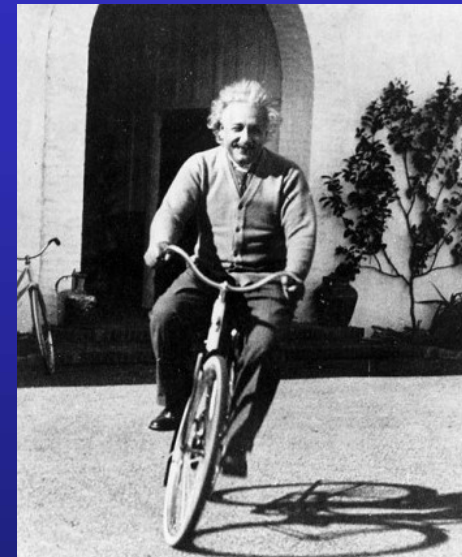


Classical Mechanics

PHYS 2006

Tim Freegarde



Classical Mechanics

LINEAR MOTION OF SYSTEMS OF PARTICLES	centre of mass
	Newton's 2nd law for bodies (internal forces cancel)
	rocket motion
ANGULAR MOTION	rotations and infinitesimal rotations
	angular velocity vector, angular momentum, torque
	parallel and perpendicular axis theorems
	rigid body rotation, moment of inertia, precession
GRAVITATION & KEPLER'S LAWS	conservative forces, law of universal gravitation
	2-body problem, reduced mass
	planetary orbits, Kepler's laws
	energy, effective potential
NON-INERTIAL REFERENCE FRAMES	centrifugal and Coriolis terms
	Foucault's pendulum, weather patterns
NORMAL MODES	coupled oscillators, normal modes
	boundary conditions, Eigenfrequencies

Newton's law of Universal Gravitation

- Exact analogy of Coulomb electrostatic interaction
- gravitational force between two masses m_1 and m_2

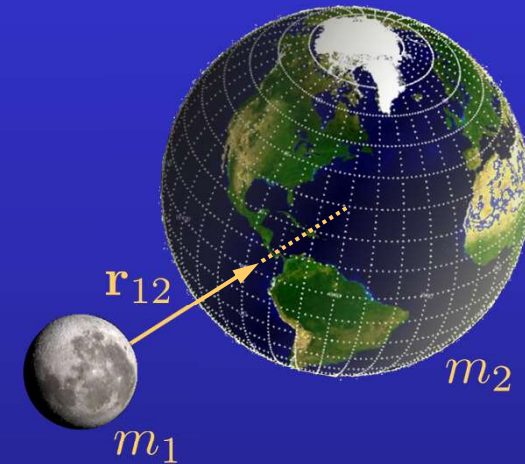
$$\mathbf{F}_{12} = -\mathbf{F}_{21} = \frac{Gm_1m_2}{r_{12}^2} \hat{\mathbf{r}}_{12} = m_1\mathbf{g}$$

