Physic^2 121:
Phundament°ls of Phy^{2}ics I

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Exam Info

$$v = v_0 + at$$

$$x = \tfrac{1}{2}at^2$$

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2$$

$$\Delta x = v_0 t + \tfrac{1}{2}at^2$$

$$\vec{I} = \vec{F}\Delta t = \Delta\vec{p}$$

$$\vec{p} = m\vec{v}$$

$$W = \vec{F}\cdot\Delta\vec{x} = (F\cos\theta)\Delta x$$

$$W_{Net} = \Delta KE$$

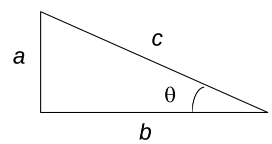
$$KE = \tfrac{1}{2}mv^2$$

$$PE_{grav} = mgh$$

$$PE_{spring} = \tfrac{1}{2}kx^2$$

$$f_s \le \mu_s |n|$$

$$f_k = \mu_k |n|$$



$$\cos\theta = \frac{b}{c} \quad \sin\theta = \frac{a}{c} \quad \tan\theta = \frac{a}{b}$$

You may assume that g = 10 m/s^2 throughout the exam.

- **Newton's Laws**
- An object moves with a velocity that is constant in magnitude and direction, unless acted on by a nonzero net force.
- The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass:

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

- If object 1 and object 2 interact, the force exerted by object 1 on object 2 is equal in magnitude but opposite in direction to the force exerted by object 2 on object 1.

Exam Topics

- Vectors in more than one dimension
- Motion in 2-D
  - Projectile motion
  - Ramps
- Forces of friction
  - Static friction
  - Kinetic friction
- Statics
- Momentum
  - Impulse
  - Conservation of Momentum
- Energy
  - Work
  - Kinetic Energy
  - Potential Energy (gravitational and spring)
  - Conservation of Energy

Newton's Law of Universal Gravitation

- Every particle in the Universe attracts every other particle with a force that is directly proportional to the product of the masses and inversely proportional to the square of the distance between them.

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

Applications of Universal Gravitation

- Acceleration due to gravity

- g will vary with altitude

$$g = G\frac{M_E}{r^2}$$

TABLE 7.1

Free-Fall Acceleration *g* at Various Altitudes

Altitude (km)[a]	*g* (m/s²)
1 000	7.33
2 000	5.68
3 000	4.53
4 000	3.70
5 000	3.08
6 000	2.60
7 000	2.23
8 000	1.93
9 000	1.69
10 000	1.49
50 000	0.13

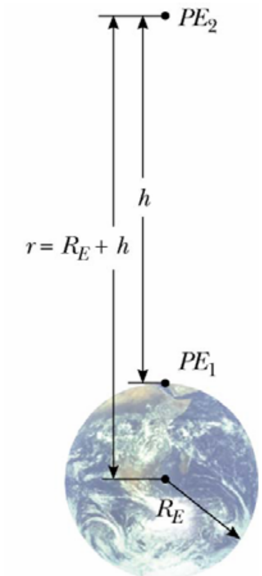
[a]All figures are distances above Earth's surface.

Gravitational Potential Energy

- PE = mgy is valid only near the earth's surface
- For objects high above the earth's surface, an alternate expression is needed

$$PE = -G\frac{M_E m}{r}$$

  - Zero reference level is infinitely far from the earth
  - Otherwise, PE < 0 (negative)



Escape Speed

- The escape speed is the speed needed for an object to soar off into space and not return
- Initial Energy:

$$E_i = KE + PE$$
$$= \tfrac{1}{2}mv^2 - G\frac{M_E m}{R_E}$$

- Really far from the earth ($r \to \infty$), PE → 0. To "escape", object needs to get infinitely far away. To just barely escape, it will slow down to zero at $r = \infty$, so KE = 0. This means total energy = 0:

$$0 = \tfrac{1}{2}mv^2 - G\frac{M_E m}{R_E}$$
$$\tfrac{1}{2}mv^2 = G\frac{M_E m}{R_E}$$
$$v_{esc} = \sqrt{\frac{2GM_E}{R_E}}$$

- For the earth, v_{esc} is about 11.2 km/s
- Note, v is independent of the mass of the object

Kepler's Laws

- All planets move in elliptical orbits with the Sun at one of the focal points.
- A line drawn from the Sun to any planet sweeps out equal areas in equal time intervals.
- The square of the orbital period of any planet is proportional to cube of the average distance from the Sun to the planet.
  - $T^2 \propto r^3$

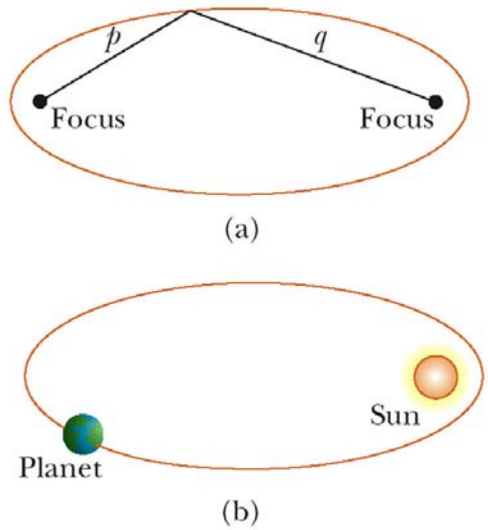
Kepler's Laws, cont.

- Based on observations made by Tycho Brahe

- Newton later demonstrated that these laws were consequences of the gravitational force between any two objects together with Newton's laws of motion

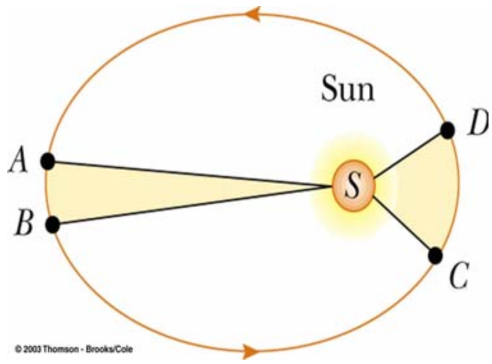
Kepler's First Law

- All planets move in elliptical orbits with the Sun at one focus.
  - Any object bound to another by an inverse square law will move in an elliptical path
  - Second focus is empty



Kepler's Second Law

- A line drawn from the Sun to any planet will sweep out equal areas in equal times
  - Area from A to B and C to D are the same



Kepler's Third Law

- The square of the orbital period of any planet is proportional to cube of the average distance from the Sun to the planet.

$$T^2 = Kr^3$$

  - For orbit around the Sun, $K = K_S = 2.97 \times 10^{-19}\ s^2/m^3$
  - K is independent of the mass of the planet