ASTR 220 Spring 2024
Learning Goals for Midterm 2 & Equation List

Learning Goals

- Overall
  - The student should be able to define the astronomical terms introduced and be able to use them appropriately.
- Lecture 11: The student should be able to...
  - ...explain how astronomers use spectroscopy to determine surface compositions of asteroids.
  - ...discuss the most common surface compositions of asteroids.
  - ...discuss the two primary methods astronomers use to calculate an asteroid's mass.
  - ...mathematically calculate an asteroid's mass given a word problem with physical information.
  - ...determine the overall compositions of objects based on their average densities.
  - ...explain how astronomers have determined that asteroids are porous.
  - ...discuss the connection between asteroids and meteorites.
  - ...describe a comet's changing appearance as it orbits the Sun and explain why the appearance changes.
  - ...explain why comets are considered less of an impact threat than asteroids.
- Lecture 13: The student should be able to...
  - ...explain what happens to dust when it "impacts" the Earth.
  - ...explain what happens in detail to various size objects of less than 50-m diameter when they impact the Earth.
  - ...discuss specific examples of well-studied airbursts or impacts.
- Lecture 14: The student should be able to...
  - ...explain what a shockwave is and how it might be created by an impact.
  - ...explain how the impact of a meteor creates an impact crater in the Earth's surface.
  - ...discuss other effects of an impact, such as the shockwave, ejecta, heat, and climate change.
  - ...use given distances at which various impact effects occur for specific impactor sizes in order to estimate the effect distance for a different impactor size.
  - ...discuss specific examples of historical impacts.
- Lecture 15: The student should be able to...
  - ...list characteristics that scientists look for in order to determine if a geologic structure is an impact crater, and why.

  - ...enumerate the approximate number of impact craters confirmed on the Earth's surface.
  - ...discuss what geologic processes affect impact craters on the Earth's surface and how.
  - ...describe and discuss what a plot of asteroid size versus impact frequency looks like, and why, and what implications that has for asteroids impacting the Earth.
  - ...explain why an impact frequency does not give a prediction of when an impact will occur.

- Lecture 16: The student should be able to...
  - ...discuss and describe the methods astronomers use to search for new asteroids.
  - ...discuss how astronomers use asteroid images to determine the characteristics of a new asteroid's orbit.
  - ...describe how and why an asteroid's region of uncertainty changes shape and size as more observations of it are taken over time.
  - ...discuss why multiple images are needed in order to determine the orbital path of a newly discovered asteroid.

- Lecture 17: The student should be able to...
  - ...describe and sketch the concepts of the region of uncertainty, B-plane, and capture radius, and how these are used to evaluate the chance of an asteroid impact on Earth.
  - ...explain why an asteroid's region of uncertainty generally grows with time unless more observations are taken of the asteroid.
  - ...describe how the path of risk of a potential asteroid impact is determined from the region of uncertainty.
  - ...explain what an "apparition" is in relation to asteroid observations.
  - ...discuss how long astronomers need to observe asteroids of various sizes in order to give a well-determined percent chance of impact.

- Lecture 18: The student should be able to...
  - ...discuss cases of asteroid impacts for which evacuation is a valid defense and why.
  - ...explain why "destroying" an asteroid is not feasible.
  - ...explain the general idea of how to make an asteroid's orbit larger or smaller.
  - ...describe what a "keyhole" is in relation to near-Earth asteroids and impacts.
  - ...discuss Apophis's path in the future and how we know it will not impact the Earth.

- Lecture 21: The student should be able to...
  - ...be able to explain and apply Newton's Second Law of Motion.
  - ...be able to explain and apply Newton's Third Law of Motion.
  - ...discuss the physical method underlying the Kinetic Impactor deflection strategy.
  - ...be able to compare implementations of the Kinetic Impactor deflection strategy using proportional reasoning.
  - ...be able to mathematically calculate a deflection distance using the Kinetic Impactor deflection strategy from information given in a word problem.
  - ...discuss the physical method underlying the Nuclear deflection strategy.

  - ...compare implementations of the Nuclear deflection strategy using proportional reasoning.
  - ...mathematically calculate a deflection distance using the Nuclear deflection strategy.
  - ...discuss pros and cons of using both the Kinetic Impactor and Nuclear deflection strategies.

- Lecture 22: The student should be able to...
  - ...discuss the physical method underlying the Gravity Tractor deflection strategy.
  - ...compare implementations of the Gravity Tractor deflection strategy using proportional reasoning.
  - ...mathematically calculate a deflection time using the Gravity Tractor deflection strategy from information given in a word problem.
  - ...discuss pros and cons of the Gravity Tractor deflection strategy.
  - ...discuss the physical method underlying the Disruption deflection strategy.
  - ...mathematically calculate a deflection energy required using the Disruption deflection strategy from information given in a word problem.
  - ...discuss pros and cons of the Disruption deflection strategy.

