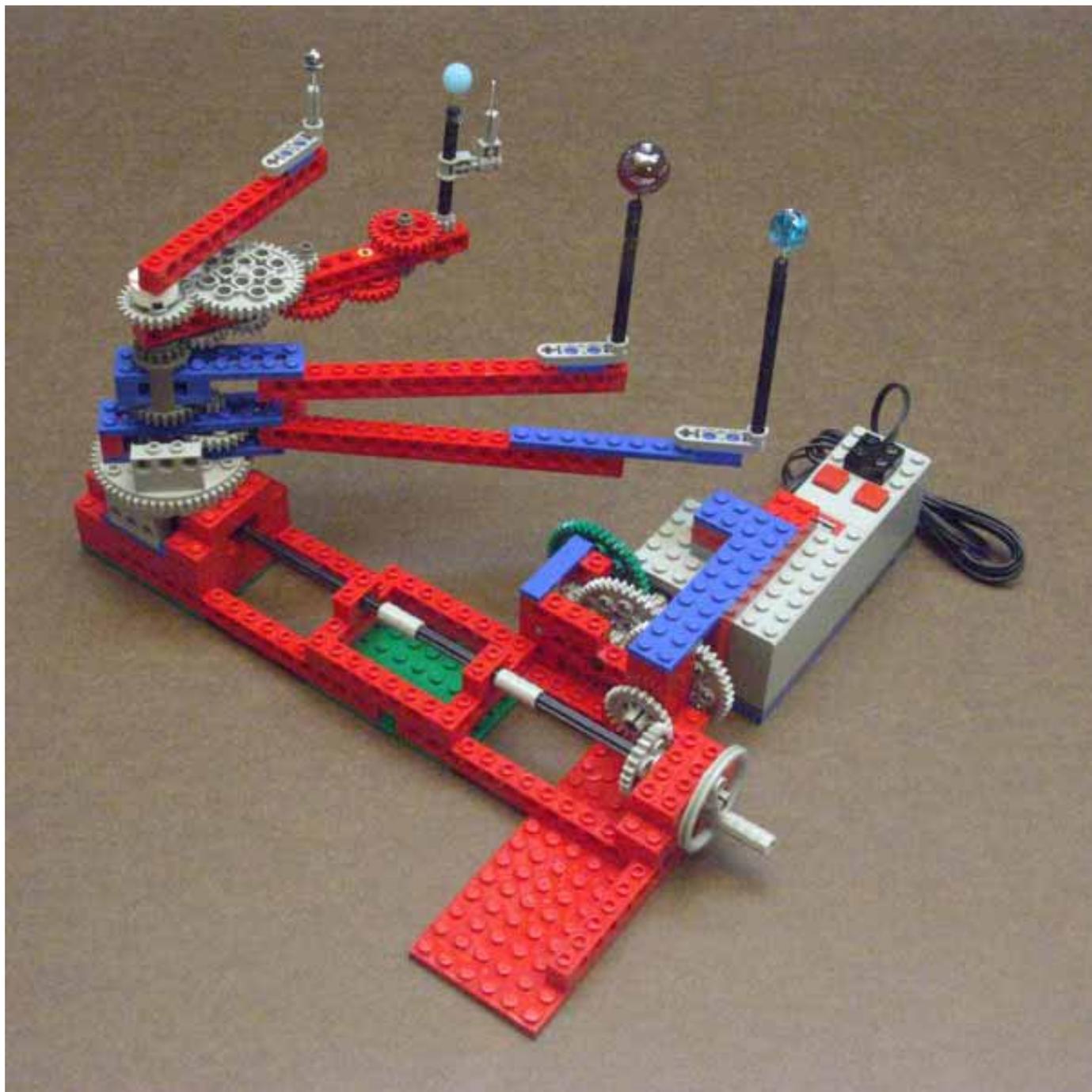


Kepler Planet Transit Demonstration



Demonstrates how the Kepler science team will use the Kepler satellite photometer to discover Earth-size planets around other stars by the transit method.



Kepler Planet Transit Demonstration

including a LEGO orrery* with 4-planets+1moon

The Kepler Transit Demonstration illustrates how the Kepler science team will discover Earth-size planets around other stars by the transit method with the Kepler satellite photometer.

This document can be downloaded from the Kepler Education website at <http://kepler.nasa.gov/education/Modelsand-Simulations/LegoOrrery/>

* An orrery is a model of planets going around a star.

Components:

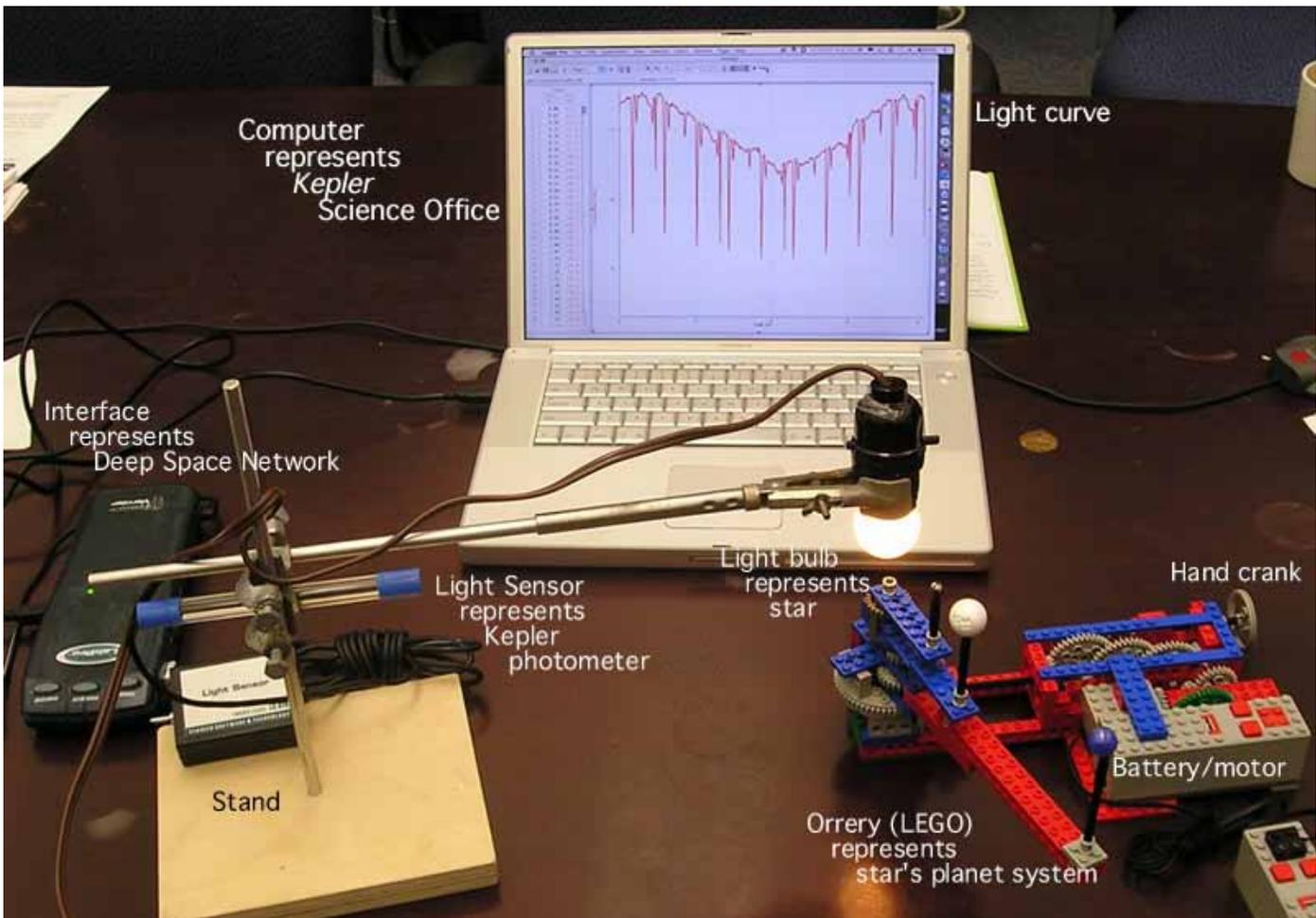
A LEGO-orrery model represents a planet system that can be set in motion with either a hand crank or electric motor.

