Physics 151 Roster No.:__________________________

**Due: Wednesday, March 19, 2008**

**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 or 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. Use *scientific notation* where appropriate (very large or very small values). Express all final values to *THREE significant figures*.

**a.** 9.80 $m/s^2$ = _________________________ (km/h)/s or km/(h·s) ("h" = hour)

**b.** 45.0 $lb/in^2$ = _________________________ $N/cm^2$ ("lb" = pound; "in" = inch)

**c.** 60.0 Hz = _________________________ rpm ("rpm" = rev/min)

**d.** 1.00 $ft^3$ = _________________________ $mm^3$ ("ft" = foot)

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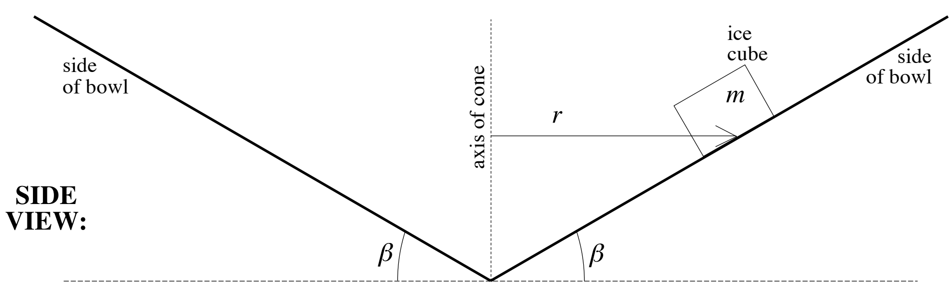
**2.** An ice cube (mass $m$) can slide *frictionlessly* on the inside of a cone-shaped bowl, whose sides make an angle β with respect to the horizontal, as shown at right:




Suppose that the ice cube is *released from rest* at the position shown above.

**a.** (1 pt.) **Draw a vector** on the ice cube in the diagram above to show the **direction of the net (total) force** acting on the ice cube.

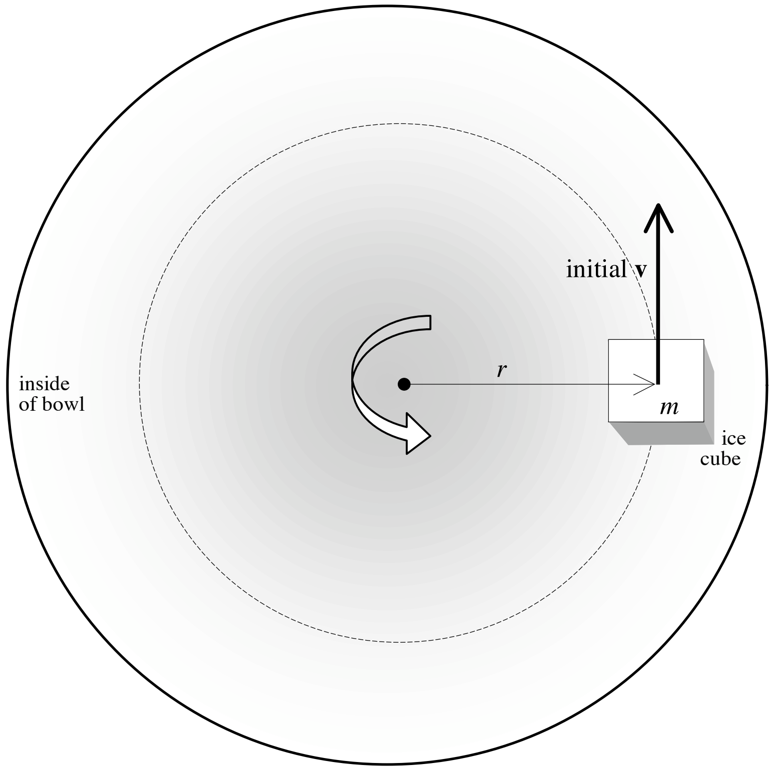
**Express your next two answers ONLY in terms of $m$, $g$, $\beta$, and $r$**, and numerical constants:

