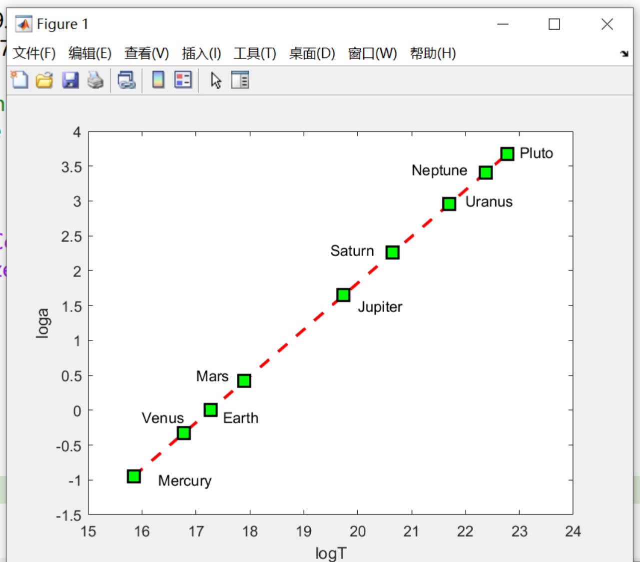
1 AU = 1.495×10^{11} m

```
%plot(T,semia)
% T unit : second ; the third one is the earth. An astronomical unit (AU) of length is defined as one-half
% the sum of the longest and shortest distance of earth from the sum   sun
% (semimajor axis)
loga = log(semia);
logT =log(T);
plot(logT,loga,'--rs','LineWidth',2,'MarkerEdgeColor','k',...
                       'MarkerFaceColor','g',  'MarkerSize',10);
 axis([15 24 -1.5 4]);
 text(16.3,-1,'Mercury');
 text(16,-0.1,'Venus');
 text( 17.5,-0.1,'Earth');
 text(17,0.5,'Mars');
text( 20,1.5,'Jupiter');
 text( 19.5,2.3, 'Saturn');
text(22,3,'Uranus')
text(21,3.45,'Neptune');
text(23,3.7,'Pluto');
xlabel('logT')
ylabel('loga')
end
```

```
function fitplanet
semia = [0.387 0.723 1.000 1.523 5.202 9.554 19.
T = [7.6*10^6, 1.94*10^7, 3.16*10^7, 5.94*10^7
%plot(T,semia)
% T unit : second ; the third one is the earth. An
% the sum of the longest and shortest distance
% (semimajor axis)
loga = log(semia);
logT =log(T);
plot(logT,loga,'--rs','LineWidth',2,'MarkerEdgeC
                     'MarkerFaceColor','g',  'MarkerSiz
 axis([15 24 -1.5 4]);
 text(16.3,-1,'Mercury');
 text(16,-0.1,'Venus');
 text( 17.5,-0.1,'Earth');
 text(17,0.5,'Mars');
text( 20,1.5,'Jupiter');
 text( 19.5,2.3, 'Saturn');
text(22,3,'Uranus')
text(21,3.45,'Neptune');
text(23,3.7,'Pluto');
```



the angle between the planet's orbit and the plane of earth's orbit (ecliptic) 黄道面

TABLE 9.2

Planet	Semimajor axis, AU	Period, s	Eccen-tricity	Incli-nation	Mass, relative to sun's mass, kg
Mercury	0.387	7.60×10^6	0.2056	7°00	1.671×10^{-10}
Venus	0.723	1.94×10^7	0.0068	3°24′	2.448×10^{-9}
Earth	1.000	3.16×10^7	0.0167	…	3.003×10^{-9}
Mars	1.523	5.94×10^7	0.0934	1°51′	3.227×10^{-10}
Jupiter	5.202	3.74×10^8	0.0481*	1°18′	9.548×10^{-7}
Saturn	9.554	9.30×10^8	0.0530*	2°29′	2.858×10^{-7}
Uranus	19.218	2.66×10^9	0.0482*	0°46′	4.361×10^{-8}
Neptune	30.109	5.20×10^9	0.0054*	1°46′	5.192×10^{-8}
Pluto	39.60	7.82×10^9	0.251*	17°8′	5.519×10^{-10}

* Eccentricity varies with the time because of perturbations of other planets. These are values set for 1972.

