IYNT 2017

Qingdao NO.2 Middle School

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Problem No. 3
Invent Yourself: Curved Mirrors

Suggest and demonstrate interesting experiments in which large concave mirrors can be used to heat up or cool down various objects.

Experiment Objective

- **Prove that large concave mirrors can be u sed to heat up various objects.**
- **Prove that light that parallels the principl e axis all converges at the focus and deter mine the position of the focus.**
- **Prove that the temperature of the focus is the highest.**

Experiment Equipment

Q3 Curved Mirrors

1	2	3
Parabolic solar cooker	Sticks, Paper, 250ml Water	Stopwatch, 250ml Beaker
1	2	3

Experiment Principle

Q3 Curved Mirrors

Curved mirror

1. A curved mirror is a mirror with a curved reflecting surface. The surface may be either *convex* (bulging outward) or *concave* (bulging inward). The concave mirror has a reflecting surface that bulges inward. The principle of concave mirror is reflecting light which abides by the law of reflection. Concave mirrors are used to focus light.

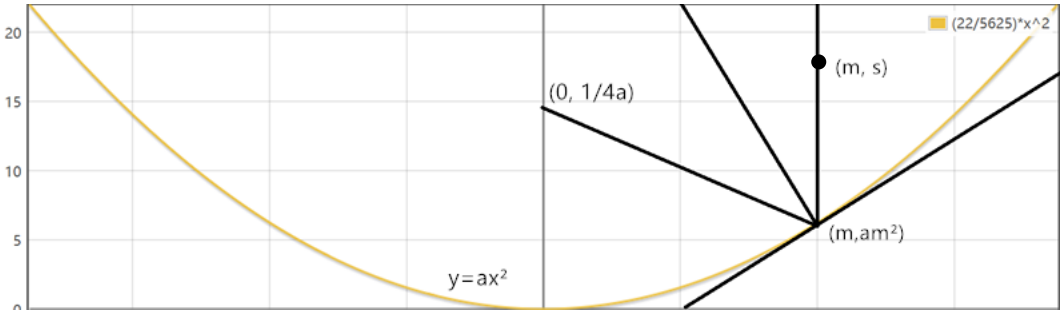
2. There are two main types of Concave mirrors: spherical, parabolic.

Experiment Principle

Parabolic solar cooker principle

Converting light energy to heat energy: Solar cookers concentrate sunlight onto a receiver such as a cooking pan. The interaction between the light energy and the receiver material converts light to heat.

Experiment Principle



Suppose that $y=ax^2$ （a>0）

x=m

intersection point (m, am^2)

the slope of L1 is 2am

the slope of L2 is $-\frac{1}{2am}$

$$\frac{y-am^2}{x-m}=-\frac{1}{2am}$$

$$y=-\frac{1}{2am}x+\frac{1}{2a}+am^2$$

Suppose the coordinate of the symmetric point of the point (m, s) is (x_0, y_0)

$\frac{y_0-s}{x_0-m}=2am$①

$\frac{y_0+s}{2}=-\frac{1}{2am}\cdot\frac{x_0+m}{2}+\frac{1}{2a}+am^2$②

①$y_0=2amx_0-2am^2+s$③

②$y_0=-\frac{1}{2am}x_0+\frac{1}{2a}+2am^2-s$④

$x_0=\frac{8a^2m^3-4ams+m}{4a^2m^2+1}$

$y_0=\frac{8a^3m^4-4a^2m^2s+m}{4a^2m^2+1}$

$k=\frac{y_0-am^2}{x_0-m}=am-\frac{1}{4am}$

$y-am^2=(am+\frac{1}{4am})(x-m)$

$y=(am-\frac{1}{4am})x+\frac{1}{4a}$

Thus, it's obvious that light which parallels the principle axis all converges at the focus and the focus follows the equation that $4FD=R^2$.