**b.** (2 pts.) Find the magnitude of the **net force** acting on the ice cube: __________________

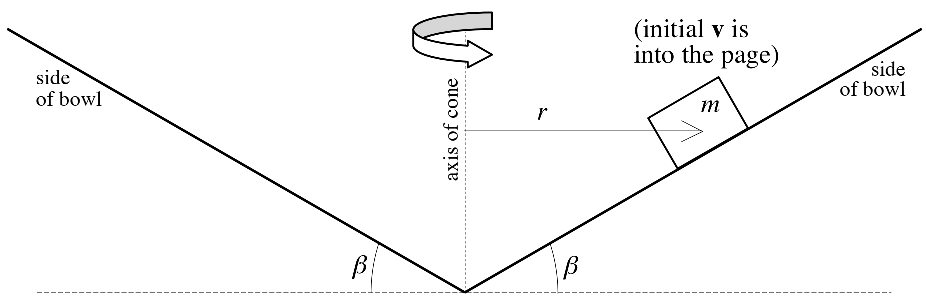
**c.** (2 pts.) Find the **speed** of the ice cube just before it reaches the bottom of the bowl: __________________
(Assume that the ice cube is much smaller than shown in the sketch above.)

***2. continued:***

**TOP VIEW:**




**SIDE VIEW:**




In a different scenario, you release the ice cube with *just* the right initial tangential velocity **v** (as shown above), so that the cube slides frictionlessly around the bowl in a perfect circle of radius $r$.

**d.** (2 pts.) **Draw a vector** showing the **direction of the net force** on the ice cube in **EACH** of the two diagrams above.

**Express your next two answers ONLY in terms of $m$, $g$, $\beta$, and $r$** (but NOT v!), and numerical constants:

**e.** (3 pts.) While the ice cube continues to follow a circular path around the bowl, the magnitude of the *net force* on the ice cube can be shown to equal $mg\tan\beta$. Find an expression for the **period *T*** of the ice cube:

______________________

**f.** (1 pt.) What is the **net (total) work** done by all forces on the ice cube as it completes one circle?

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**3.** During 2007 & 2008, the Cassini spacecraft has been exploring Saturn and its very large moon, Titan. Suppose that one day, in the distant future, astronauts can visit Titan and live in a base-station on its surface, where the surface gravity is 1.35 $m/s^2$.

**a.** (2 pts.) Suppose that fly-by photographs show that the radius of Titan is 2680 km (not actually true, but pretend for the purposes of this problem). Calculate Titan's **mass**: ____________________ **kg**

**b.** (2 pts.) When an astronaut drops a 1.25-kg hammer from rest, and lets it fall through a distance of 2.00 meters in her room on Titan, how much **gravitational potential energy** does it lose?

____________________

**c.** (2 pts.) The hammer's **final speed** on Titan is ____________________ times its speed when it falls from rest through the same distance on Earth. (Ignore air resistance.)

A heavy crate (245 kg) sits at rest on a level platform, with a coefficient of static friction $\mu_s = 0.95$.

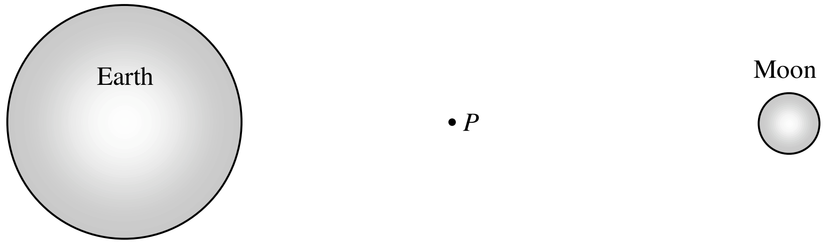
**d.** (1 pt.) The **horizontal force** strength needed to dislodge the crate (to start it moving) on Titan is

__________________ times the force required to do so on Earth.

**e.** (1 pt.) Instead, if one end of the platform is slowly raised, the crate will eventually break free of the static friction at an incline angle $\alpha$. The value of $\alpha$ on Titan is __________________ its value on Earth.

A. smaller than B. the same as C. larger than

*Note:* This diagram is *NOT* drawn to scale.




