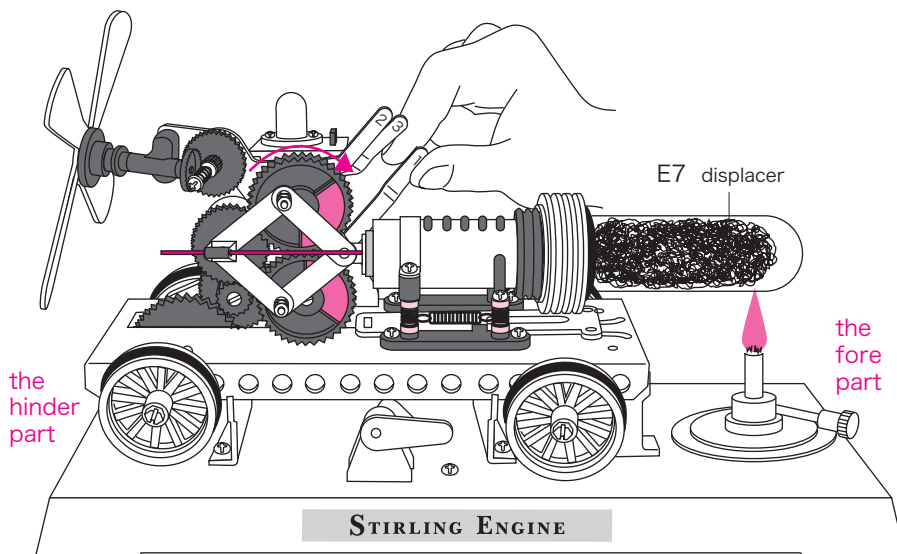
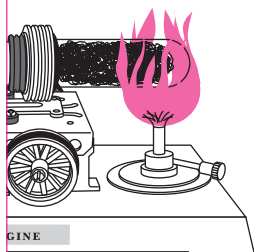


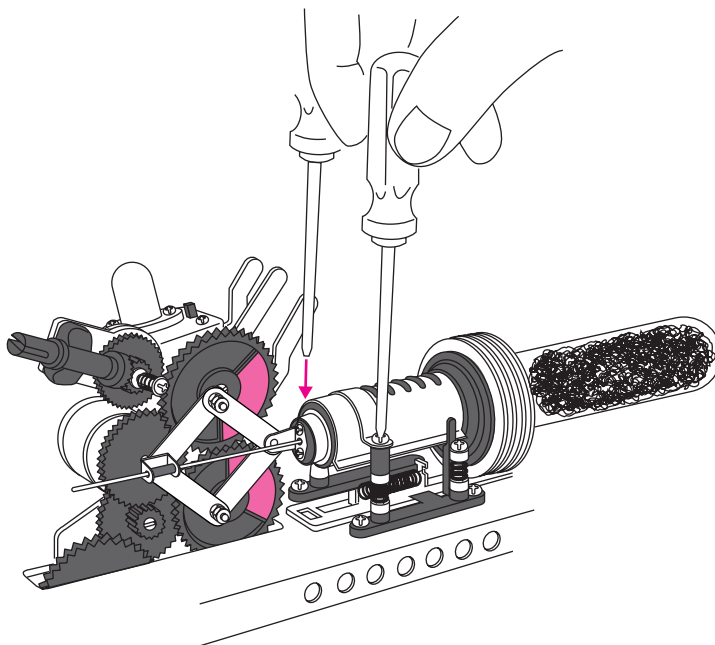
Figure — 31

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.



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





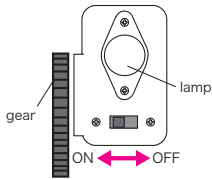
# 8 Making Experiments of the Generator, the Fan and the Car

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.)

The switch of the lamp of the generator  
(Top view)



## 32

The generator experiment.

