

**Physics of Astronomy – Winter midterm –.Thus.2.Feb.2006**

This is a CLOSED-BOOK exam to be taken in class. You have two hours, so pace yourself. SHOW YOUR WORK, to receive full credit, and include units wherever appropriate. Please circle or underline your answers, on problems with considerable calculation.

(sign legibly) \_\_\_\_\_  
*I affirm that I have worked this exam with WITHOUT using a calculator, text, HW, quizzes, computer, classmates, or other resources.*

- Keep answers in exact form or make order-of-magnitude estimates
- Return your exam to Pat or Ruth in \_\_\_\_ Lab II by 2:30.
- Then head to the library for your 3:00 workshop in the Mac Lab.
- Feel free to discuss exam questions with classmates who have taken the exam, after you all have turned them in.

**Math-A students – take the Astro-A and Phys-A parts of this midterm.** (Parts I-III)  
B-parts are optional.

**Math-B students – take the whole midterm.** The A-parts should be quick and easy for you.

	<b>Possibly useless data:</b>		
$G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$	$g=9.8 \text{ m/s}^2$	parsec ~ 3 lightyears	
	Sun	Earth	Moon
Radius	$7 \times 10^5 \text{ km}$	$6.4 \times 10^3 \text{ km}$	$1.74 \times 10^3 \text{ km}$
Mass	$2 \times 10^{30} \text{ kg}$	$6 \times 10^{24} \text{ kg}$	$7.35 \times 10^{22} \text{ kg}$

Distance between centers of Sun & Earth =  $1.5 \times 10^8 \text{ km}$

Distance between centers of Earth & Moon =  $3.84 \times 10^5 \text{ km}$

*Please leave the space below blank:*

**(I) Astro-A. mostly qualitative**

**(II) Astro-A. quantitative (resolution):**  
**fundamentals**

**application**

**(III) Physics-A: kinematics**

**dynamics**

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**Physics-B: I.fundamentals (orbits)**

**II.application**

**(I) Astro-A:** Astronomy questions: *Most of these are taken directly from the online quizzes. You should be able to answer them easily. If not, move on to the next question.*

**What is a solar system?**

- A collection of two or a few suns (stars) orbiting around each other.
- A collection of a million to a hundred billion or more suns (stars) in a large system, often containing spiral arms; for example, our own Milky Way Galaxy.
- A collection of planets and other, smaller objects orbiting around a star (e.g., the Sun).

You are standing somewhere on Earth on a bright, sunny day when you notice that a tall, vertical telephone pole has no shadow. From that observation by itself, what do you know about **where you might be standing**?

- Exactly on the equator.
- Anywhere between the Tropic of Cancer and the Tropic of Capricorn.
- Exactly at the North or South Pole in midsummer (24-hour daylight).

**It is warmer in summer** than in winter because

- the Sun is lower in the sky and sunlight passes through a longer path in the atmosphere, thereby heating it more in summer.
- the Sun is higher in the sky and the days are longer.
- the Earth is closer to the Sun.

**The Earth is closest to the Sun**

- during winter in the southern hemisphere.
- during summer in the southern hemisphere.
- when the Sun is directly overhead at the equator.

**The Moon shows different phases** because

- it moves slowly in and out of the Earth's shadow in its orbital motion around the Earth.
- we view the sunlit hemisphere of the Moon from different angles as the Moon orbits the Earth.
- it rotates slowly to reveal more or less of its illuminated hemisphere while remaining relatively fixed against the celestial sphere of stars.

**The declination of the Sun** on the first day of spring is

- variable, depending on the year.
- $23.5^\circ$  north.
- $0^\circ$ .

Stars on the equator appear to move through a full 360 degrees in about 1 day because of the Earth's rotation. **How fast are they moving** in degrees per minute? (Show your work)

- 4 degrees per minute
- $1/4$  degree per minute
- 15 degrees per minute

The constellation Cygnus appears overhead to an observer in the state of New York, USA, at midnight on a particular night. **In which part of the sky will this constellation appear to an observer at the same latitude** in Montana, 30° farther west in longitude, if observed at precisely the same absolute time (Universal Coordinated Time, or UTC) (which will be 10 PM, Montana local time)?

- Overhead, of course.
- In the western sky.
- In the eastern sky.

**As the Moon orbits around the Earth**, its path on the celestial sphere

- is very close to the celestial equator.
- is very close to the path followed by the Sun (the ecliptic).
- is very close to a line of right ascension, passing close to each celestial pole once each orbit.

At what time in its monthly cycle **will the Moon be seen high in the sky in the daytime**, from midlatitudes?

- Only when it is full
- The Moon is never visible in the daytime.
- Quarter Moon

**When does the new Moon rise**, approximately?

- Close to sunrise
- At midnight
- At sunset

**Where in the sky will the full Moon appear at sunset**, in the northern hemisphere?

- Low in the eastern sky
- High in the southern sky
- Low in the western sky

**If you were an astronaut on the Moon**, in what position close to the Moon's equator would you have to stand in order to be in perpetual darkness?

- On the side of the Moon that faces away from the Earth.
- On the side of the Moon that faces away from the Sun.
- You cannot do this. There is nowhere near to the Moon's equator where you can be in perpetual darkness.

**Lunar eclipse:** Which of the following statements is true?

- A lunar eclipse occurs only at new Moon and can be seen from anywhere on the nighttime hemisphere of Earth.
- A lunar eclipse occurs only at full Moon phase and can be seen from anywhere on the nighttime hemisphere of Earth.
- A lunar eclipse occurs only at full Moon and can be seen from within a narrow strip on the Earth's surface.