- gravitational field

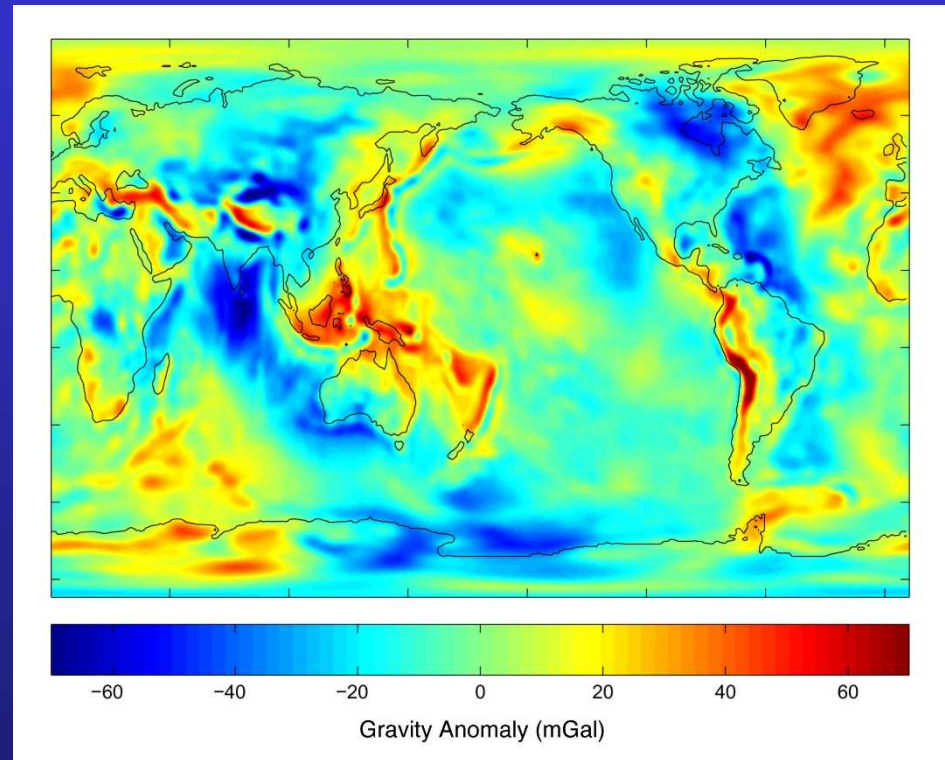
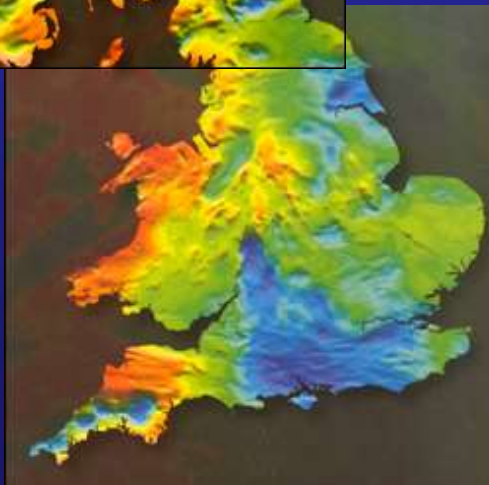
$$\mathbf{g}(\mathbf{r}_{12}) = -\frac{Gm_2}{r_{12}^2} \hat{\mathbf{r}}_{12} = -\nabla\Phi$$

- gravitational potential

$$\Phi(r_{12}) = -\frac{Gm_1}{r_{12}}$$



Gravity anomaly



NASA/JPL/University of Texas Center for Space Research

- gravity anomaly = variation from uniform solid
- $1 \text{ Gal} \equiv 0.01 \text{ m s}^{-2} \approx g/1000$

Gravitational attraction of a spherical shell

- Exact analogy of Coulomb interaction
- gravitational force between two masses

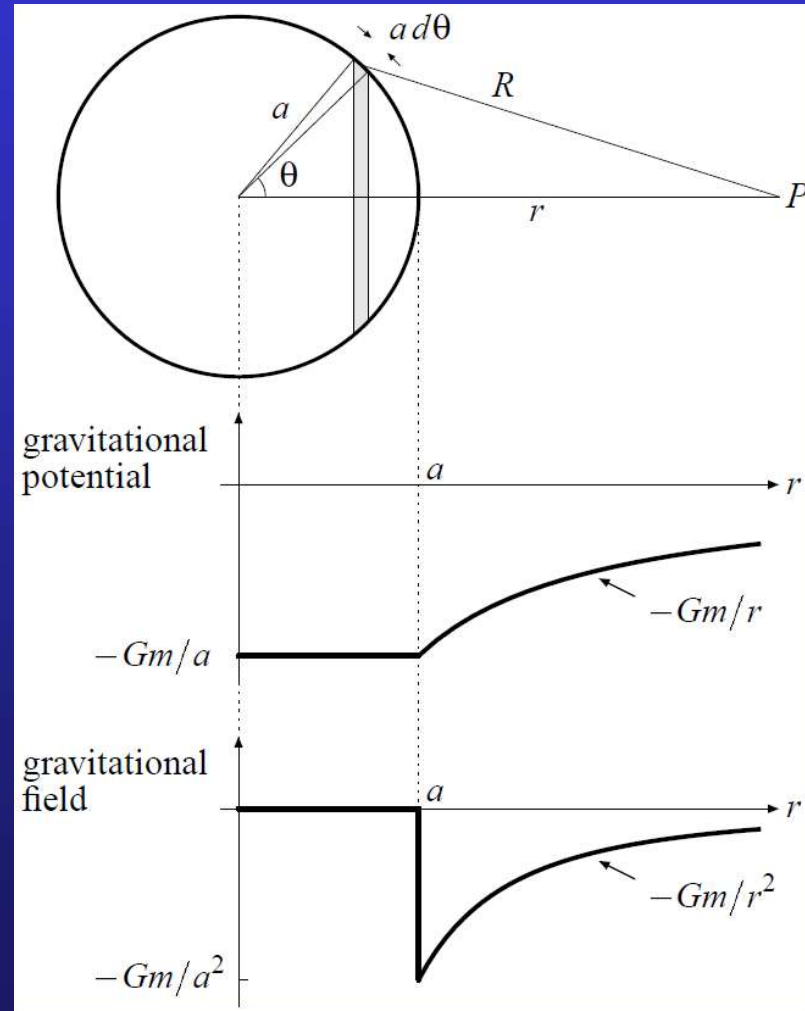
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- gravitational potential

