Physics 151
Due: Friday, March 23, 2007

Roster No.:________________________

Score:___________________________

Take-Home Midterm Exam #2, Part A

NO exam time limit. Calculator required. All books and notes are allowed, and you may obtain help from others. Complete all of Part A ***AND*** Part B.

You do NOT need to show your work for fill-in-the-blank and multiple-choice questions. For multiple-choice questions, circle the letter of the one best answer (unless more than one answer is asked for). For all fill-in-the-blank answers, be sure to provide **proper units** and **significant figures**!

Show your work on all free-response questions. Be sure to use **proper units** and **significant figures** in your final answers.

Ignore friction and air resistance in all problems, unless told otherwise.

Physical constants: It's an open-book test, so you can look them up in your textbook!
Useful conversions: It's an open-book test, so you can look them up in your textbook!

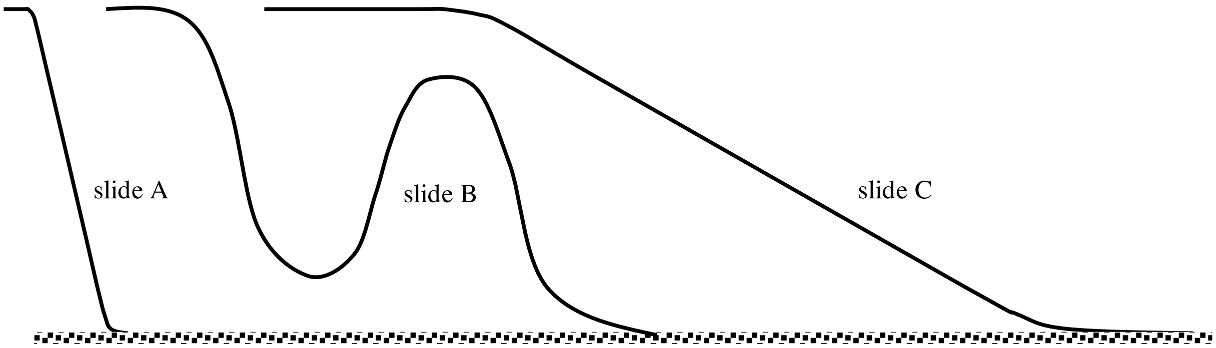
1. (4 pts.) **Convert** the following quantities into the given units. Fill in the blanks. (You do NOT need to show your work.) Use *scientific notation* where appropriate (very large or very small values). Express all final values to *THREE significant figures*.

a. 433 MHz = _______________________ GHz

b. 3.00×10^{10} cm/s = _________________ AU/min (1 AU = average Earth–Sun distance = 1.50×10^{8} km)

c. 7850 rpm = _______________________ rad/ms ("rpm" = rev/min)

d. 875 MJ = _________________________ kW·h ("h" = hour)

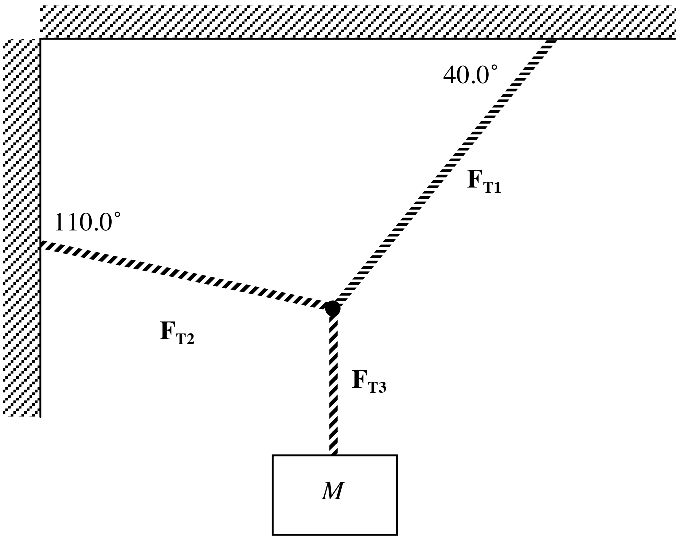


2. In a particular park, children can choose from three different *FRICTIONLESS* slides, as shown above. All three start and end at the same vertical positions. Assume that *all* children start from *rest* at the top of any slide.

a. (1 pt.) If a heavy child and a lightweight child both descend the *same* slide, which one will be **TRUE**?
A. The heavier child will reach the bottom with greater speed and shorter time.
B. The heavier child will reach the bottom with greater speed, but equal time.
C. The heavier child will reach the bottom with equal speed, but shorter time.
D. The heavier child will reach the bottom with equal speed and equal time as the lightweight child.