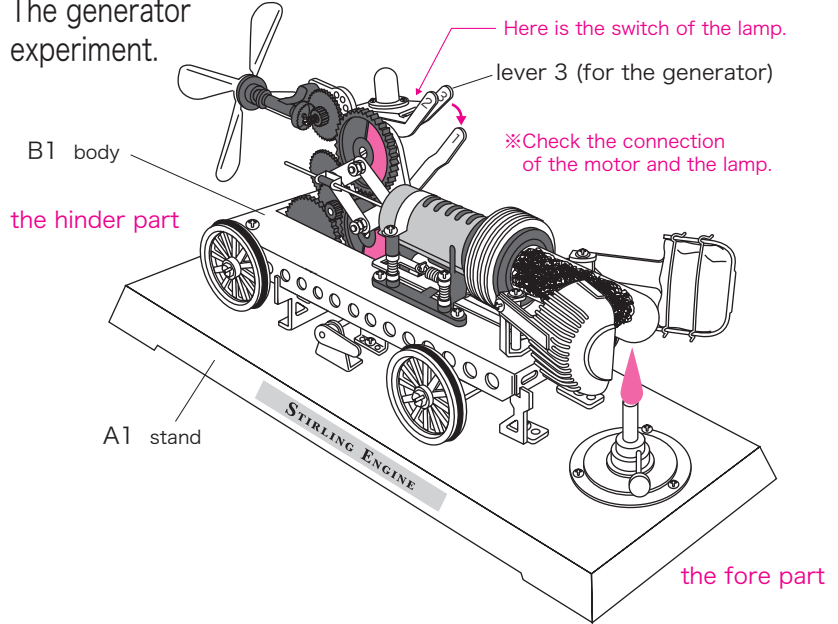


Figure — 33

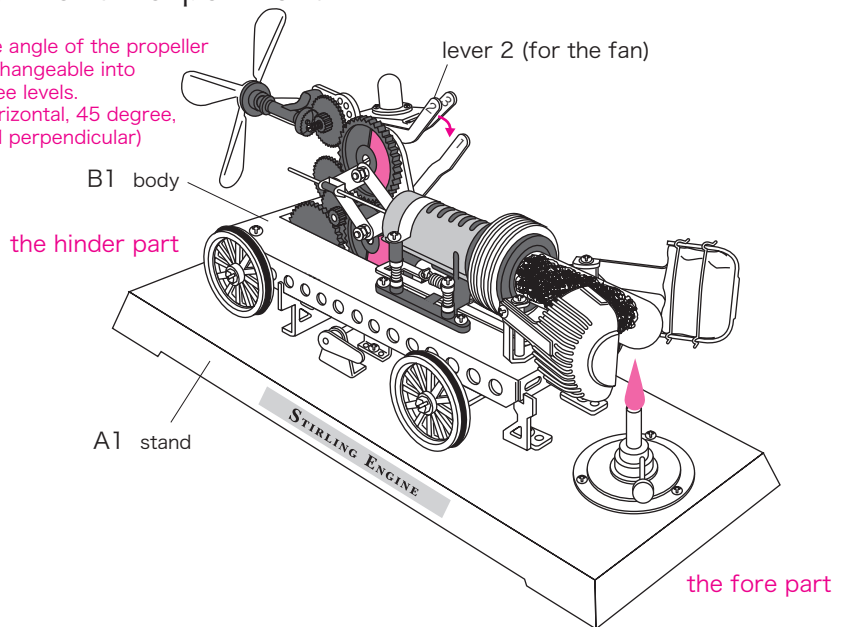
<The fan experiment>

- 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.)

## 33

The fan experiment.

※The angle of the propeller is changeable into three levels. (horizontal, 45 degree, and perpendicular)