$$\Phi(r_{12}) = -\frac{Gm_1}{r_{12}}$$



Galilean equivalence principle

- gravitational field

$$\mathbf{g}(\mathbf{r}_{12}) = -\frac{Gm_2}{r_{12}^2} \hat{\mathbf{r}}_{12}$$

- gravitational motion of mass m

$$m\ddot{\mathbf{r}} = m\mathbf{g} = -m\frac{GM}{r^2} \hat{\mathbf{r}}$$

↑ ↑ ↑
inertial mass gravitational mass

- equivalence principle

the trajectory of a point-like mass in a gravitational field is independent of the composition and structure of the mass

⇒ inertial mass = gravitational mass



Apollo 15, David R Scott (7 August 1971)
www.youtube.com/watch?v=MJyUDpm9Kvk
history.nasa.gov/alsj/a15/a15.clsout3.html

nssdc.gsfc.nasa.gov/planetary/lunar/apollo_15_feather_drop.html

Newton's law of Universal Gravitation

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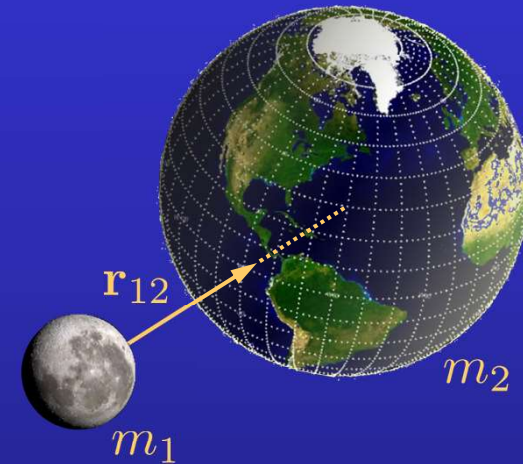
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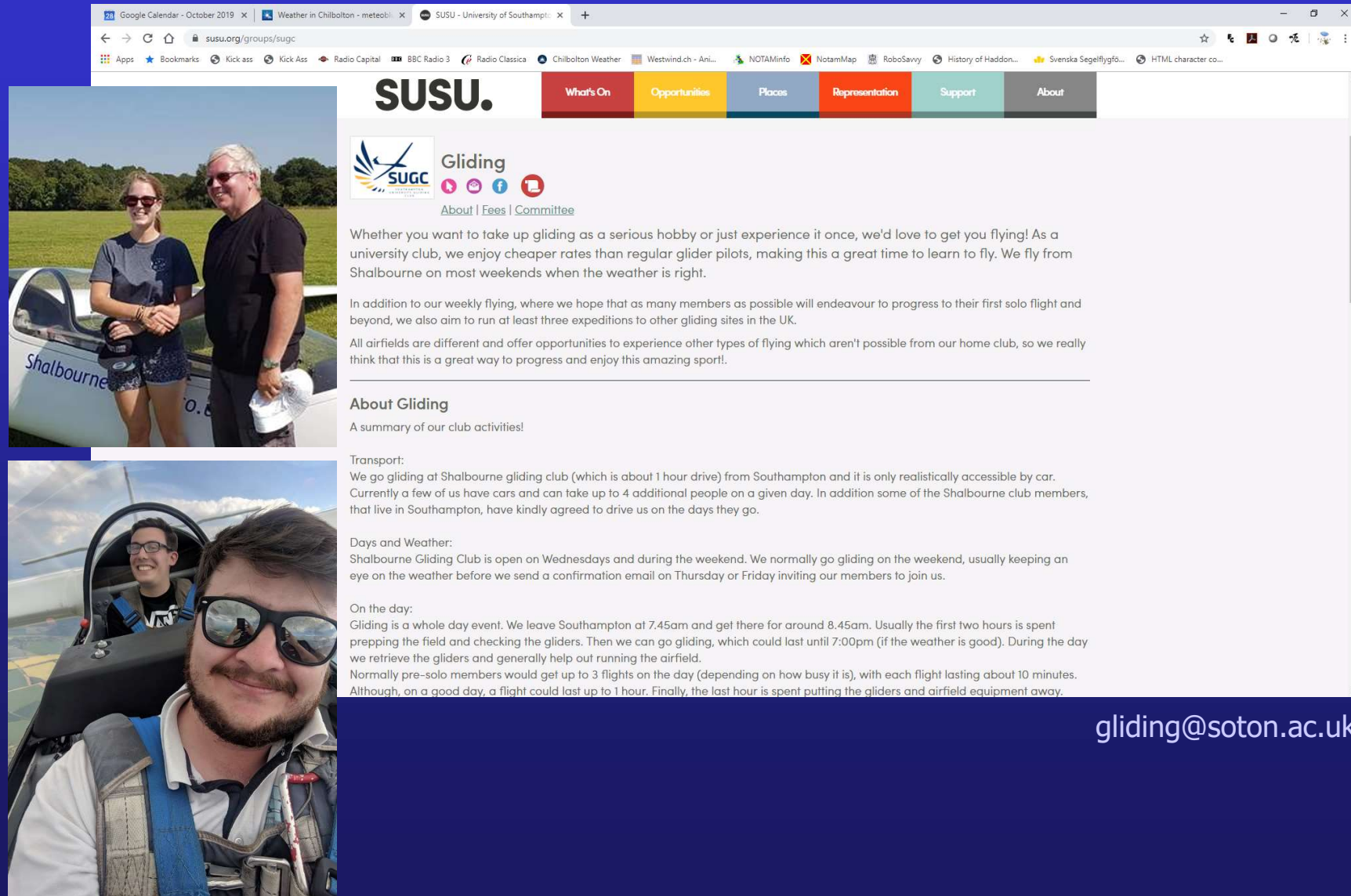
GliderFX