ASTR 220 Spring 2024
Equation List

Equations

No need to memorize these, but know how to use them

$$F = \frac{GM_1M_2}{d^2} \tag{1}$$

F = gravitational force, G = gravitational constant, M_1 = mass of one object, M_2 = mass of other object, d = distance between the two masses

$$v_{ave} = \sqrt{\frac{GM_r}{r_{ave}}} \tag{2}$$

v_{ave} = average speed of orbiting mass, M_r = mass of the object that is being orbited, r_{ave} = average distance between the two masses

$$P = \frac{2\pi r_{ave}}{v_{ave}} \tag{3}$$

P = period of small mass around a larger one, r_{ave} = average distance between the two masses, v_{ave} = average speed of the orbiting mass

$$E_k = \frac{1}{2}mv^2 \tag{4}$$

E_k = kinetic energy of object, m = mass of object, v = speed of object

$$c = \lambda f \tag{5}$$

c = speed of light, λ = wavelength of the light, f = frequency of the light

$$L = 2.4 \times 10^{-7} d \tag{6}$$

L = size (in meters) of smallest object a telescope could resolve, d = distance to the object we are trying to observe with our telescope (in meters)

$$I = \frac{L}{4\pi d_{Sun-asteroid}^2} \tag{7}$$

I = intensity of sunlight hitting the asteroid, L = luminosity of the Sun, $d_{Sun-asteroid}$ = distance between the Sun and the object we are observing

$$\sigma = \frac{4\pi d_{Earth-asteroid}^2 b}{IA} \tag{8}$$

σ = cross-sectional area of asteroid, $d_{Earth-asteroid}$ = distance between the Earth and asteroid, b = apparent brightness of the asteroid, I = intensity of sunlight hitting the asteroid, A = asteroid albedo

$$R = \sqrt{\frac{\sigma}{\pi}} \tag{9}$$

R = radius of the asteroid, σ = cross-sectional area of the asteroid

$$M_r = \frac{4\pi^2 r_{ave}^3}{GP^2} \tag{10}$$

M_r = mass inside orbit, r_{ave} = average radius of orbit, G = gravitational constant, P = orbital period

$$\rho = \frac{M}{V} \tag{11}$$

ρ = average density, M = mass, V = volume

$$D = 1.16L\left(\frac{v^2}{gL}\right)^{0.22} \tag{12}$$

D = diameter of crater created, L = diameter of asteroid, v = velocity of asteroid at impact, g = gravitational acceleration of Earth

$$r_{ave} = \sqrt[3]{P^2} \tag{13}$$

Kepler's 3^{rd} law: r_{ave} = average radius of orbit (in units of AU), P = orbital period (in units of years)

$$d_{E-a}^2 = d_{S-a}^2 + d_{S-E}^2 - 2d_{S-a}d_{S-E}cos(A) \tag{14}$$

d_{E-a} = distance between Earth and asteroid, d_{S-a} = distance between Sun and asteroid, d_{S-E} = distance between Sun and Earth, A = angle between d_{D-a} and d_{S-E}

$$p = \frac{\sigma}{a} \times 100\% \tag{15}$$

p = percent chance of impact, σ = planet's cross-sectional area, a = cross-sectional area of the region of uncertainty

$$F = ma \tag{16}$$

F = force, m = mass, a = acceleration

$$d = \frac{\beta m U}{M} t \tag{17}$$

d = distance that the asteroid is deflected by, β = force multiplication factor, m = mass of kinetic impactor, U = kinetic impactor speed at impact, M = mass of asteroid, t = time elapsed since impact deflection

$$d = (2.25 \times 10^{-9} \text{ m}^4/\text{s}/\text{J}) \frac{W}{D^3} t \tag{18}$$

d = distance that the asteroid is deflected by, W = energy released by nuclear explosion, D = diameter of asteroid, t = time elapsed since nuclear deflection

$$t = \sqrt{\frac{d}{a}} \tag{19}$$

t = time needed to increase/decrease orbit by distance d, d = distance that the asteroid orbit is increased/decreased by, a = acceleration of asteroid

$$E_{disrupt} = (1.7 \times 10^3 \text{ J/kg}) M \left(\frac{R}{1 \text{ m}}\right)^{-0.36} + (7.8 \times 10^{-2} \text{ J/kg}) M \left(\frac{R}{1 \text{ m}}\right)^{1.36} \tag{20}$$

$E_{disrupt}$ = energy needed to disrupt and disperse asteroid within 6 months, M = mass of asteroid, R = radius of asteroid

Constants and Quantities

Gravity constant:	$G = 6.674 \times 10^{-11} \text{ m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$
Astronomical unit:	$1 \text{ au} = 1.496 \times 10^{11} \text{ m}$
Mass of Earth:	$M_\oplus = 5.972 \times 10^{24} \text{ kg}$
Radius of Earth:	$R_E = 6,400 \text{ km}$
1 day	$= 86,400 \text{ s}$