**(II) Astro-A:** *quantitative question: Resolving Venus*

*Fundamentals:*

**Find the angle**  $\theta$  subtended by an object of diameter  $D$  at a distance  $d$ .

$$\theta =$$

Specify the units of  $\theta$ .

**Diagram** this relationship and **label** all quantities.

How many arcminutes are in one radian? (Show your work.)

*Application:* When Venus is a distance of 0.72 AU from Earth, **is it nearer than the Sun** or further? Find the distance in km.

The diameter of Venus is roughly  $12 \times 10^3$  km. **What angle does Venus subtend** at the distance in part (a)? Express your answer in arcmin.

A person with good vision can resolve details as small as 1 arcminute. **Could this person resolve the crescent of Venus** with naked eye? Explain.

**(III) Physics-A:** *Everyone should be able to answer this in about 10 minutes. (No tricky integrals on this one.)*

1. (a) What is the fundamental relationship between force  $F$  and acceleration  $a$ ? \_\_\_\_\_

(b) Do accelerations cause forces? Y N      Or do forces cause accelerations? Y N

2. Write down the **fundamental defining relationships** between position, velocity, and acceleration.

(a) **Differential** relationships:

$$v =$$

$$a =$$

(b) **Integral** relationships:

$$x =$$

$$v =$$

3. The force acting on some mass  $m$  is  $F = mg - b t^2 + ct^{1/2}$ , where  $b$  and  $c$  are constants. **Find the acceleration, velocity, and position** of this mass, assuming that it starts at the origin at rest.

**(IV) Astro B:** *These questions should be quick and easy. If not, move on to the next question.*

The **Ptolemaic model** successfully described and predicted the apparent motions of the planets, by assuming them to orbit the Earth, with the planets moving

- in circles around the Earth, the planes of which were precessing slowly around a direction perpendicular to the ecliptic plane.
- in ellipses, with their respective foci at the center of Earth.
- in small circles, the centers of which were moving around the Earth more slowly in larger circles.

**An object orbiting the Sun** with an orbital eccentricity of 0.1 has an orbit whose shape is

- a long, narrow ellipse.
- circular, but with the Sun off-center in the circle.
- slightly elliptical, but almost circular.

### Kepler's laws

- apply for all objects orbiting the Sun, such as planets, comets, asteroids and man-made space probes, but do not hold for objects orbiting any other object in the universe.
- apply only to large planets orbiting our Sun, but provide only an approximate description for smaller objects, such as asteroids, etc. and are not applicable at all for other situations such as mutually orbiting binary stars.
- can be shown to apply universally, whenever two objects orbit each other under gravitational attraction.

If there is a force of gravity from the Earth on an artificial satellite of mass 1000 kg, what is the size of the **force exerted on the Earth** by the satellite?

- Essentially zero because the satellite's mass is negligible compared to that of the Earth.
- Exactly the same as the force on the satellite.
- Much larger than that on the satellite because the Earth's mass is so large.

**A wheelbarrow** of mass  $M$  kg was transported **to the Moon** during an Apollo mission. Its weight on the Earth was  $W$ . Which of the following conditions is found to hold on the surface of the Moon?

- Mass and weight of the wheelbarrow are reduced by the same fraction, to  $1/6$  of their values on Earth.
- The mass of the wheelbarrow remains the same while weight is found to be zero because the wheelbarrow is at a large distance from the center of the Earth.
- The mass of the wheelbarrow remains the same, but its weight on the Moon is less.

According to Kepler's third law, an **asteroid orbiting the Sun** in a circular orbit **at twice the Earth's distance** from the Sun would have a sidereal period of (show your work)

- 4.0 years.
- 2.8 years.
- 8.0 years.

**(V) Physics B** - *This is optional for A-group students.*

**Fundamentals:** Consider a small mass ( $m$ ) orbiting a big mass ( $M$ ) with a circular orbit of radius  $R$  and period  $T$ .

- (a) What is the orbital speed  $v$  in terms of  $R$  and  $T$ ?
- (b) What is the centripetal acceleration  $a$ ?
- (c) What is the force responsible for this acceleration?
- (d) Put these together to find a relationship between **speed  $v$  and radius  $R$**  (in terms of  $M$  and fundamental constants), starting from  $F=ma$ .
- (e) **SKETCH** the speed  $v$  versus the period  $R$
- (f) Briefly describe what this means, in words.

**(VI) Physics B – Application:**

The Sun orbits with a speed about 250 km/sec at distance of about 9 kpc from the center of our Milky Way galaxy.

(a) Use these data to calculate how much mass ( $M_1$ ) is inside Earth's orbit. Express your answer in terms of the Sun's mass:  $M_1/M_{\text{sun}} =$

Surprisingly, stars near the dim edge of the Milky Way galaxy (say at 15 kpc) orbit the galaxy's center at the same speed.

(b) Why is this surprising?

(c) How much mass ( $M_2$ ) is inside the distant star's orbit? Express this in terms of the Sun's mass:  $M_2/M_{\text{sun}} =$

(d) What percent of the Milky Way's mass lies between 9 and 15 kpc from its center, if 15 kpc is the outer edge of the galaxy?

(e) SKETCH the  $v$  versus  $R$  curve for stars in our Galaxy (based on these two data points).

(f) Compare this to the velocity curve in Part (V) above. What does this mean, conceptually?