Experiment Principle

Q3 Curved Mirrors

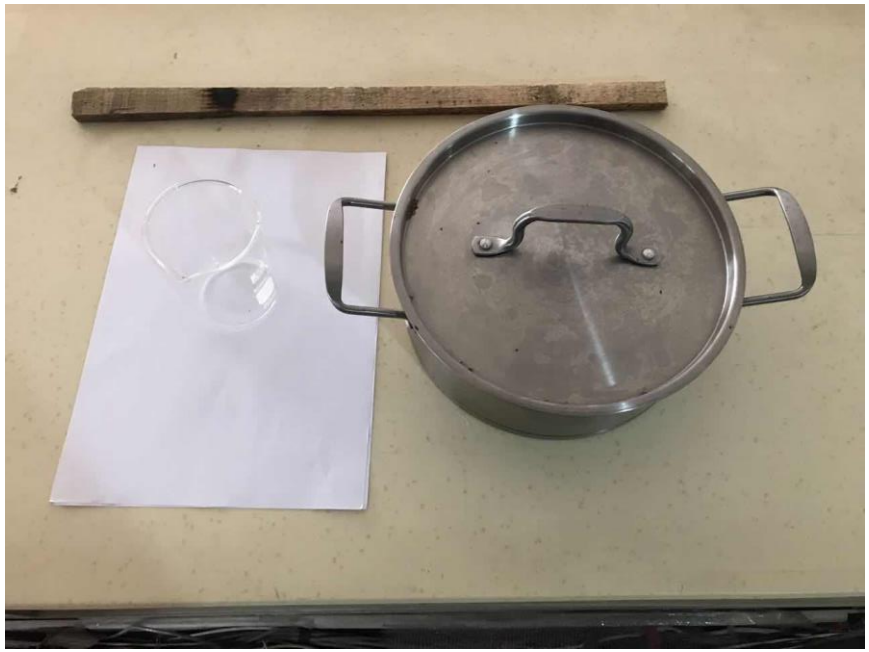
The focus

If a parabola is positioned in Cartesian coordinates with its vertex at the origin and its axis of symmetry along the y-axis, so the parabola opens upward, its equation is $4fy=x^2$, where f is its focal length. Correspondingly, the dimensions of a symmetrical paraboloidal dish are related by the equation **$4FD=R^2$**, where F is the focal length, D is the depth of the dish (measured along the axis of symmetry from the vertex to the plane of the rim), and R is the radius of the rim. All units must be the same. If two of these three quantities are known, this equation can be used to calculate the third.

$4*F*22=75^2$**, F=63.92**

Experiment Equipment

Q3 Curved Mirrors



Experiment Procedure

at the focus

Q3 Curved Mirrors

1. Put the solar cooker towards the sun at 11:30 in Qingdao. The air temperature is about 27 degrees centigrade.

2. Change the position of the paper until the light converges to a dot. Measure the distance between the paper and the bottom of the sun oven.

3. record the time needed for a piece of paper and a piece of wood to burn respectively.

4. Record the time needed for 250ml water in a black bottom pan to boil.

Experiment Result

at the focus

Q3 Curved Mirrors

Item	Time
The burning time of the paper	10s
The burning time of the stick	23s
The boiling time of 250ml water in a black bottom pan	15min 54sec

Experiment Result

at the focus

Q3 Curved Mirrors

1

2

3

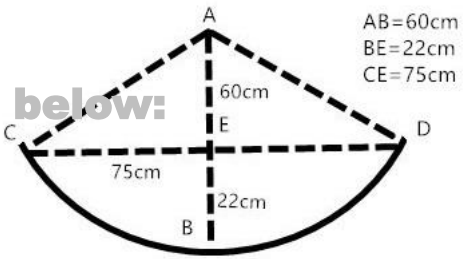
4

Experiment Procedure

different positions

Q3 Curved Mirrors

1. The measurement as shown below:



2. According to the formula $4FD=R^2$, calculate the focal length of the concave mirror, $4\times F\times 22=75^2$, F=63.92cm.

3. Place paper in different positions, observe and record the burning time of paper in different positions.

4. Analyze the data.

Experiment Result

different positions

Q3 Curved Mirrors

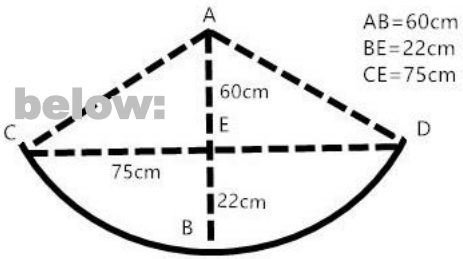
Distance from the object to the curved mirror center	Paper burning time
33.92cm	Can not burn
43.92cm	18.54s
53.92cm	13.27S
63.92cm	10.34s
73.92cm	14.63s
83.92cm	18.32s

Experiment Procedure

different positions

Q3 Curved Mirrors

1. The measurement as shown below:



2. According to the formula $4FD=R^2$, calculate the focal length of the concave mirror, $4\times F\times 22=75^2$, F=63.92cm.

3. Place the black bottom pot with 250mL water in it in different positions, observe and record the time for the water to boil in different positions.

4. Analyze the data.

Experiment Result

different positions

Q3 Curved Mirrors

Why?

Distance from the object to the curved mirror center	250mL water time
33.92cm	21min
43.92cm	16 min
53.92cm	15 min 30s
63.92cm	16min
73.92cm	16min 30s
83.92cm	16min 30s

Experiment Result

different positions

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In the previous problem, because most light converges at the focus, the temperature of the focus is the highest and so it takes the shortest time to burn the paper when the paper is put at the focus. However, in this problem, what matters the most is the amount of light energy that transfers into the heat energy to boil the water. Thus, as long as the amount of light that gets to the black bottom pot is the same, it doesn't matters whether the light is converged into one point or not.

Experiment Conclusions

Q3 Curved Mirrors

Large concave mirrors

1. Large concave mirrors can be used to heat up various objects.
2. light that parallels the principle axis all converges at the focus and the position of the focus can be calculated by the formula 4FD=R2.
3. The black surface absorbs most heat and has the best heating effect.

THANK YOU

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