Project H2O https://www.youtube.com/watch?v=VN_VG07qcPU 2:31

Project Gravity https://www.youtube.com/watch?v=9G_djIzd21A 1:47

SU Gliding Club



The screenshot shows a web browser displaying the SUSU Gliding website. The browser tabs include Google Calendar, Weather in Chilbolton, and SUSU - University of Southampton. The website URL is susu.org/groups/sugc. The page features a navigation menu with links for 'What's On', 'Opportunities', 'Places', 'Representation', 'Support', and 'About'. The main content area includes the SUSU logo, a 'Gliding' sub-header with social media icons, and a list of links: 'About | Fees | Committee'. The text on the page describes the club's activities, including weekly flying, solo flight progress, and expeditions to other sites. It also provides information on transport, days and weather, and the typical day of a gliding event. Two photographs are included: one of a man and a woman standing by a glider at Shalbourne, and another of a man in a glider cockpit.

SUSU. What's On Opportunities Places Representation Support About

Gliding
About | Fees | Committee

Whether you want to take up gliding as a serious hobby or just experience it once, we'd love to get you flying! As a university club, we enjoy cheaper rates than regular glider pilots, making this a great time to learn to fly. We fly from Shalbourne on most weekends when the weather is right.

In addition to our weekly flying, where we hope that as many members as possible will endeavour to progress to their first solo flight and beyond, we also aim to run at least three expeditions to other gliding sites in the UK.

All airfields are different and offer opportunities to experience other types of flying which aren't possible from our home club, so we really think that this is a great way to progress and enjoy this amazing sport!.

About Gliding

A summary of our club activities!

Transport:
We go gliding at Shalbourne gliding club (which is about 1 hour drive) from Southampton and it is only realistically accessible by car. Currently a few of us have cars and can take up to 4 additional people on a given day. In addition some of the Shalbourne club members, that live in Southampton, have kindly agreed to drive us on the days they go.

Days and Weather:
Shalbourne Gliding Club is open on Wednesdays and during the weekend. We normally go gliding on the weekend, usually keeping an eye on the weather before we send a confirmation email on Thursday or Friday inviting our members to join us.