A light bulb at the center of the orrery represents the star.

A light sensor represents the Kepler spacecraft photometer.

The light sensor is connected through an interface box (which represents NASA Deep Space Network) to...

A computer that represents the Kepler Science Office.

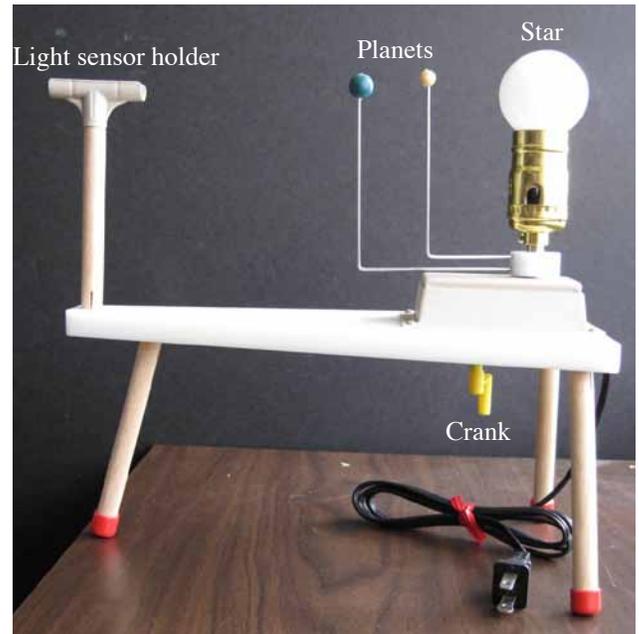


Setting Up the Demonstration

1. Assemble the LEGO orrery that makes beads (planets) go in orbits (if it's not already assembled).
2. Position the light (star) near the center of the planet orbits.
3. Mount and aim the light sensor to point at the star. It should be far enough away from the light that the planets do not hit it, but in general, the closer the better, even though this is one of the unrealistic elements of the model.
4. Connect the light sensor through the interface module and into the computer.
5. Start up the graphing software. Ideally, set the Experiment run time to at least 30 seconds. (in LoggerLite, this function is in the "Experiment < Data Collection" dialog box).

Do the Demonstration

1. Explain the parts of the model.
 - a. The light is a star that the Kepler telescope is aimed at.
 - b. The balls on arms that go around are planets orbiting the star.
 - c. The light sensor is the Kepler telescope—photometer.
 - d. The wire and interface from the light sensor to the computer is the Deep Space Network—radio telescopes on Earth that receive data from the Kepler spacecraft.
 - e. The computer is the the Kepler Science Office where Kepler data is analyzed.
2. Do a test run of the software (Click "Collect" data) and demonstrate how graph behaves if something (like your finger) goes between the light sensor and the light. Optional: click on the Auto-Scale button (big letter A)
3. Click "Collect" and then turn the crank to make the planets orbit the light (or have a volunteer do the cranking).



This is a version of orrery that was designed by Marshall Montgomery and Alan Gould to be used in the Full Option Science System (FOSS) course Planetary Science. It may be commercially available in the fall of 2011. Check the Kepler website for update:

<http://kepler.nasa.gov/education/ModelsandSimulations/LegoOrrery/>

The most obvious weakness of this model is that the light sensor, which represents the Kepler spacecraft, is so close to the star. In reality *Kepler* does not go to the stars. It observes from an orbit around our own Sun, hundreds or thousands of light years from the target stars. For more information about how the real *Kepler* mission works, we invite you to explore the *Kepler* mission website:

<http://kepler.nasa.gov>

4. Have the group analyze the resulting graph. Ask focusing questions such as:
Can you tell how many planets there are (just looking at the graph)? [Yes, different depths of dips in brightness for each planet.]
Can you tell the planets are different sizes? How? [Bigger planet causes bigger drop in brightness.]
Which planet is closest to the star, the big or [one of] the other(s)? How can you tell which planet is closest to the star? Closer in planets take less time to orbit, so they have brightness dips that are closer together.]

Sources of components:

(Updated June 2011)

From LEGO supply—these kits:

W979649 LEGO Technology Resource Set (\$80 June, 2010; <http://www.legoeducation.us/>)

LEGO Technic Turntable Platform Gear (do Internet search with that phrase in quotes for current sources)

LEGO Technic 9V electric motor (optional; locate with Internet search)

Computer-interfaced light sensor

(e.g. from Vernier or Pasco)

From a science company (e.g. Science Kit <http://www.sciencekit.com/>)

Metal Base (10cm x 15cm) with Rod Size (8mm dia x 46mm long) \$8.95
WW6308001

Buret Clamp Plain jaws \$7.60

WW6107500 Plastic jaws \$8.75

WW6108000, adjustable, to hold light sensor

Right Angle Clamp Holder - (6112000) \$7.95
(holds horizontal rod for clamp on light)

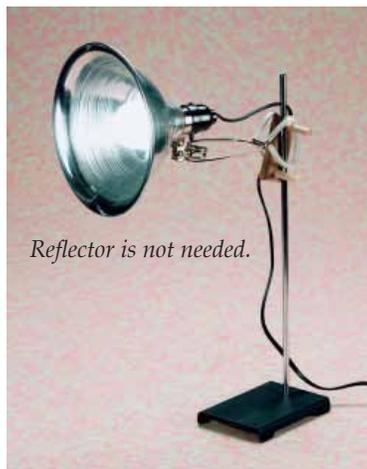
Clamp On Utility Light \$11.90
WW4639500

From a hardware store

Light bulb (7.5W) or maglite flashlight with ping pong ball diffuser over the bulb.

A stand with horizontal support for clamp-on utility light. One can be assembled from PVC tubing and fittings, or rods—photos on these pages may provide inspiration

for how to make a stand for the light.



