Chapter 7 - Gravitation

(2wk)

Obj:
- Relate Kepler's laws to law of univ. grav.
- Calculate orb. speeds & periods
- Describe impact of Cavendish's exp.

Vocab - Kepler's Laws (1st, 2nd, 3rd)
perihelion
aphelion

I) Planetary Motion & Gravitation

A) Intro

1) Nicholas Copernicus - (pub 1543) the motion of planets can be explained by a heliocentric model

2) Tycho Brahe (after Copernicus) - had the lab / tools to make measurements (a lot)

B) Keplers laws (Kepler inherited Brahe's data)

1) Kepler's First Law - planets travel in ellipses w/ the sun at one of the foci (p 172)

p173 → 2) Second Law - a line drawn from sun-planet will 'sweepout' equal areas (p 173)

3) Third Law the ratio of periods of two planets squared equals the ratio of their distances to the sun cubed

$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

: where: T = Period for planets "A" & "B"
r = distance to sun (average)

Practice Problems → p174 # 1-5
Assign:

C) Newton's Law of Universal Gravitation

1) a) $F_{gravity} \propto \frac{1}{r^2}$

2) Newton theorized that the same force that pulls us down extends forever, this "gravitational force" is:

a) (above)

b) Proportional to the mass of each body ($F_g \propto m_1$ & $F_g \propto m_2$)

c) So $F_g \propto \frac{m_1 \cdot m_2}{r^2}$

i) he called this ratio 'G' (a "universal gravitational constant")

Therefore $F_g = G\frac{m_1 m_2}{r^2}$

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D) Kepler, meet Newton

1) An object in circular motion $v = \frac{2\pi r}{T}$ $\left(\begin{matrix} r = \text{radius} \\ T = \text{period} \end{matrix}\right)$

$$a_c = \frac{v^2}{r} = \frac{\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 r}{T^2} = a_c$$

Newton's Law of U. Grav: $F_g = G\frac{m_1 m_2}{r^2}$

2) A ~~planet~~'s body's gravitional force: $\Sigma F_g = m_b \cdot a_c = \frac{m_b}{1} \cdot \left(\frac{4\pi^2 r}{T^2}\right)$

3) Combined w/ Newton's law of Universal Gravitation:

$$G\frac{m_a m_b}{r^2} = \frac{m_b 4\pi^2 r}{T^2}$$

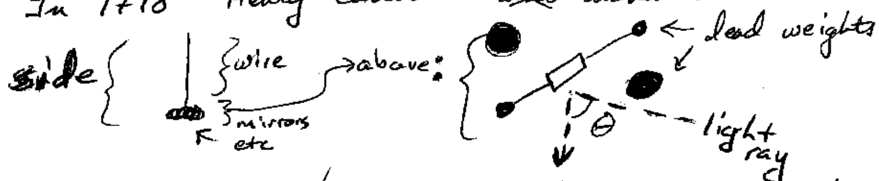
Rearrange, solve for T

For a planet orbiting the sun: $\boxed{T = 2\pi\sqrt{\frac{r^3}{G M_{sun}}}}$

Assign:

E) Finding G

1) In 1798 Henry Cavendish ~~used~~ invented:



Then, by measuring the torque on the wire (how far the light ray moves with various masses) at different distances (r). He found the slope of the graph &

units meant to simplify equation →

$$\boxed{G = 6.67 \times 10^{-1} \frac{Nm^2}{kg^2}}$$

2) Once we had G we could find the mass of earth

$$m_1 g = (F_g) = G\frac{m_1 m_E}{r_E^2} \Rightarrow m_e = \frac{g \cdot r_E^2}{G}$$

Section rvw p 178 →
#6-11

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Objectives
- Solve orbital motion problems
- Relate weightlessness to objects in freefall
- Describe gravitational fields
- Compare views on gravitation

Vocab:
- grav. field
- inertial mass
- gravitational mass

Practice Problems → p 181 # 12-14

II Using the Law of Universal Gravitation

A) Newton's thought experiment

1) p 179

2) Recall: $\Sigma F = m a_c = \frac{m v^2}{r}$ & $F_g = G\frac{m_E m}{r^2}$

so: $G\frac{m_E m}{r^2} = \frac{m v^2}{r}$

And: $\boxed{v = \sqrt{\frac{G m_E}{r}}}$ where v = speed of a satellite

3) Recall: $T_{planet} = 2\pi\sqrt{\frac{r^3_{to\ sun}}{G m_{sun}}}$

so: $\boxed{T = 2\pi\sqrt{\frac{r^3}{G m_E}}}$ where r = dist to planet (center-center) & T = period of satellite

a) notice mass of satellite is not important

B) Distance from earth

1) $F = G\frac{m_E m}{r^2}$ & $F = ma$ so: $a = G\frac{m_E}{r^2}$

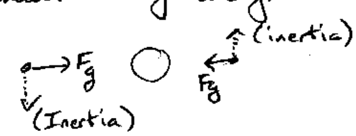
2) In FreeFall $a = g$ @ earth's surface BUT:

as r (dist between centers) changes from r_E (radius of earth)

$a = g\left(\frac{r_E}{r}\right)^2$ (when $r = r_E$ then $\frac{r_E}{r} = 1$)

3) So: dist. from earth's center means $a \leq g$

C) Understanding weightlessness

1) 

*Everything in the shuttle is Free Falling at the same acc. while moving @ the same speed

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D) Gravitational fields

1) The force exerted by gravity can be imagined as a theoretical force exerted on an imaginary object anywhere within a **field**

2) Within this Field the $\overrightarrow{\text{Force}}$ can be measured, and follows this relationship:

$$g = \frac{GM}{r^2}$$

where g = gravitational Field
M = mass of an object
r = dist to center of that object

(units of g are $\frac{N}{kg}$ $\left(= \frac{m}{s^2}\right)$) so $g = 9.8\ N/kg$

E) Types of mass

1) Inertial mass: $m_i = \frac{\Sigma F}{a}$

2) Gravitational mass: $m_{grav} = \frac{r^2 F_g}{G\, m_{\text{other object}}}$

3) Principle of equivalence: $m_i = m_{grav}$

a) Interesting because mass is just an explanation of a property of things. That the 2 properties (inertia and gravity) are related is weird.

F) Einstein's theories of Gravity

1) Hypothesized that gravity is not some invisible force communicated over space & time, but rather a bending of "space-time"

2) These theories predicted also that light will change direction based on gravitational fields.

a) Apparently Einsteins theories predicted light bending and black holes

Section Rvw p 185 →