Cavendish's experiment

$$F = G\frac{mm'}{r^2}.$$

All the masses and distances are known. You say, "We knew it already for the earth." Yes, but we did not know the *mass* of the earth. By knowing G from this experiment and by knowing how strongly the earth attracts, we can indirectly learn how great is the mass of the earth! This experiment has been called "weighing the earth" by some people, and it can be used to determine the coefficient G of the gravity law. This is the only way in which the mass of the

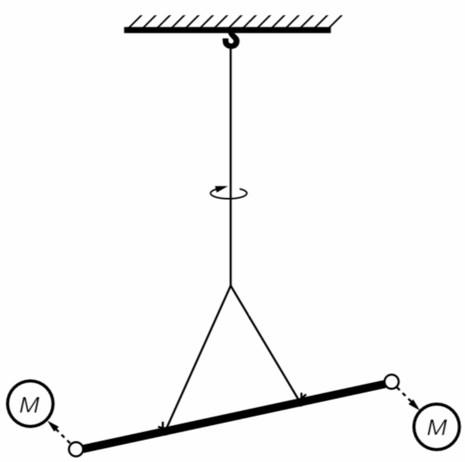
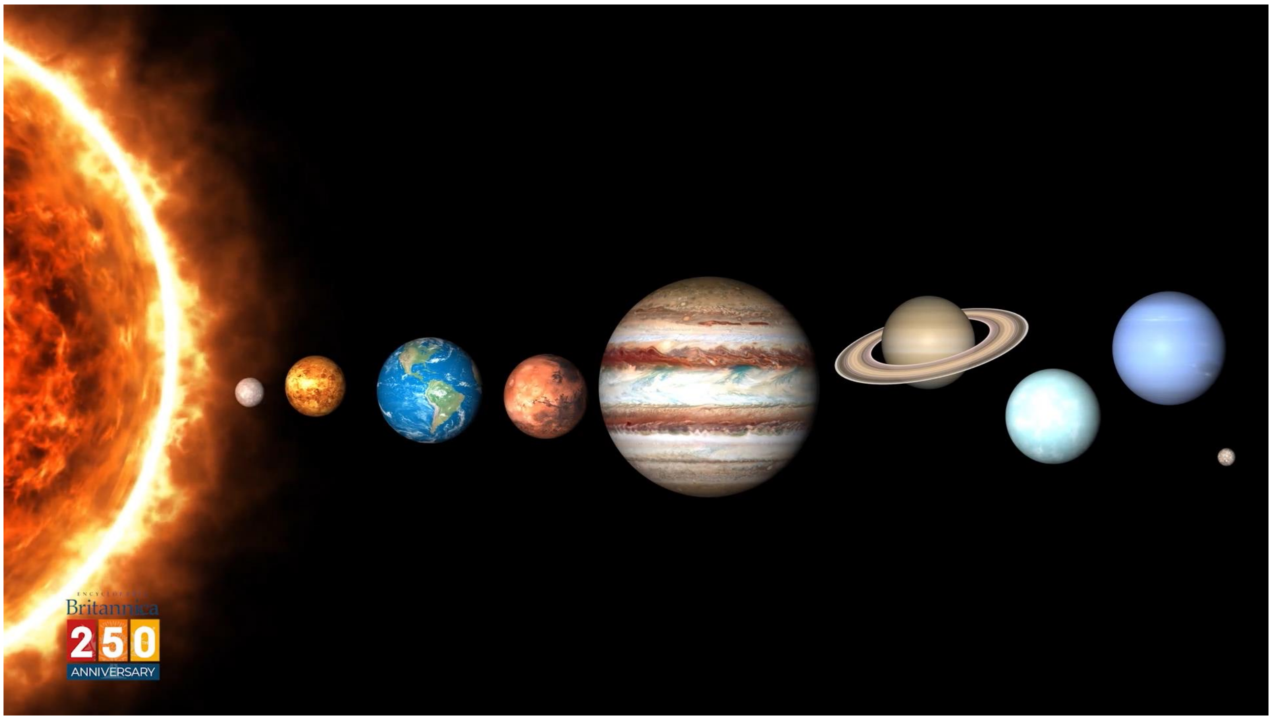


Fig. 7-13. A simplified diagram of the apparatus used by Cavendish to verify the law of universal gravitation for small objects and to measure the gravitational constant G.

6.670×10^{-11} newton · m²/kg²



In 2006 the International Astronomical Union (IAU) demoted the much-loved Pluto from its

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position as the ninth planet from the Sun to one of five “dwarf planets.”

Why is pluto no longer a planet?

