

# OPERATING INSTRUCTIONS

## Magdeburg Hemispheres with Stand No. 32136

### 1. Introduction

You can use this set of Magdeburg Hemispheres to show Guericke's method of illustrating atmospheric pressure.

### 2. Description

The set consists of two hemispheres, each with an inside diameter of 10cm, made of pressed steel. Each half has a handle firmly bolted to its top. The two hemispheres are not identical — one has a raised edge to hold a rubber seal. The other hemisphere is fitted with a brass nipple and a stopcock for the purpose of attaching to vacuum tubing to evacuate the air contained within the hemispheres when they are bolted together. A stand is included to hold the hemispheres while you are evacuating them.

### 3. Background

Otto von Guericke (1602-1686) was a German physicist who was born in the town of Magdeburg; years later, he became mayor of that city. In his day, little was known about vacuum, and this became a topic of great interest to Guericke. There was a good bit of discussion around this time as to whether such a thing as a vacuum could even exist, with some quoting Aristotle's contention that it could not.

Guericke dealt with the problem by building the first air pump (in 1650) and using it to evacuate a variety of devices. He showed that sound cannot travel in a vacuum nor can candles burn in one. He also demonstrated the surprising force of air pressure using various evacuated devices including the Magdeburg Hemispheres, named after his home town.

The original hemispheres were built for a demonstration before the emperor Ferdinand III. When the hemispheres were evacuated, not even teams of horses could pull them apart; but when air was allowed back into them, they separated easily.

### 4. Theory

A force can be applied and sustained only at the surface of an enclosed fluid. With the fluid at rest, this force is always directed at right angles to the fluid's surface. This force is often referred to in terms of its effect over the entire surface of the fluid and is called pressure.

The mathematical relationship between pressure and force is  $F = PA$ , where A is the surface area over which the force F is applied.

In the case of the Magdeburg Hemispheres, the pressure distributed around the exterior of the hemispheres is atmospheric; therefore,  $P = 1$  atmosphere.

If the stopcock of the apparatus is open, the pressure inside the hemispheres is equal and opposite to that outside and no force is required to pull them apart. However, if a vacuum is drawn inside the hemispheres, it will create a pressure differential across the hemispheres that will produce a resultant force that tends to keep the hemispheres together.

If the differential pressure is known, this force can be calculated by the equation

$$F = \int_0^{\pi/2} \int_0^{2\pi} P \cos\theta \, r^2 \sin\theta \, d\theta \, d\phi,$$

where  $P$  = differential pressure across the hemispheres, and  $r$  = radius of the hemispheres.

By completing the integration across one hemisphere, it can be shown that the force necessary to separate the two spheres is:

$$F = p \, r^2 \, P$$

Since we know the diameter of the apparatus (10cm), we can calculate the area of the circular cross-section where the hemispheres meet and where the force under study is being exerted. This area is 78.5 square centimeters. If the differential pressure  $P$  is known, the force necessary to separate the two hemispheres can be calculated.

## 5. Operation

Air is evacuated from and let into the apparatus by means of a threaded brass intake nipple situated on one of the hemispheres. The flow of air is controlled by the stopcock that is fitted into the brass nipple.

Set the bottom hemisphere into its metal stand. Apply some petroleum jelly to the lip of the bottom hemisphere and set the rubber gasket into place. Set the top hemisphere on top of the bottom one.

To evacuate the apparatus, first press the hemispheres firmly together. The hemispheres can be evacuated by connecting a vacuum pump such as the Cenco 31805 Piston Pump directly to the intake using vacuum tubing or by connecting the intake to an air pump plate (such as Cenco 94205) and thus to a pump.

Once a vacuum is drawn inside the hemispheres, close the stopcock and remove the hemispheres from the vacuum source. You may then invite students to try to separate the hemispheres by hand, for a qualitative demonstration of the amount of force involved.

The actual force required to separate the hemispheres will depend on how strong the vacuum is internal to the hemispheres, but the force can be as high as 914.9N.

After the demonstration, open the stopcock and allow air to re-enter the apparatus. Show students that in the absence of a vacuum, the hemispheres come apart easily.

## 6. Maintenance

The Magdeburg Hemispheres with Stand needs no special maintenance. If you should experience any difficulty with a hemispheres set, please contact Central Scientific Company, giving details of the problem. To ensure better service, please do not return any apparatus to Central Scientific Company until we have sent you authorization.

## 7. Accessories

The Magdeburg Hemispheres demonstration requires the use of a pump for producing a vacuum. If

you do not have a pump or an air pump plate on hand, we recommend the following:

<u>Name</u>	<u>Cenco No.</u>
Piston Pump	31805
Air Pump Plate	94205

You can read complete descriptions of these items in the Laboratory Equipment section of the Central Scientific Company catalog.

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