On the day:
Gliding is a whole day event. We leave Southampton at 7.45am and get there for around 8.45am. Usually the first two hours is spent prepping the field and checking the gliders. Then we can go gliding, which could last until 7:00pm (if the weather is good). During the day we retrieve the gliders and generally help out running the airfield.
Normally pre-solo members would get up to 3 flights on the day (depending on how busy it is), with each flight lasting about 10 minutes. Although, on a good day, a flight could last up to 1 hour. Finally, the last hour is spent putting the gliders and airfield equipment away.

gliding@soton.ac.uk

Elliptical orbit

- eccentricity

$$e$$

- constant

$$k = GMm$$

- semi latus rectum

$$l = \frac{L^2}{mk}$$

- polar equation

$$\frac{l}{r} = 1 + e \cos \vartheta$$

- Cartesian equation

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

- semimajor axis

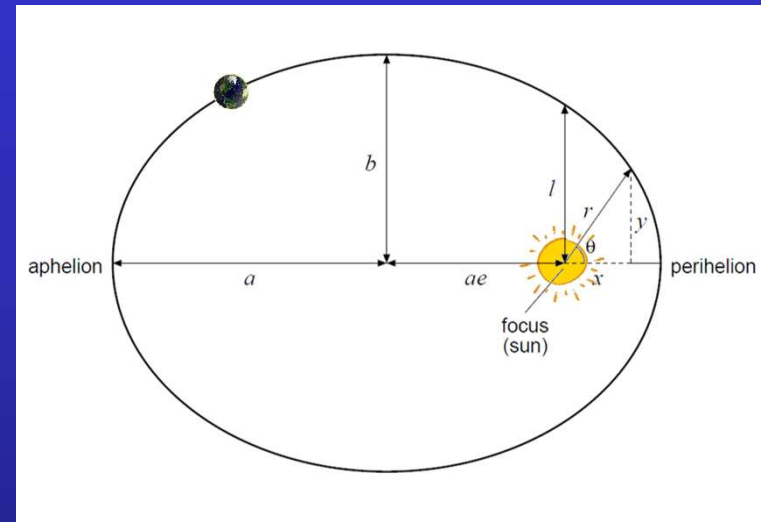
$$a = \frac{l}{1 - e^2} = -\frac{k}{2E}$$