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



**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 : 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.

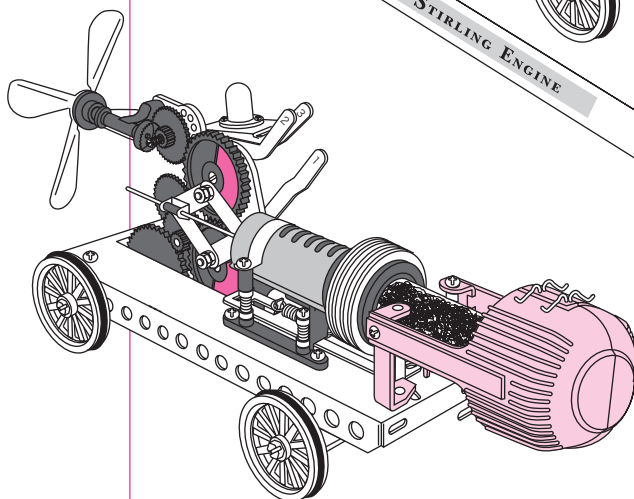
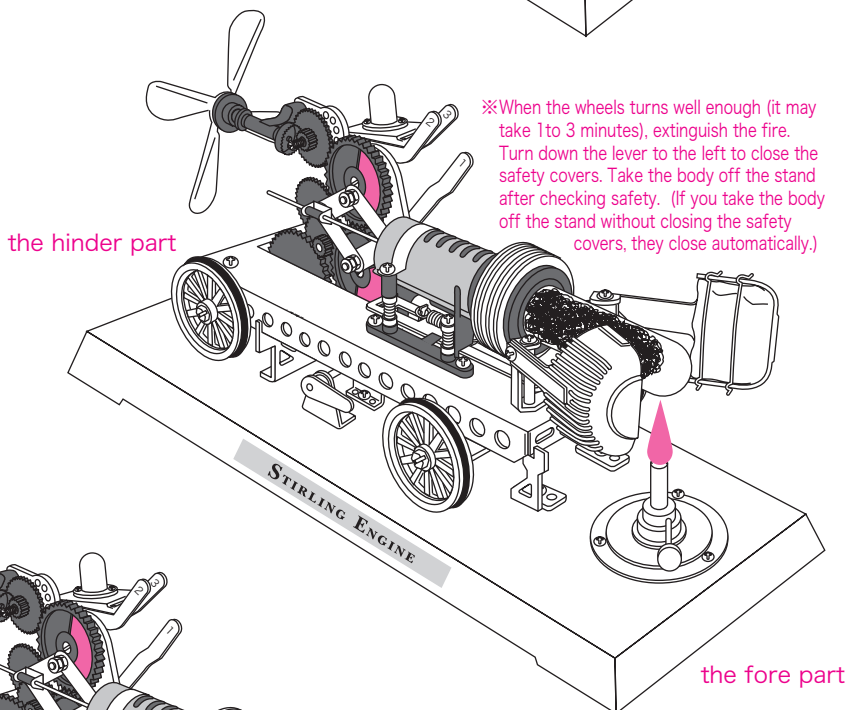
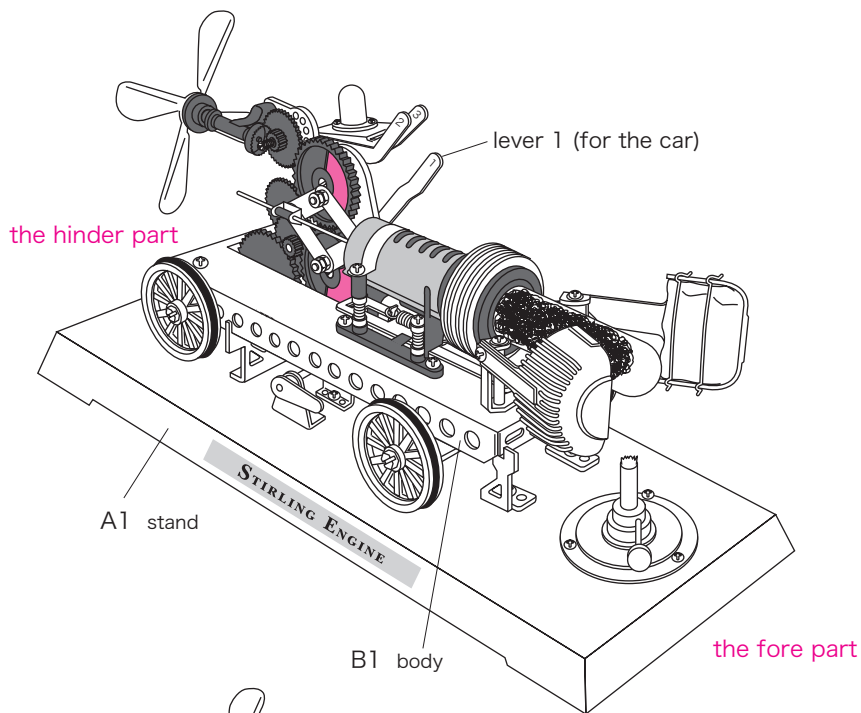
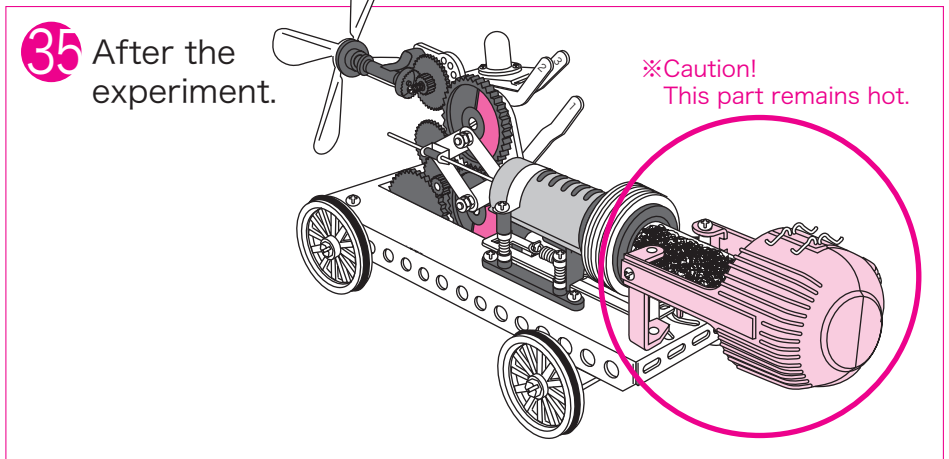