b. (1 pt.) If the *same* child descends each slide in turn, which slide will give her the **greatest final speed**?
A. slide *A* B. all slides are equal C. slide *C* D. not enough information given

c. (1 pt.) If the *same* child descends each slide in turn, which slide will give her the **fastest time of descent**?
A. slide *A* B. all slides are equal C. slide *C* D. not enough information given

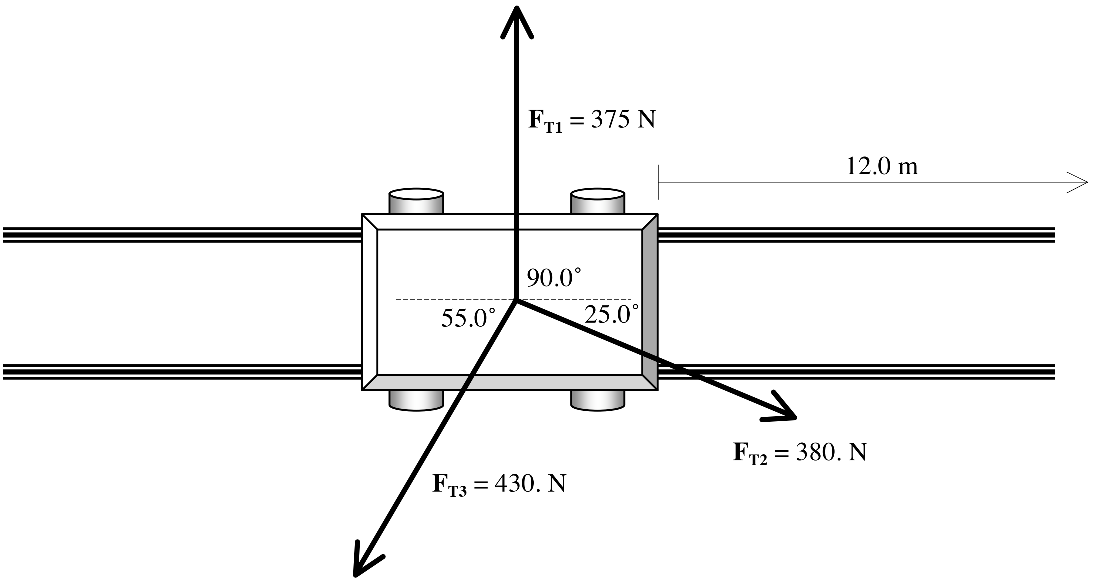


3. (5 pts.) The mass M = 125 kg hangs *at rest* as shown above, suspended by three massless cables. The cables are joined at the center, and cable #3 hangs straight down.

a. What is the magnitude of **tension F_{T1}**? ____________________

b. What is the magnitude of **tension F_{T2}**? ____________________

c. What is the magnitude of **tension F_{T3}**? ____________________



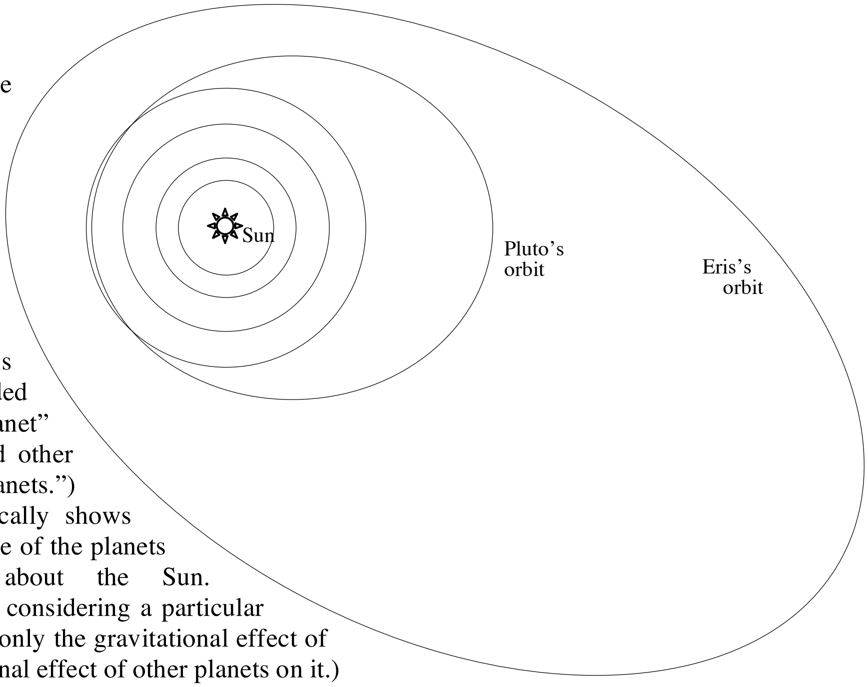
4. (6 pts.) A heavy rail car (m = 1500 kg) rolls on the ground on rails, and is constrained so that it can only move to the right or left, as shown in the top-view above. Three people supply constant forces by pulling on cables attached to the car's center. (Assume that the three forces do NOT change magnitude or direction as the car moves.) The car *starts from rest*, and there is *no friction*. When the car has moved 12.0 m to the right, what is…