- semiminor axis

$$b = \frac{l}{\sqrt{1 - e^2}} = \sqrt{al}$$

- total energy

$$E = -\frac{mk^2}{2L^2} (1 - e^2) = -\frac{k}{2a}$$



Conic section orbits

- eccentricity

e

- constant

$$k = GMm$$

- semi latus rectum

$$l = \frac{L^2}{mk}$$

- polar equation

$$\frac{l}{r} = 1 + e \cos \vartheta$$

- Cartesian equation

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

- semimajor axis

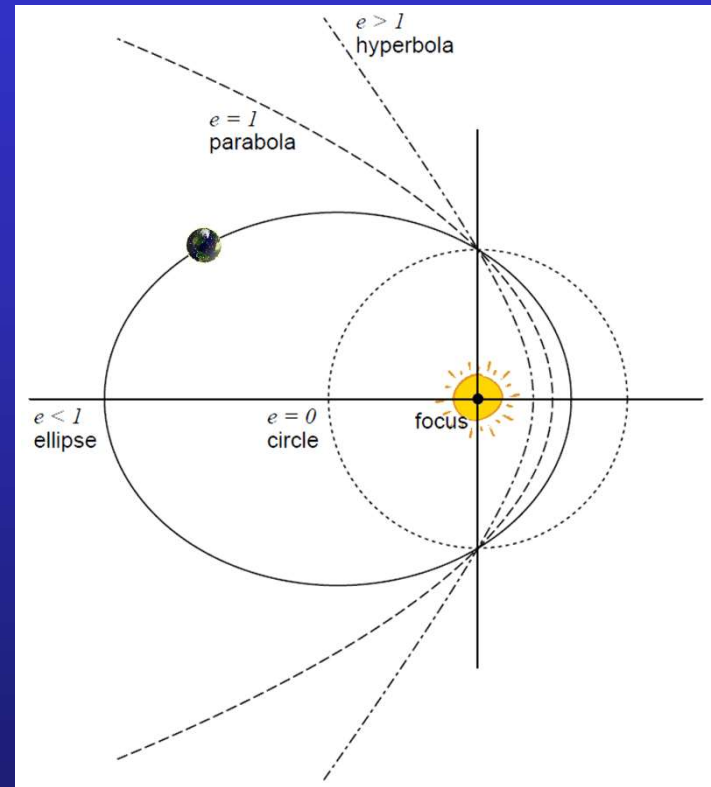
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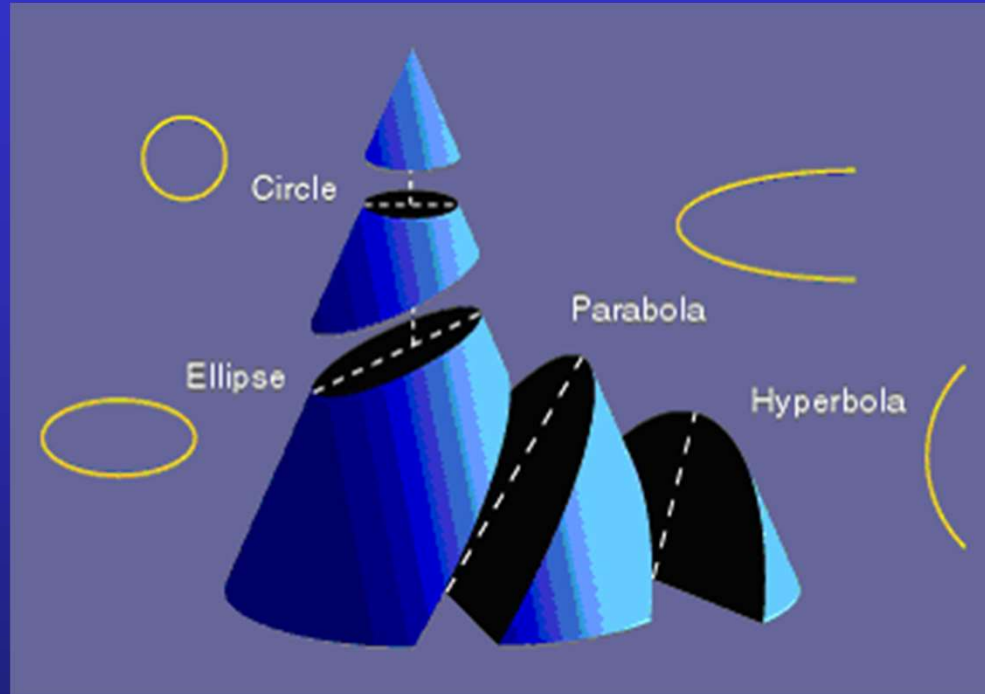
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- total energy

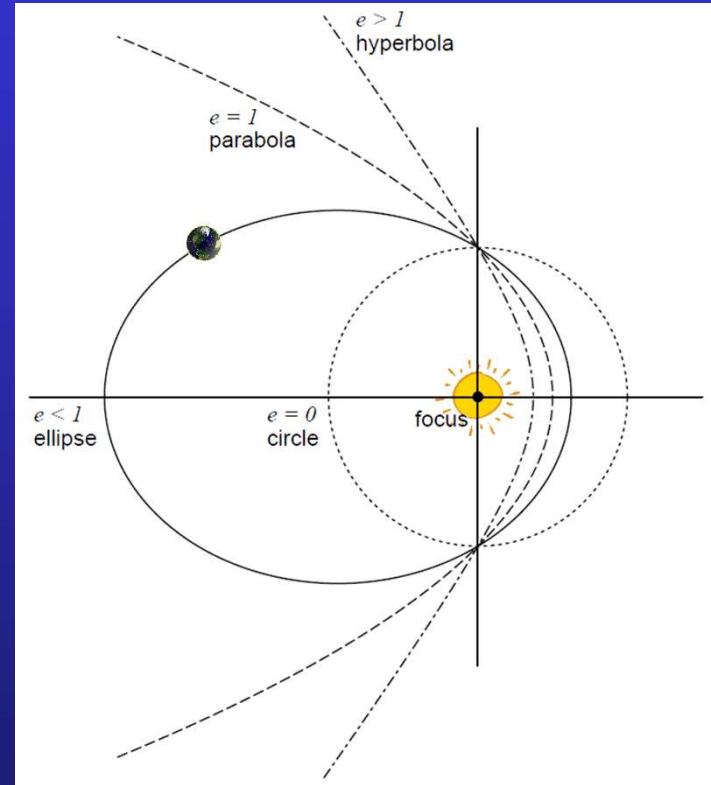
$$E = -\frac{mk^2}{2L^2} (1 - e^2) = -\frac{k}{2a}$$