Buret Clamps

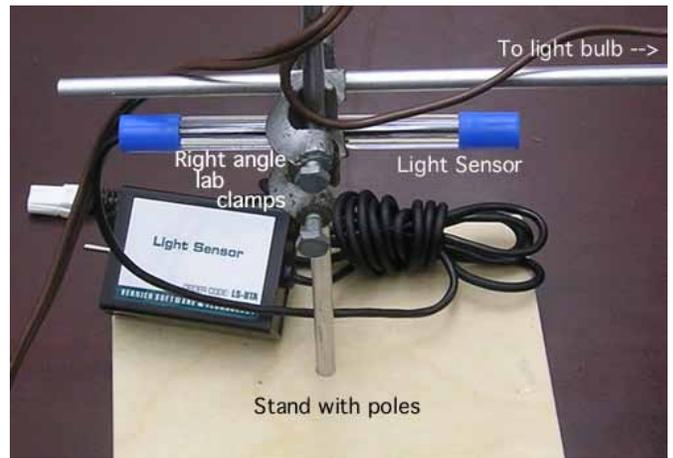
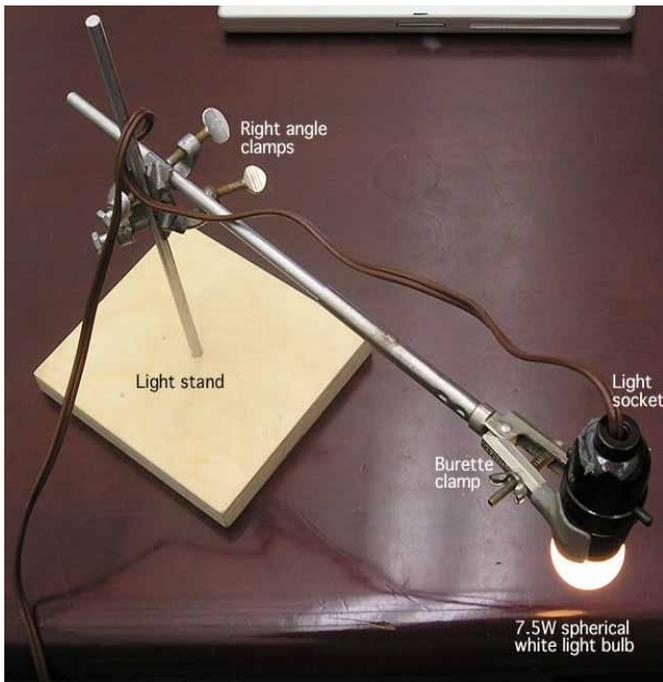


This is the Vernier Light Sensor LS-BTA \$55.00 (June 2011). A Vernier interface that works is Go! Link \$61.00 (June 2011; includes LoggerLite graphing software).

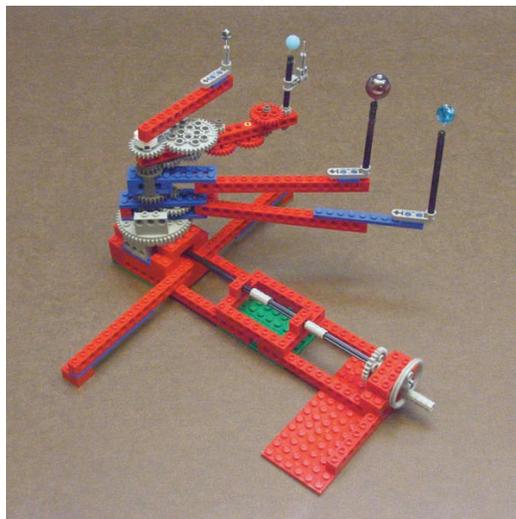


From a Bead or Craft Store

4 (or 5) beads from 3 to 20 mm in diameter for planets.

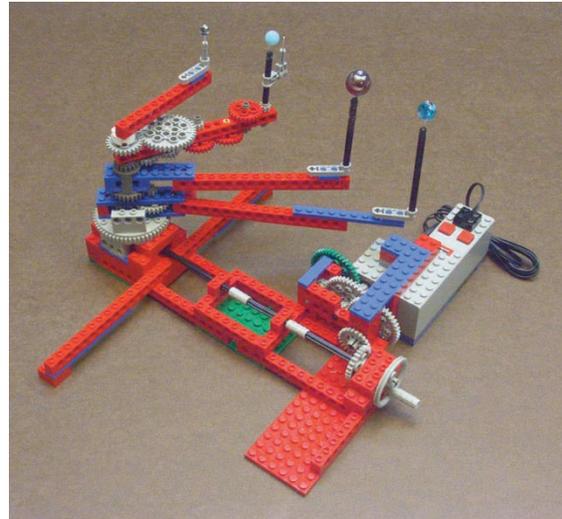


LEGO orrery—version 2006 (4-planet plus moon) assembly instructions



Hand-cranked

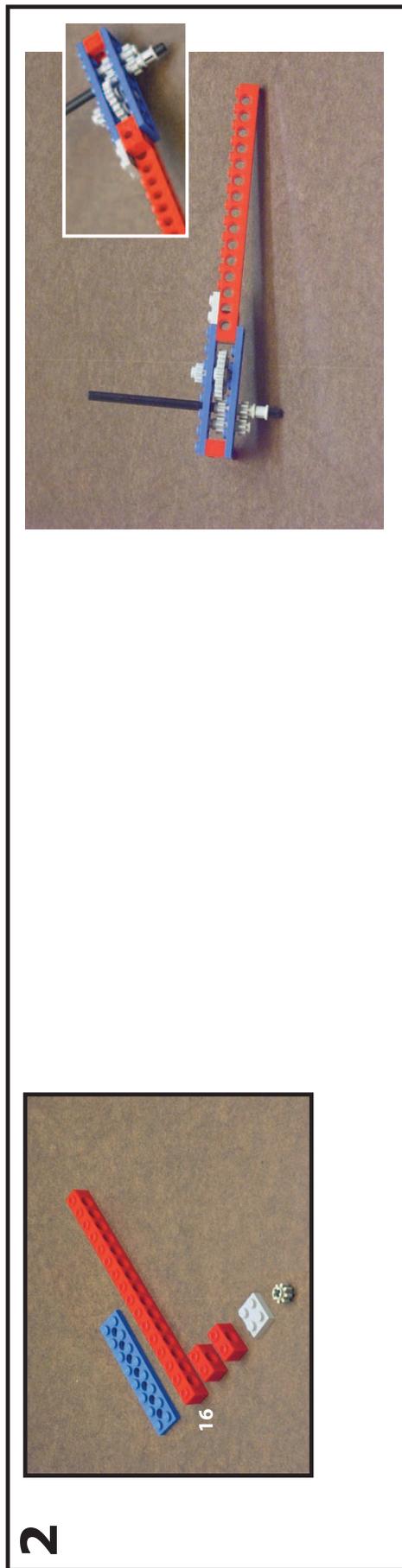
The following kits together contain enough parts to make two non-motorized orreries:
 W979649 LEGO Technology Resource Set
 W779876 LEGO Large Turntable (set of 2)