a. the **work** done on the car by F_{T1}? ____________________

b. the **work** done on the car by F_{T2}? ____________________

c. the **work** done on the car by F_{T3}? ____________________

d. the **final speed** of the car? ____________________



5. Mid-2005 saw the announcement of the discovery of a so-called "10th planet," now officially named Eris (but at the time nicknamed "Xena"). Eris was measured to be slightly larger in physical size than Pluto, so this led to a debate in 2006 about what should qualify as a "planet." (As you probably know, it was decided to demote Pluto from its "planet" status, and now Pluto, Eris, and other small bodies are called "dwarf planets.")

This diagram schematically shows the orbits of Eris, Pluto, and some of the planets (Jupiter through Neptune) about the Sun. (Throughout this problem, when considering a particular planet's orbit, you may consider only the gravitational effect of the Sun, and ignore the gravitational effect of other planets on it.)

a. (1 pt.) What is the **name** of the mathematical curve that describes the shape of Eris's orbit?

____

b. (1 pt.) **Label** the points on Eris's orbit (above) where its linear speed along its orbit is at its **fastest** and its **slowest**.

c. (1 pt.) Based on the diagram, **which** of these two bodies has the **greater average linear speed** along its orbit?
A. Pluto B. Eris

d. (1 pt.) Based on the diagram, **which** of these two bodies has the **longer orbital period**?
A. Pluto B. Eris

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e. (2 pts.) Eris has a physical radius of 1200 km and a mass of 1.6×10^{22} kg. If you were to visit the surface of

Eris, how many **gees** of **surface gravity** would you experience? ____________________ **gees**

(*Recall:* 1 gee = 9.80 m/s^2.)

We can only use the equation $U_{gr} = mgy$ to calculate *gravitational potential energy* of a small body m that is in a region of *uniform* gravitational acceleration g (such as near the surface of the Earth). However, for astronomical situations like this one, the value of g is NOT uniform throughout space. So, to find U_{gr} for a body like Eris relative to the Sun, we must use the more general equation instead:

$$U_{gr} = -\frac{Gm_1 m_2}{r}$$

where $m_1 = M_{Sun}$, $m_2 = m_{Eris}$, and r is the distance between their centers. (Note the minus sign! Also, $U_{gr} = 0$ when $r = \infty$.)

f. (2 pts.) At Eris's farthest distance from the Sun, $r = 97.6$ AU, it has a linear speed of 2.57 km/s. (1 AU = average Earth–Sun distance = 1.50×10^8 km.) Eris experiences no friction in orbit. Use *conservation of energy* to determine

Eris's **linear speed** (in **km/s**) when it is at its **closest approach** to the Sun, 37.8 AU: ____________________**km/s**

Note: Does your answer here agree with your answer to part (b) above?

Physics 151
Spring 2007

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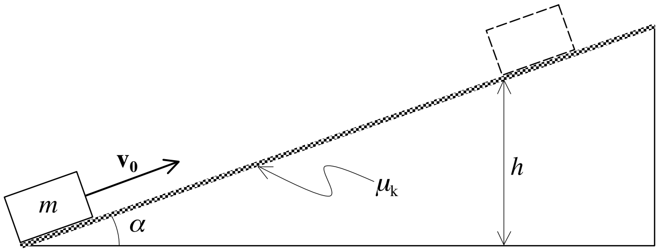
Take-Home Midterm Exam #2, Part B



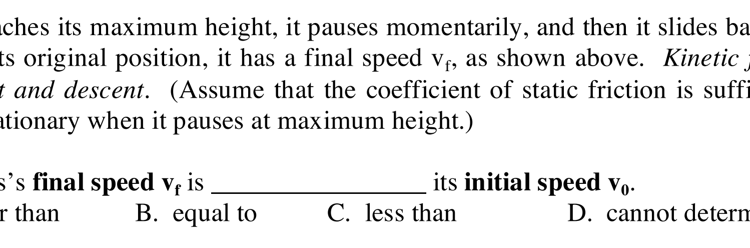
1. A mass m is launched with an initial speed v_0 up an incline with a coefficient of kinetic friction μ_k.