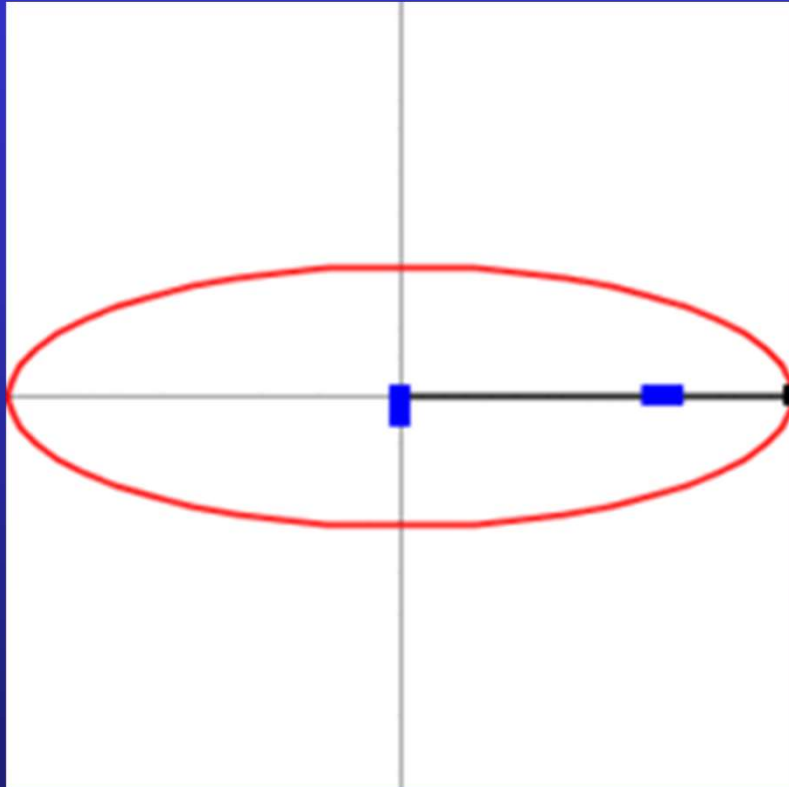
Conic section orbits



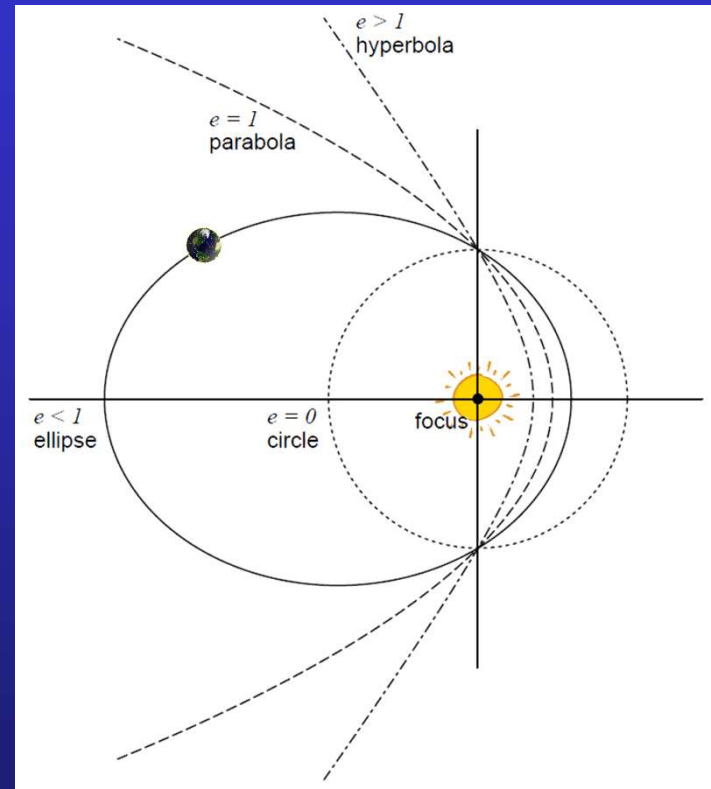
<http://www.personal.psu.edu/smh408/>



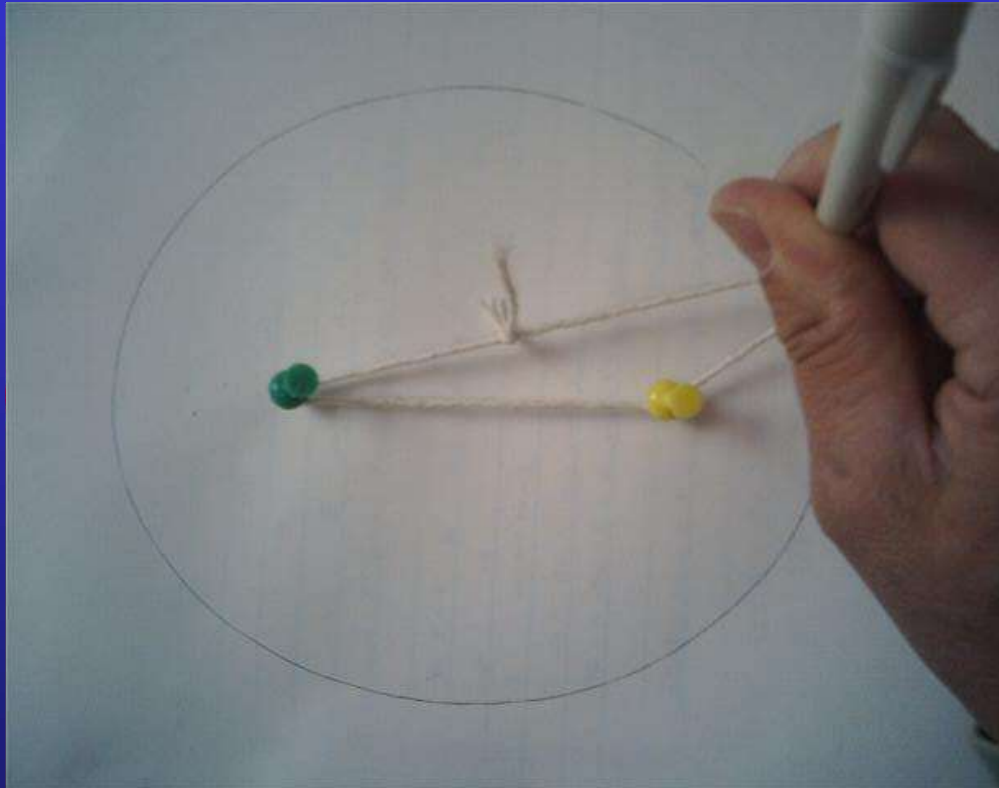
Conic section orbits



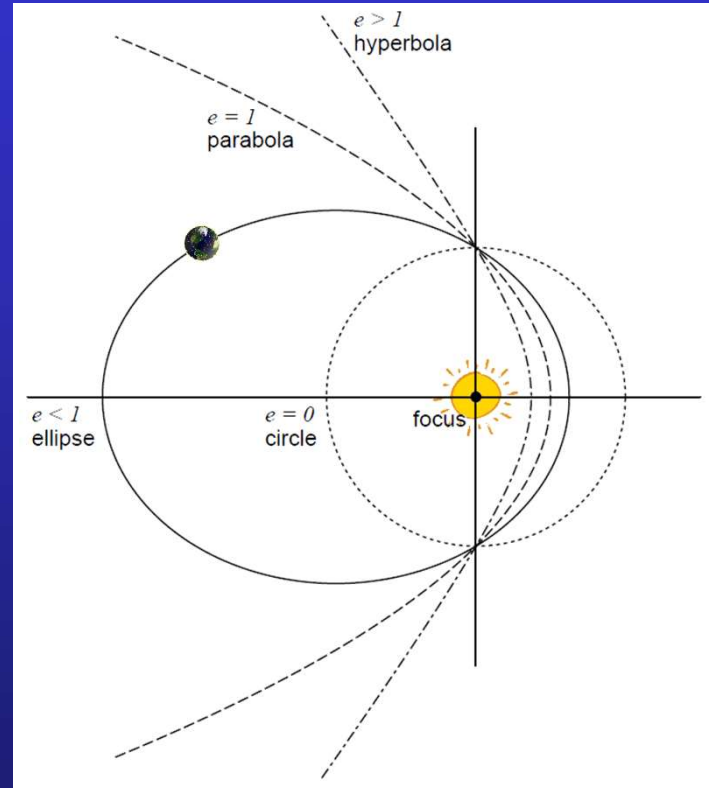
Alastair Rae



Conic section orbits



Magnus Manske



Kepler's laws

1. Planetary orbits are ellipses with the Sun at one focus
2. The radius vector from Sun to planet sweeps out equal areas in equal times
3. The square of the orbital period is proportional to the cube of the semimajor axis

$$T^2 \propto a^3$$