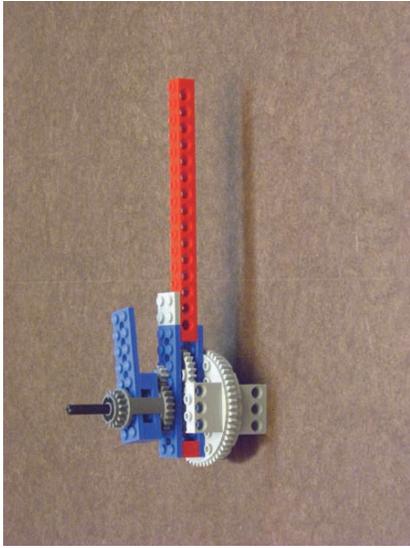


Motorized

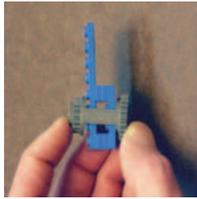
Add one W979615 kit (LEGO 9V motor and battery box) plus three extra spur gears (W970620, package of 100) per orrery to make the motorized version.

Kits available at <http://www.legoeducationstore.com/>

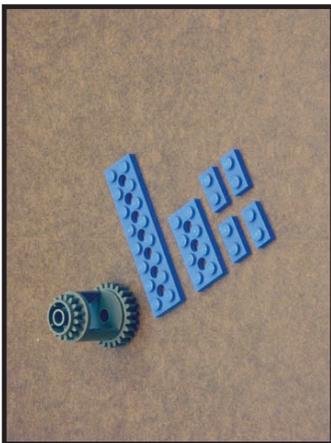




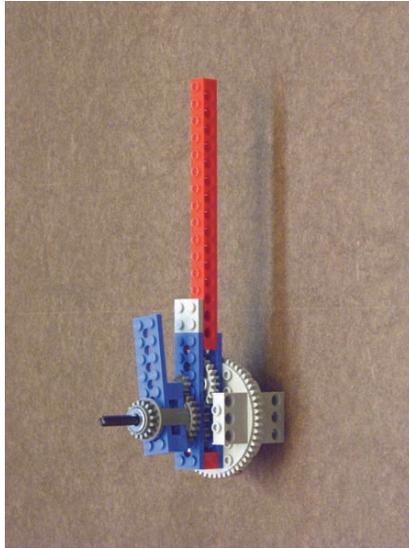
a.



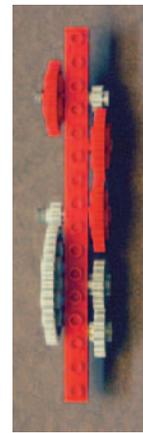
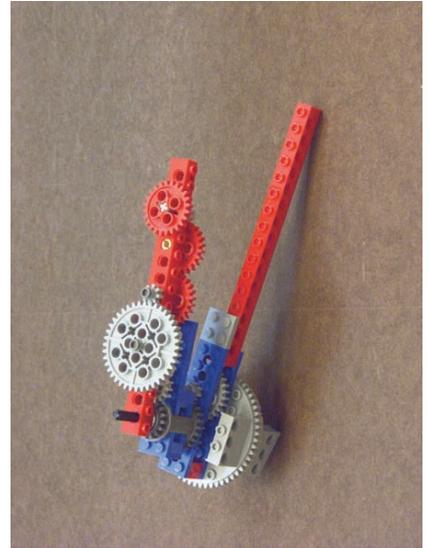
b.



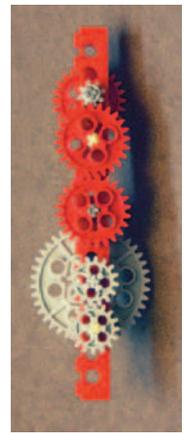
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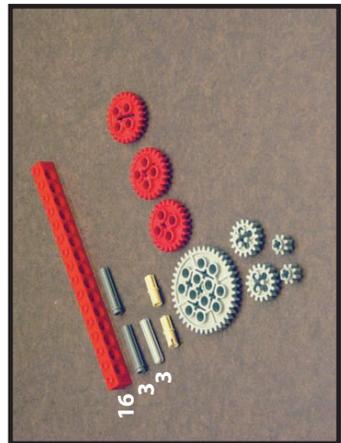
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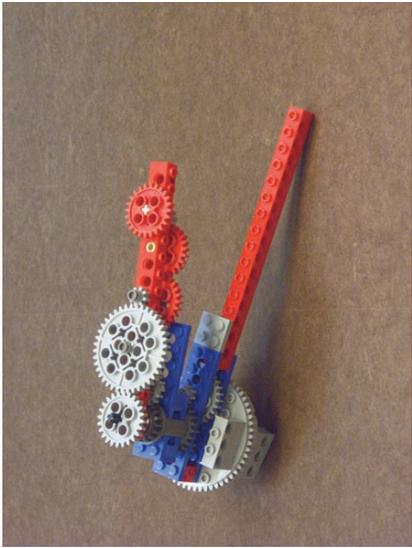
front view