a. (3 pts.) Find an algebraic expression for the **maximum height *h*** reached by the mass when there is ***NO friction*** ($\mu_k = 0$). *SIMPLIFY* your final answer algebraically, and express it ***ONLY*** in terms of m, v_0, g, α, and any numerical constants. You may use whatever method you wish, but you must show your work.

b. (6 pts.) Now, find a *new* algebraic expression for the **maximum height *h*** reached by the mass when there *IS* ***kinetic friction*** present. *SIMPLIFY* your final answer algebraically, and express it ***ONLY*** in terms of μ_k, m, v_0, g, α, and any numerical constants. You may use whatever method you wish, but you must show your work.

1. continued:

c. (1 pt.) Show that, as $\mu_k \rightarrow 0$, your answer to part (b) simplifies to the same expression as your answer to part (a).



When the mass reaches its maximum height, it pauses momentarily, and then it slides back down the incline. When the mass reaches its original position, it has a final speed v_f, as shown above. *Kinetic friction* μ_k *acts on the mass during both ascent and descent*. (Assume that the coefficient of static friction is sufficiently small that the mass does not remain stationary when it pauses at maximum height.)

d. (1 pt.) The mass's **final speed** $\mathbf{v_f}$ is ________________ its **initial speed** $\mathbf{v_0}$.

A. greater than B. equal to C. less than D. cannot determine with information given

e. (1 pt.) The mass's **time of ascent** is ________________ its **time of descent**.

A. greater than B. equal to C. less than D. cannot determine with information given

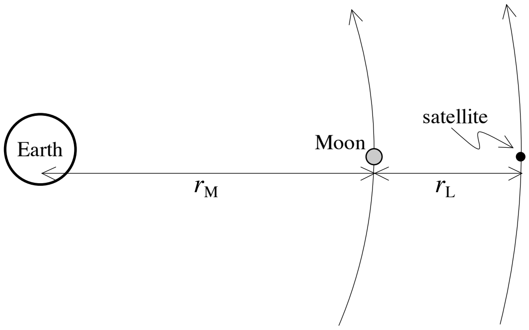
2. A small satellite (m = 100. kg) orbits the Earth at a distance greater than our Moon. Assume that both the Moon and the satellite have exactly circular orbits.

When all three bodies are in a straight line, as shown at right, the distances between the centers of Earth, Moon, and satellite are:

r_{M} = 384,000 km

r_{L} = 61,500 km

Masses of the Earth and Moon can be found inside the rear cover of your textbook.



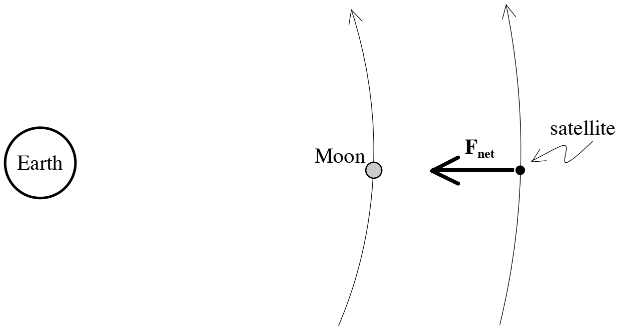
a. (4 pts.) *If the Moon exerted NO gravitational pull on the satellite* (i.e., *only the Earth* pulls gravitationally on the satellite), calculate what the **orbital period** of the **satellite** would be, in **days**. Show your work. Express your final answer to *3 significant figures*.

b. (5 pts.) *If BOTH the Moon AND Earth exert gravitational forces on the satellite*, calculate the magnitude of the **net (total) gravitational force** on the satellite, at the moment shown in the diagram above. Show your work.

2. continued:

c. (3 pts.) If the net gravitational force on the satellite calculated in part (b) is the *actual* centripetal force acting on the satellite, calculate the satellite's *actual* **period** (in **days**) of its uniform circular motion about the Earth.

(Assume that the Earth, Moon, and satellite remain aligned as they orbit, so that the magnitude of the centripetal force on the satellite remains constant.) Show your work. Express your final answer to *3 significant figures*.



Note: Your answer to part (c), for the satellite's orbital period, should be quite close (to within ±1 day) of the Moon's own orbital period!

This special location in space is called the "L2" Lagrangian Point; there are a total of five such points in space around the Earth–Moon system where a satellite can be placed so that it orbits around the Earth with approximately the same period as the Moon does. There are many advantages to placing a satellite at the L2 point; for example, it would be especially useful for telecommunications to the far side of the Moon someday.