Exam 1

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Name

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TA/ Section #

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Recitation Time

May 23, 2007, 8:00am

You have 1 hour to complete the exam. Please answer all questions clearly and completely, and that you clearly indicate your final answer to each problem (put a box around the final answer, for example). Make sure that you show all of your work. If your exam sheets do not have enough room for you to write on, please ask for more paper.

You may use a calculator, and, of course, reference the formula sheet, attached. Beyond that, the exam is entirely closed book.

Formula Sheet

(You may tear these pages out) Physical Constants

$$G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$$
$$g = 9.8 m/s^2 \simeq 10 m/s^2$$
$$c = 3 \times 10^8 m/s$$

Some useful math relations

$$\sin\theta \simeq \theta \quad \textit{small angle}$$
$$\cos\theta \simeq 1 - \theta^2/2 \quad \textit{small angle}$$
$$\frac{dC}{dt} = 0$$
$$\frac{d(t^n)}{dt} = nt^{n-1}$$
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \textit{Quadratic Formula}$$

Projectile Relations

$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i$$
$$\vec{r} = x\hat{i} + y\hat{j}$$
$$\vec{v} = \frac{d\vec{r}}{dt}$$
$$\vec{a} = \frac{d\vec{v}}{dt}$$
$$\vec{r}(t) = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$
$$\vec{v}(t) = \vec{v}_i + \vec{a}t$$

Circular Motion

$$a_c = \frac{v^2}{r}$$
$$a_t = \frac{dv}{dt} \quad \textit{tangential acceleration}$$

Newton's Laws

$$\vec{F} = m\vec{a}$$
$$\sum \vec{F} = 0 \quad \textit{equilibrium}$$

Some Specific Forces

$$\begin{aligned} \vec{F}_g &= -mg\hat{j} \\ F_s &= -kx \\ F_G &= -\frac{GMm}{r^2} \end{aligned}$$

Friction

$$\begin{aligned} F_r &= \mu F_N \\ R &= \frac{1}{2}D\rho A v^2 \\ F_{vis} &= -bv \end{aligned}$$

Work/Kinetic Energy

$$\begin{aligned} W &= \vec{F} \cdot \vec{\Delta r} \\ &= \int_{x_1}^{x_2} F_x dx \quad (1-d) \\ K &= \frac{1}{2}mv^2 \\ W &= \Delta K \\ P &= \frac{dW}{dt} \\ E_{mech} &= K + U \end{aligned}$$

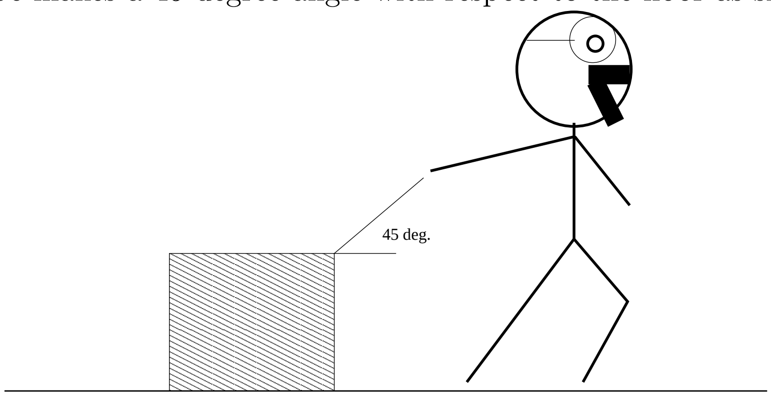
Potential Energy

$$\begin{aligned} \Delta U &\equiv -W_{int} \\ \frac{dU}{dx} &= -F_x \\ U_g &= mgy \\ U_s &= \frac{1}{2}kx^2 \\ U_G &= -\frac{GMm}{r} \end{aligned}$$

1. [35 *points*] A bit about forces.

   (a) In ranked order of strength, please list the 4 fundamental forces.

   (b) Now, consider a case in which I am trying to pull a crate along a rough surface. The coefficient of static friction between the crate and the floor is $\mu_S = 0.5$, and the coefficient of kinetic friction is $\mu_s = 0.2$. The crate has a mass of 20kg, and the rope makes a 45 degree angle with respect to the floor as shown:



   Please draw a free-body diagram for the system. Wherever possible break the forces into an x- and y- components of forces.

   (c) How much force do I need to pull with in order overcome static friction?

   (d) Once the crate starts moving, what is the force of kinetic friction?

   (e) After the crate starts moving, what acceleration does it have?

2. [30 *points*] A 0.1 kg spherical stone is dropped from a great height. It has an area of $3 \times 10^{-4} m^2$. At first, you are to ignore air resistance.

   (a) Assuming the stone falls from rest (and remember, no air resistance!), how far does it fall in the first 5 sec.?

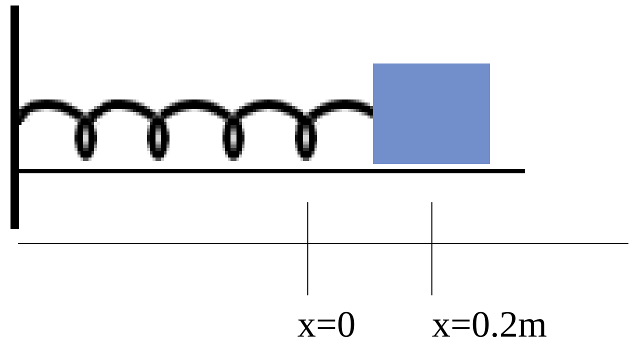
   (b) How much work does gravity during after it has fallen the amount given in part (a)?

   (c) What is the kinetic energy after the stone has fallen the amount given by part (a)?

   (d) How fast will the stone be traveling at that time?

   (e) Now add air resistance. You may set the parameter, $D = 0.5$, and note that the density of air is approximately $1.29 kg/m^3$. When the stone is falling at a speed of 10 m/s, how much air resistance is on it?

3. [35 *points*] Consider a 2kg mass on a spring with spring constant 40N/m as shown. There is no friction anywhere in this system.



(a) The mass oscillates back and forth. Sketch a diagram showing the potential energy of the mass on the spring as a function of position (U(x)).

(b) Are there any positions where the mass can be in equilibrium? At what value(s) of x? Are the equilibria stable or unstable?

(c) The mass is released from rest when the spring is extended 0.2m (as shown). What is the mechanical energy of the spring at that time?

(d) What is the kinetic energy of the mass as it passes through the origin?

(e) Imagine that instead of the spring potential which you used in part (a), there was a system with a potential

$$U(x) = Ax$$

What would the force given by that potential be?

(f) **E.C.** What is the mass-energy of the mass on a spring?