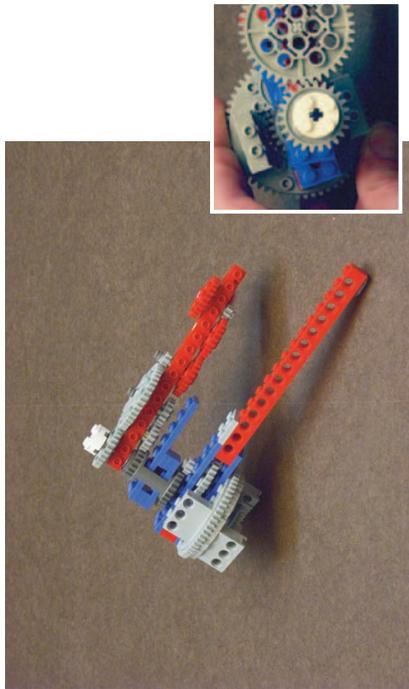
bottom view



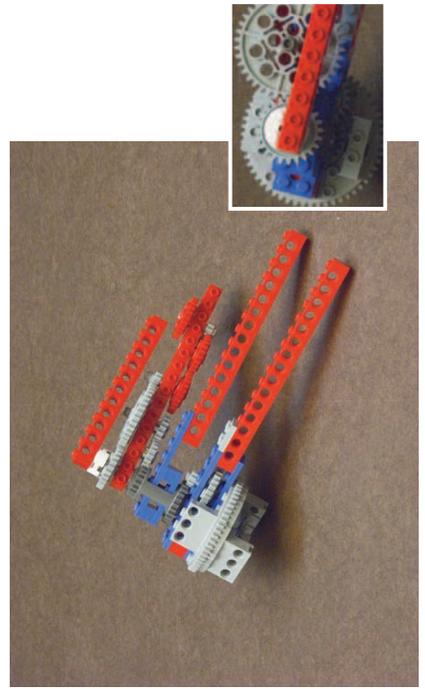
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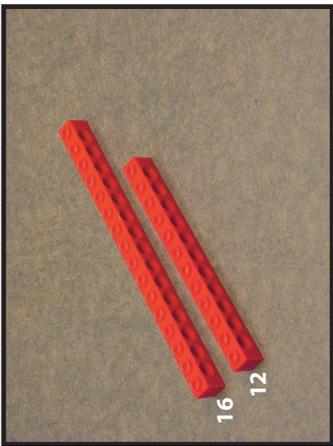
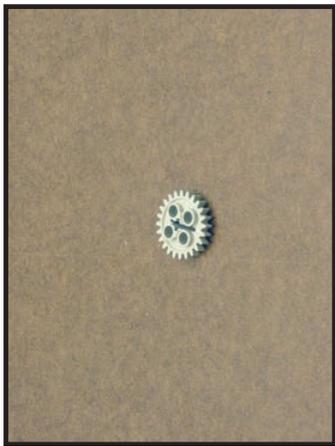
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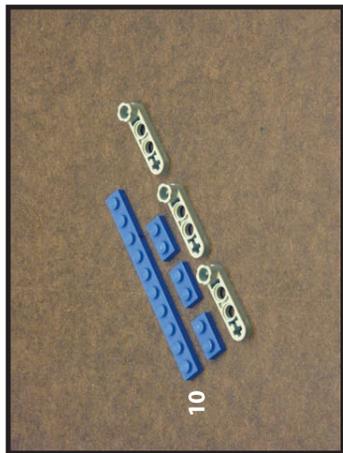
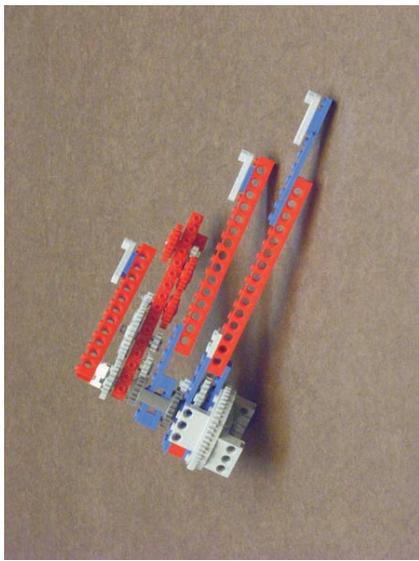


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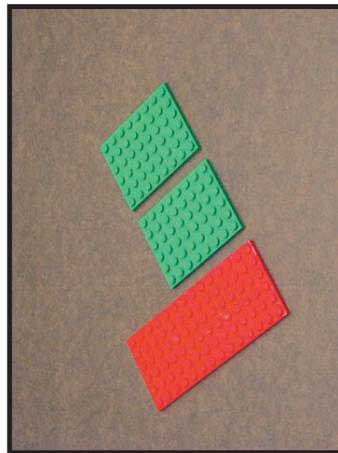
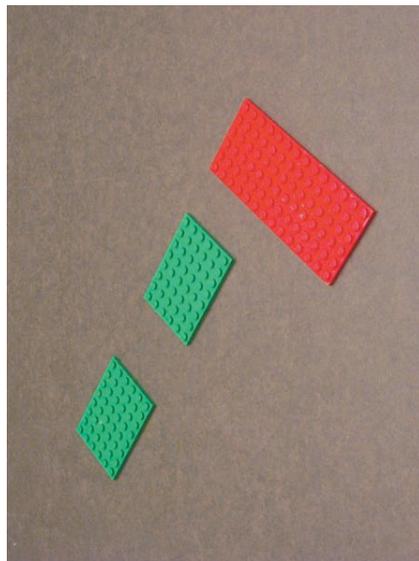


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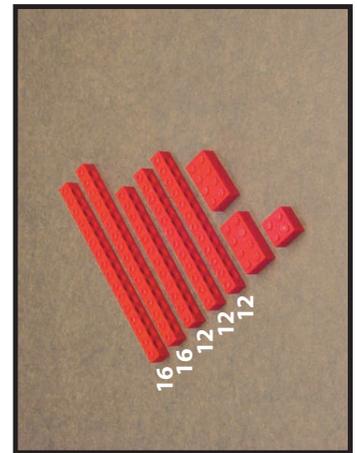
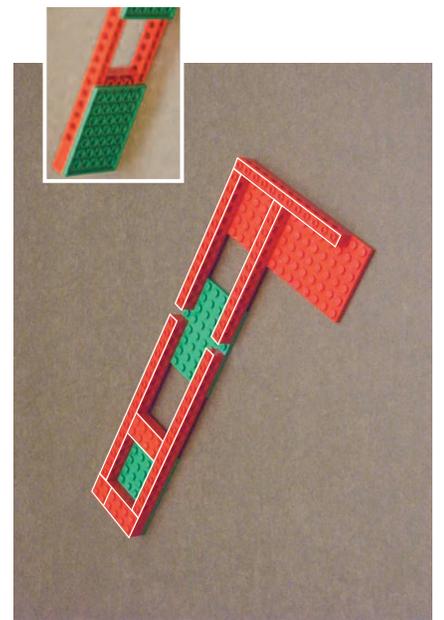




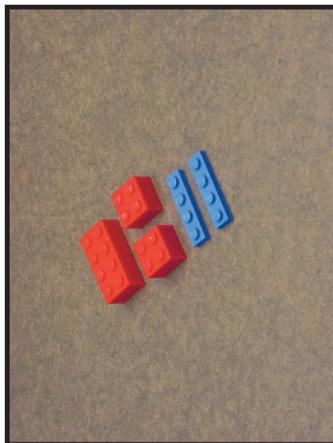
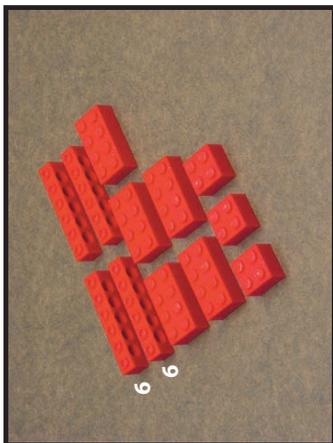
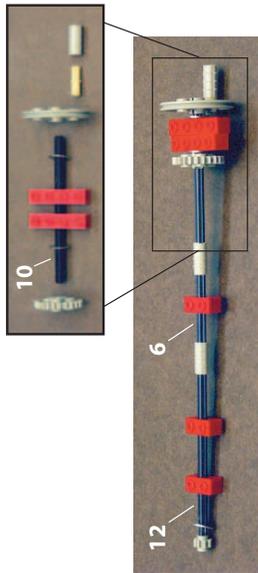
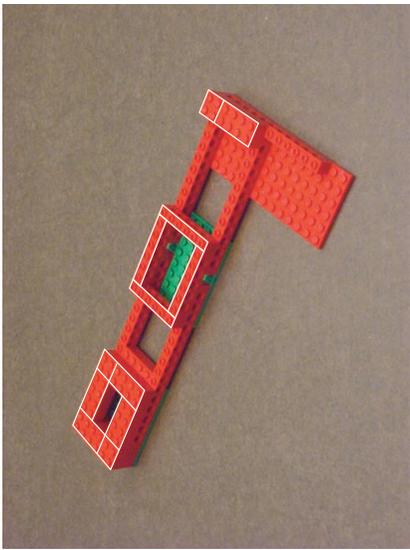
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11