**4.** Imagine that the Earth and Moon were both *released from rest* and allowed to fall toward each other gravitationally. Let their initial separation be the same as the Moon's average orbital distance. (The masses of the Earth and Moon, and the Earth–Moon orbital distance, can be found inside the back of your textbook. Assume that there are no *other* masses in the universe.) Give your numerical answers to *3 significant figures:*

**a.** (2 pts.) Immediately after release, what is the magnitude of the **Earth's acceleration**, in MKS units?

____________________

**b.** (2 pts.) Immediately after release, what is the magnitude of the **Moon's acceleration**, in MKS units?

____________________

**c.** (2 pts.) As the Earth and Moon fall toward each other, which of the following values will remain **constant** for either body? ***Circle ALL that apply:***

A. speed
B. direction of velocity
C. magnitude of acceleration
D. direction of acceleration
E. magnitude of net force
F. direction of net force
G. none of the above

**d.** (1 pt.) Point *P* is located *exactly halfway* between the centers of the Earth and Moon at the moment they are released. When the Earth and Moon finally do **collide**, it will be **at a point located**…

A. to the left of *P*
B. exactly at *P*
C. to the right of *P*

Physics 151
Spring 2008

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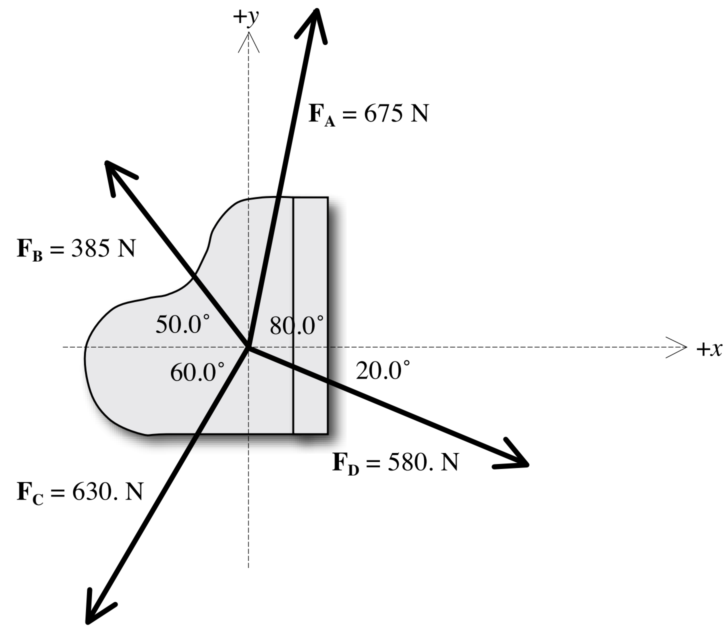
# Take-Home Midterm Exam #2, Part B

**TOP VIEW:**




**1.** A grand piano ($m$ = 350. kg) starts at rest on a wheeled dolly that allows it to move frictionlessly in any direction on level ground. Four people push on the piano with the four constant forces shown above. (Assume that the four forces do NOT change in magnitude or direction as the piano moves.) The $+x$ and $+y$-directions are given. *Show your work completely.*

**a.** (5 pts.) What is the **net force** on the piano (**magnitude & direction**)?
**b.** (3 pts.) What is the **acceleration** of the piano? (**magnitude & direction**)?

***1. continued:***

**c.** (2 pts.) At the moment that the piano's speed reaches 2.50 m/s, what is the **net (total) work** that has been done on the piano by all forces? *Show your work*.

**2.** Astronomical observations of the center of our Milky Way Galaxy starting in the 1990s revealed a number of stars orbiting quickly around a huge, invisible object. This "dark" object is now believed to be a supermassive black hole, and a similar object is thought to lurk at the center of most large galaxies. ("Black holes" have mass just like any regular object, and they exert gravitational force just as any other mass would. For this problem, you can assume that (1) the mass of the black hole is *much* greater than the masses of the individual stars; (2) all orbits are circular, and (3) the gravitational effect of individual stars on each other is negligible.)

**a.** (4 pts.) If Star *A* orbits the black hole at a distance of $2.0 \times 10^{14}$ m once every 24 years, find the **mass of the black hole**. *Show your work completely.*

**b.** (3 pts.) If Star *B* is discovered orbiting the same black hole once every 12 years, find the **orbital distance of Star *B***. *Show your work completely.*

***2. continued:***

**c.** (3 pts.) What is the **linear speed** of Star *A* along its orbit (assuming that it is circular)? Convert your final answer to **[km/s]**. *Show your work completely*.

(Just for comparison, our own Sun's linear speed around the center of our Galaxy is 220 km/s; you should find that Star *A* is moving somewhat faster.)