Figure — 35

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.

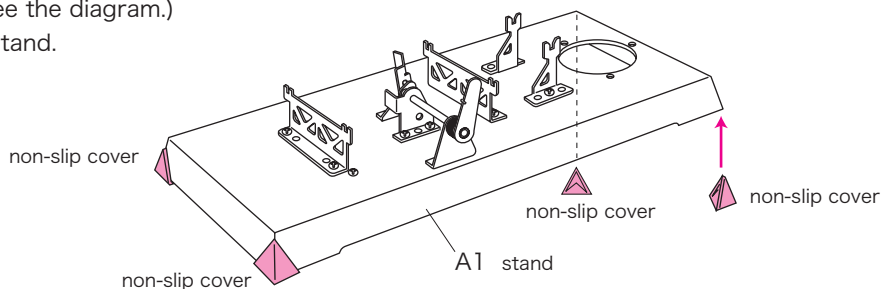
- A. Doesn't the nut at lever 2 loosen and the gear become out of mesh? (Tighten the nut of the lever 2.)

**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

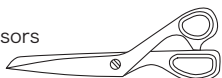
You can make your own displacer using the shaft of the displacer in the kit. In case you make one, follow the instructions below. (It is not necessary to make one if the kit moves well in the first place. Try when the original one crumbles, or the metallic part has come off, or you really want to try.)

### Things you need

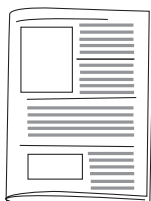
shaft of the displacer



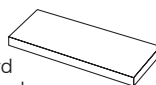
scissors



news papers



small board  
(A small book can  
be used as a substitute.)



mask

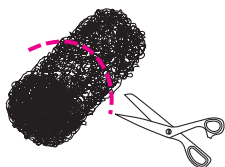


steel wool



※Please wear a mask since metallic dust floats in the air.

①Cut the steel wool  
in half.



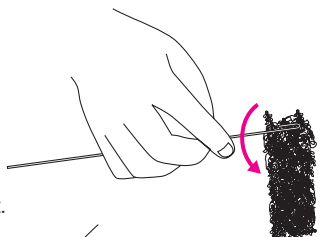
②Spread the steel wool as this diagram.



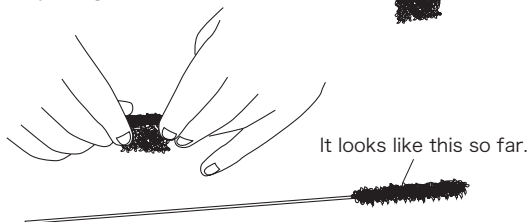
③Cut it in 1/3 and 2/3.



④Put the 1/3 around the shaft to form a core.

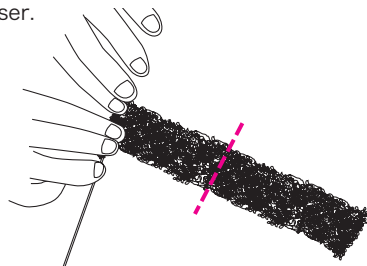


⑤Wrap it tight.



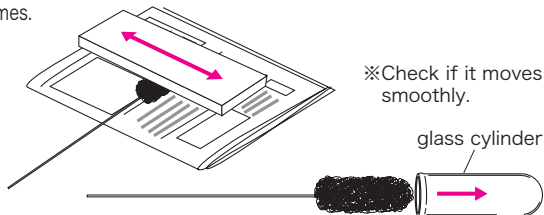
⑥Wrap what is left around the core.

Wrap the first half tight and the second half  
a little looser.



⑦Neaten 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.



⑧After 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.