Fiercely debated by the members of the union, the resolution that was passed officially defined the term planet. What was once a loose word used to describe a large object within the solar system was now specific: planets are celestial objects large enough to be made rounded by

行星 天体

their gravitational orbit around the Sun and to have shooed away neighboring planetary objects and debris. Pluto is now classified as a dwarf planet because, while it is large enough to have

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become spherical, it is not big enough to exert its orbital dominance and clear the neighborhood surrounding its orbit.

conserved quantity

$$\vec{L} = \vec{r} \times \vec{p} \qquad \frac{d\vec{L}}{dt} = 0$$

$$E = E_k + U(r) = \frac{1}{2} m v^2 - \frac{GMm}{r} = \text{const}$$

$$\frac{dE}{dt} = 0$$

Laplace - runge - Lenz vector

$$\frac{d}{dt}(\vec{v} \times \vec{L}) = \frac{d\vec{v}}{dt} \times \vec{L}$$

$$= m \frac{d\vec{v}}{dt} \times (\vec{r} \times \vec{v})$$

$$= - \frac{GMm}{r^3} (\vec{r} \times (\vec{r} \times \vec{v}))$$

$$= - \frac{GMm}{r^3} [\vec{r} . (\vec{v} . \vec{r}) - \vec{v} (\vec{r} . \vec{r})]$$

$$= - \frac{GMm}{r^3} [\vec{r}\, r v_r - \vec{v}\, r^2]$$

$$\vec{A}\times(\vec{B}\times\vec{C}) = \vec{B}(\vec{A}\cdot\vec{C}) - \vec{C}(\vec{A}\cdot\vec{B})$$

$$= -GMm\left[\frac{\vec{r}}{r^2}\frac{dr}{dt} - \frac{1}{r}\frac{d\vec{r}}{dt}\right]$$

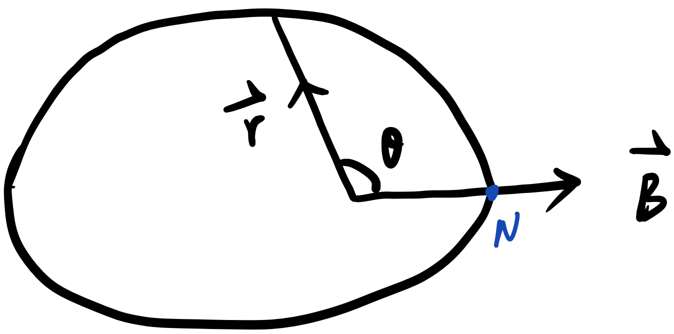
$$= GMm\left[\vec{r}\frac{d}{dt}\left(\frac{1}{r}\right) + \frac{1}{r}\frac{d\vec{r}}{dt}\right]$$

$$= GMm\frac{d}{dt}\left(\frac{\vec{r}}{r}\right) \qquad (=\hat{r})$$

$$\frac{d}{dt}\left(\vec{v}\times\vec{L} - GMm\frac{\vec{r}}{r}\right) = 0$$

$$\vec{B} \equiv \vec{v}\times\vec{L} - GMm\frac{\vec{r}}{r} = \text{const}$$

$$\begin{aligned}\vec{r}\cdot\vec{B} &= \vec{r}\cdot(\vec{v}\times\vec{L}) - GMmr \\ &= \vec{L}\cdot(\vec{r}\times\vec{v}) - GMmr \\ &= \frac{L^2}{m} - GMmr\end{aligned}$$



$\vec B$ 不变

$= \vec B(N)$

右端点 N 的 $\vec B$

$$\vec r \cdot \vec B = rB\cos\theta = \frac{L^2}{m} - GMmr$$

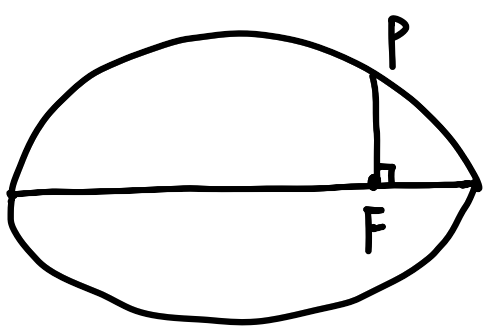
$$r = \frac{L^2/m}{GMm + B\cos\theta}$$

$$= \frac{a(1-e^2)}{1+e\cos\theta}$$

半正焦弦

$$a(1-e^2) = L^2/GMm^2$$

$$e = B/GMm \qquad e \propto B$$



$|PF| =$

$a\left(1-\frac{c^2}{a^2}\right)$

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

$$x_p = c$$

$$y_p = \sqrt{\left(1 - \frac{c^2}{a^2}\right) b^2}$$

$$= \frac{b^2}{a} = a(1-e^2)$$

$$a = -\frac{GMm}{2E}$$

(see Lec 19)

$$b^2 = -\frac{L^2}{2Em}$$

$$b^2/a = \frac{L^2}{GMm^2}$$

如果是圆轨道，$e=0$, $B=0$

$\vec{B}$ keep invariant $\longrightarrow$ ellipse (in a plane)