12



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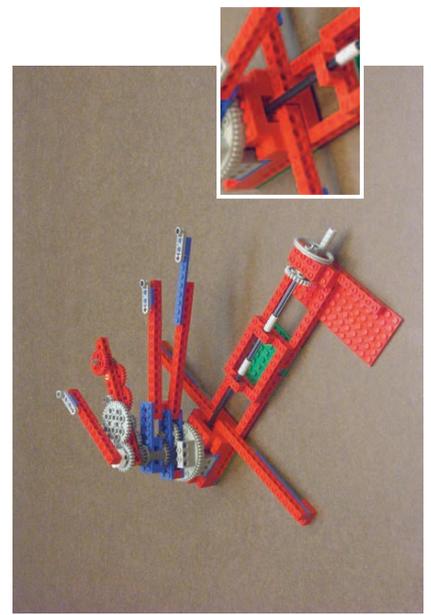
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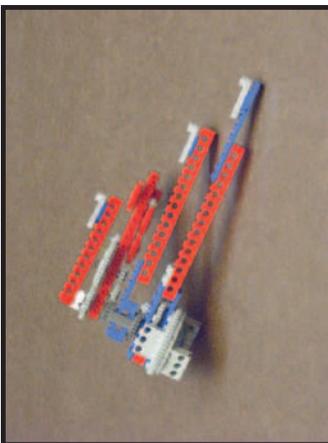
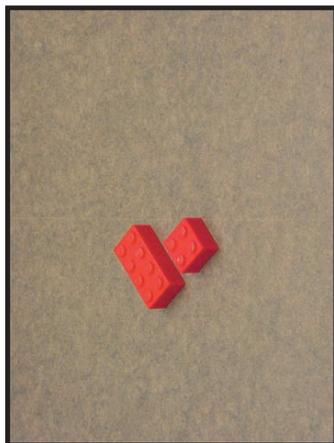
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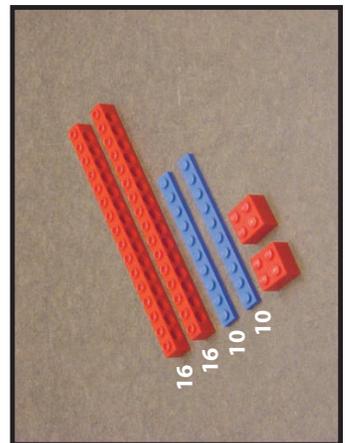
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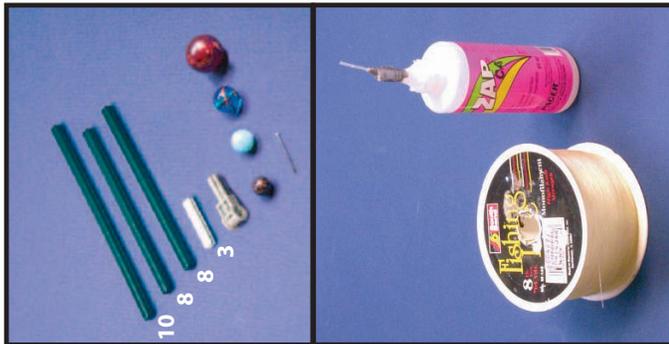
18



from step 10



19



To make planet rods:

- a. Notch LEGO rods.
- b. Glue beads to pins or nails.
- c. Tie pins/nails to LEGO rods using fishing line.
- d. Seal knots in fishing line with super glue (Note: Super glue does not stick to polyethylene LEGO rods; the glue adheres only to the pin and the fishing line.)



a.



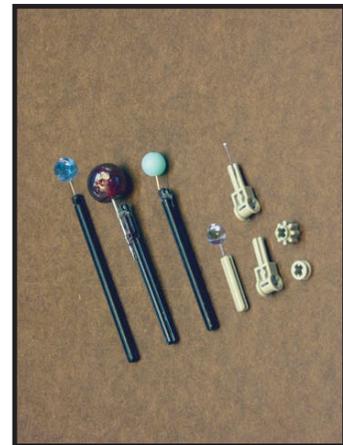
c.



d.



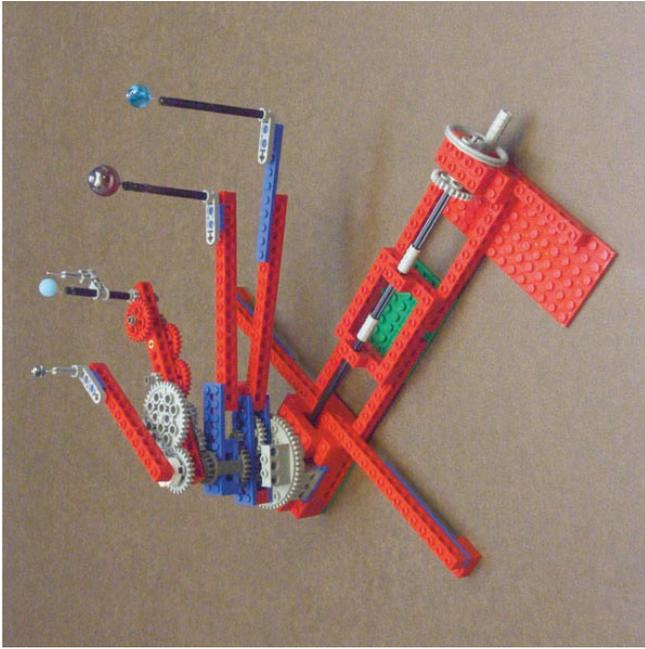
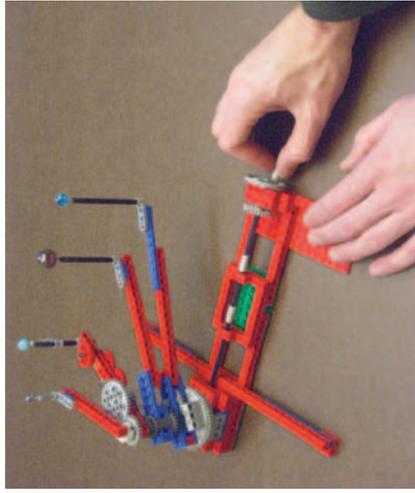
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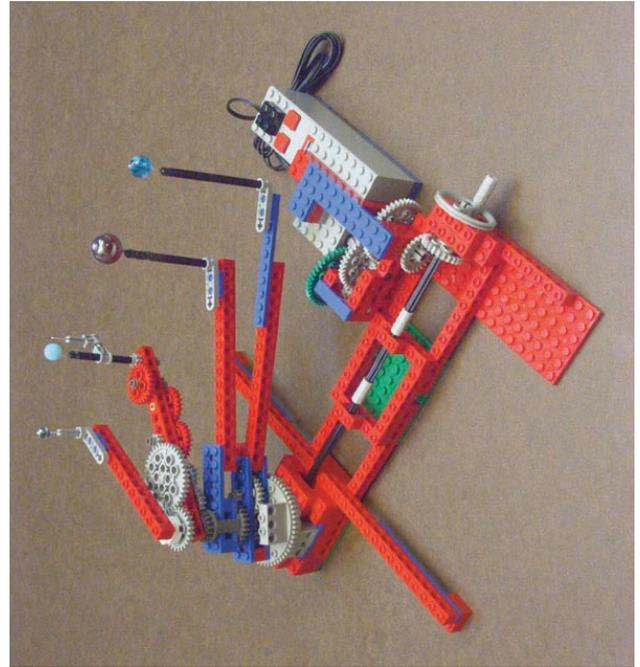
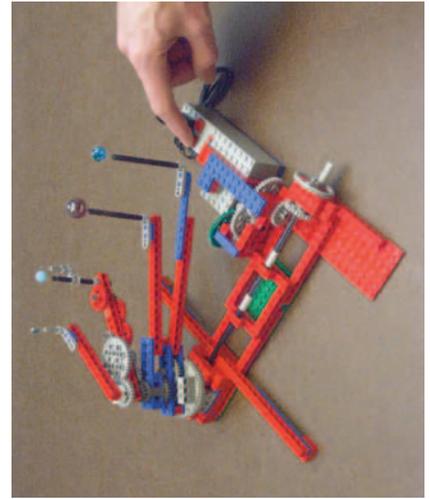
Orrery is now ready for manual operation:

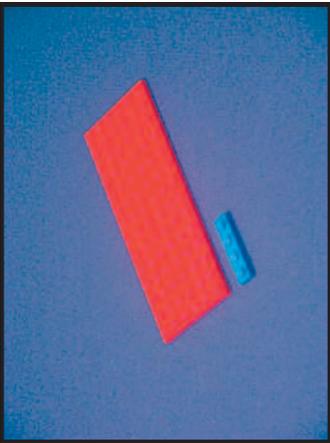
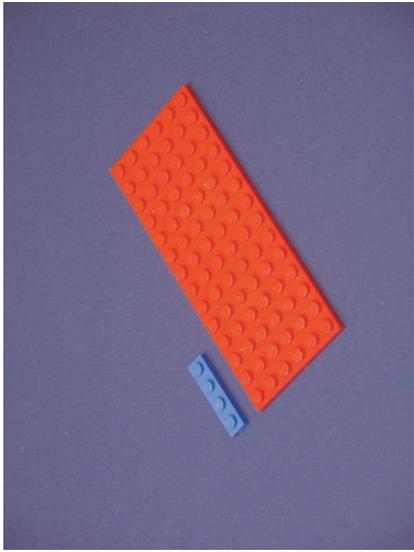
To make the model accurate in terms of Kepler's laws of planetary motion, adjust the lengths of the arms according to the formula below:

$$\frac{(\text{Orbit Period})^2}{(\text{Orbit Radius})^3} = \text{Constant}$$

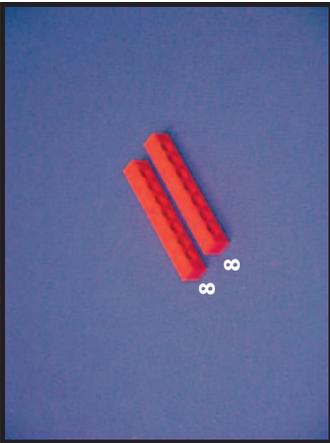
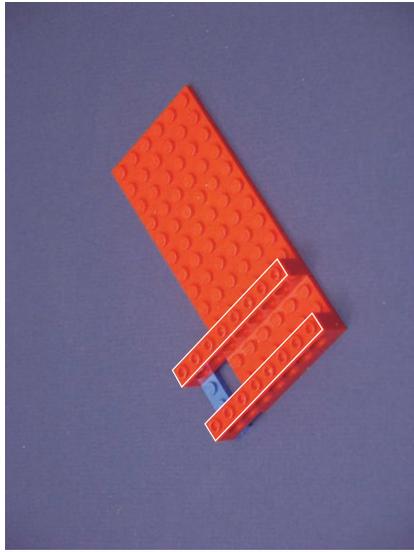


For motorized operation, build motor assembly as shown in steps 21-30

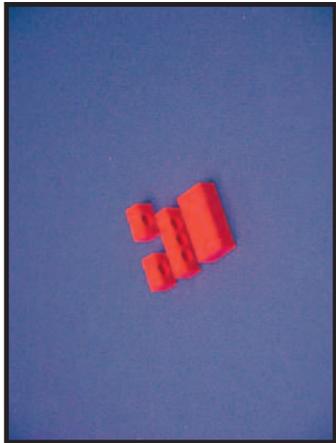
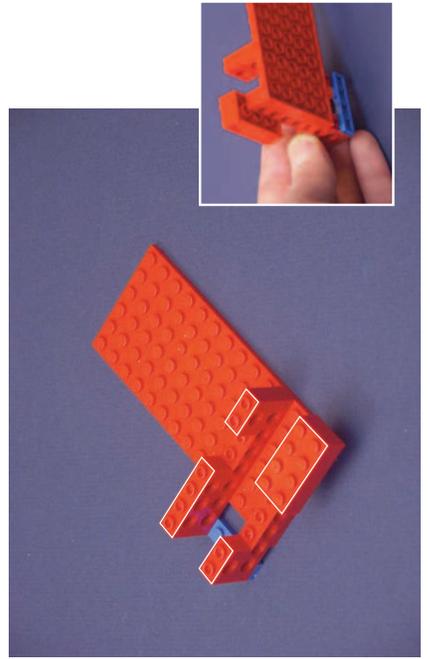




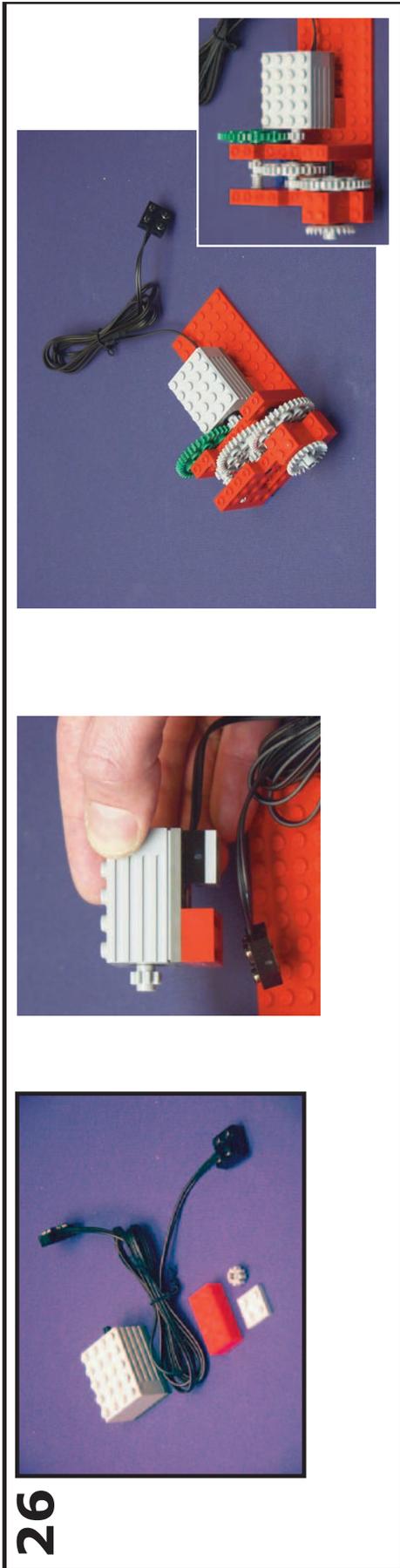
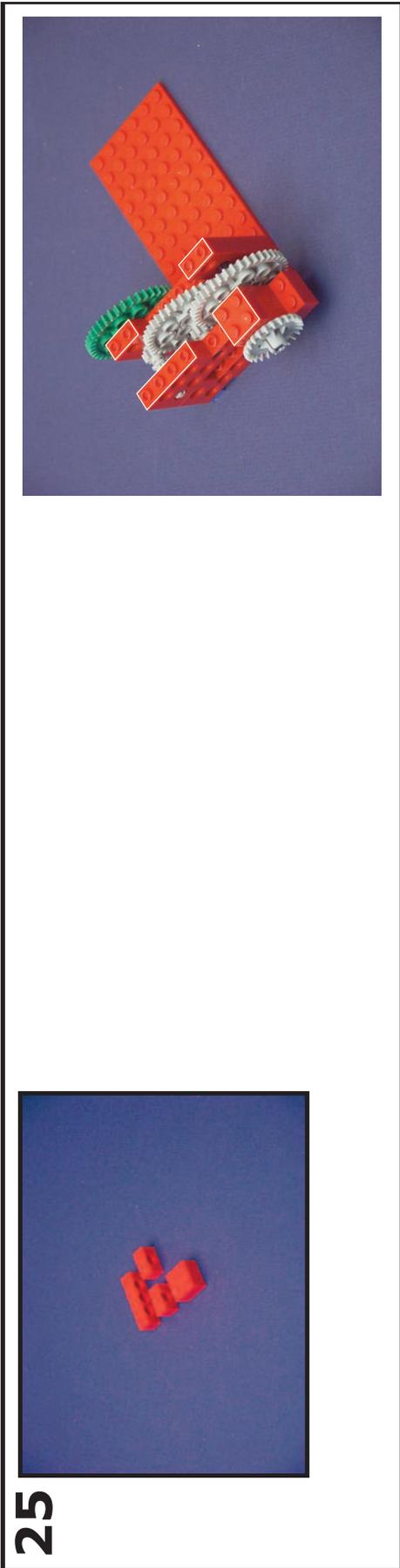
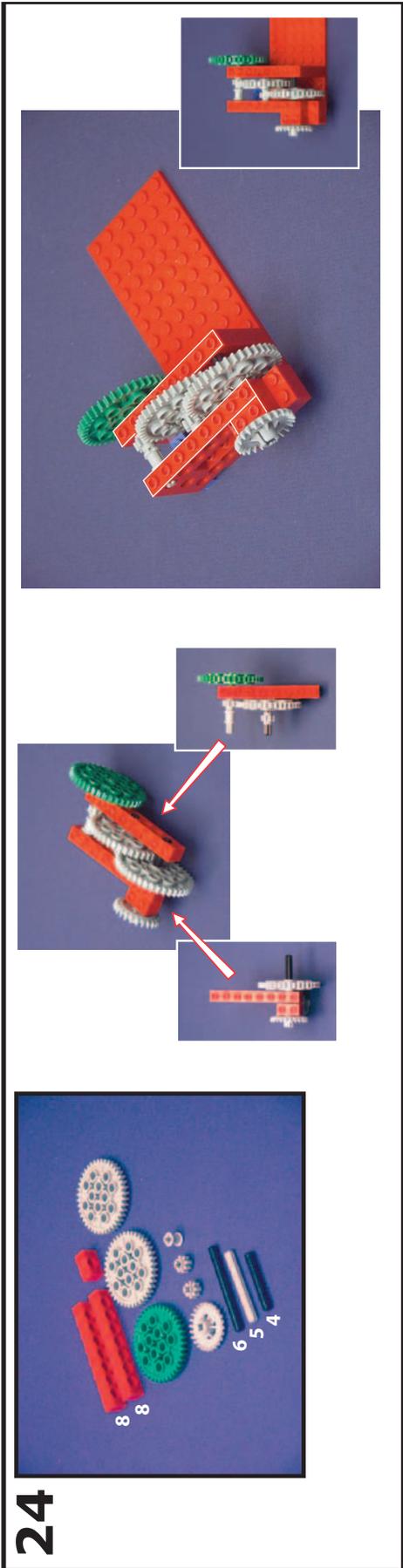
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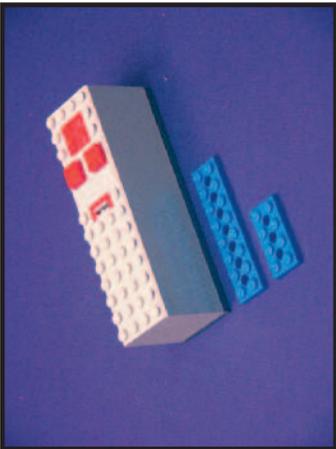


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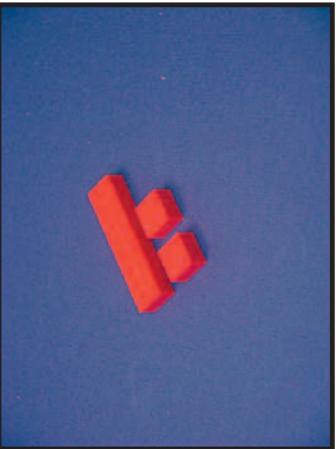




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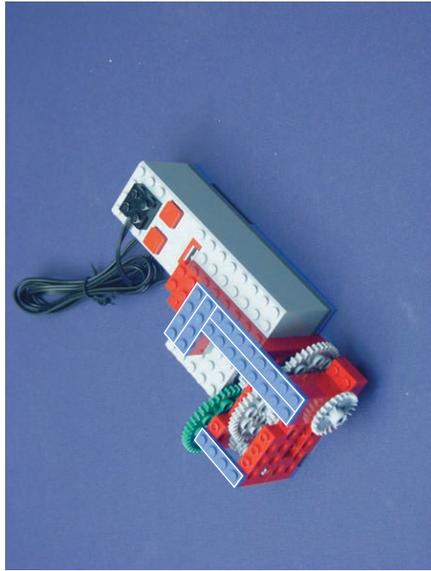


28



29

30



Attach motor assembly
as shown for motorized
operation:

