Massachusetts Institute of Technology - Physics Department

Physics - 8.01

Assignment #4

October 6, 1999.

It is strongly recommended *that you read about a subject* ***before*** *it is covered in lectures.*

Lecture Date	Material Covered	Reading
#13 Fri 10/8	Potential Energy - watch ***PIVoT***	Page 184 – 194
	Energy Considerations to derive SHM - watch ***PIVoT***	Page 387 – 389
#14 Wed 10/13	Escape Velocities - Bound and Unbound Orbits - ***PIVoT***	Page 211 – 228
	Circular Orbits (elliptical orbits will be discussed later in the course). Various Forms of Energy - Power	Page 194 – 201
#15 Fri 10/15	Momentum - Conservation of Momentum - watch ***PIVoT***	Page 113 – 114
	Center of Mass - watch ***PIVoT***	Page 245 – 261

Due Friday, Oct 15, before 4 PM in 4-339B. Solutions will be posted on the Web Sat, Oct 16.

4.1 *Air drag on very small drops.* Watch ***PIVoT*** under *resistive force.*
We release an oil drop of radius r in air. The density of the oil is 700 kg/m^3. C_1 and C_2 for 1 atmosphere air at 20° C are 3.1×10^{-4} (kg/m)/sec and 0.85kg/m^3, respectively. How small should the oil drop be so that the drag force is dominated by the linear term in the speed (in lectures we called this *Regime I*). In this regime, the terminal velocity is $mg/C_1 r$. [m is the mass of the drop].

4.2 *Drag force at very low speeds.* Watch ***PIVoT*** under *resistive force.*
At low speeds (especially in liquids rather than gases), the drag force is proportional to the speed rather than its square, i.e., $F = -C_1 rv$, where C_1 is a constant. At time $t = 0$, a small ball of mass m is projected into a liquid so that it initially has a horizontal velocity of $\boldsymbol{u}$ in the $+x$ direction. The initial speed in the vertical direction (y) is zero. The gravitational acceleration is g.

a) Write down the differential equations of motion in the x and y direction.

b) What is the horizontal component of the ball's velocity at time t?

c) What is the vertical component of the ball's velocity at time t?

d) After how many seconds is the vertical speed 99% of its maximum value? What would that be for the 1/4 inch steel ball bearing that we dropped in Karo Corn Syrup in lectures?

e) Answer the questions under b) and c) for the limiting case that t becomes infinitely large.

4.3 *SHO* – page 405, problem 1. Watch ***PIVoT*** under *simple harmonic motion.*

4.4 *SHO* – page 405, problem 4. Watch ***PIVoT*** under *simple harmonic motion.*

4.5 *Oscillating Spring.* Watch ***PIVoT*** under *simple harmonic motion.*
A 3 kg mass is attached to a spring. The period of oscillation is 0.4 sec. At $t = 0$, the mass has a speed of 3 m/sec towards equilibrium, and its displacement from equilibrium is 0.1 m.

a) Calculate the position of the mass for all time $t > 0$.

b) When will the mass first go through equilibrium; what then will be its speed, acceleration, kinetic energy, and potential energy?

c) When will the mass first reach a turning point; what then will be its speed, acceleration, kinetic energy, and potential energy?

4.6 *Vertical Spring* – page 406, problem 11.

4.7 *SHO - Tunnel through the Earth* – page 410, problem 43. I did this problem on ***PIVoT***.

4.8 *Pendulum.* Watch ***PIVoT***.
At the end of a string of length 2 m hangs a bob with a mass of 3 kg. The bob is released from rest with the string at 30° to the vertical [$g = 10$ m/sec^2].

a) How fast is the bob moving at the bottom of the swing?

b) What is its kinetic energy at the instant when the string makes an angle of 10° to the vertical?

c) How would your answers under a) and b) change if the mass of the bob were 6 kg?

4.9 *Work* – page 178, problem 8.

4.10 *Pushing a Box* – page 178, problem 10.

4.11 *Roller Coaster* – page 182, problem 52. Watch ***PIVoT*** under *roller coaster.*

4.12 *Horizontal spring with friction.* Watch ***PIVoT*** under *friction (Spring on Table with Friction).*
A 3.0 kg block rests on a leveled table. The coefficients of friction between the block and the table are $\mu_s = 0.30$ and $\mu_k = 0.20$. The block is attached to a wall by means of a horizontal spring of spring constant $k = 80$ N/m. We pull on the block and stretch to spring and then let go with the block initially at rest. Use $g = 10$ m/sec^2.

a) What is the maximum extension of the spring for which the block will remain stationary when released?

b) The block is placed in this position and then given a very gentle push towards the wall. At what position will the block reach its maximum speed?

4.13 *Pendulum in action.* I did this problem on ***PIVoT*** under *pendulum.*
A pendulum consists of a "massless" string of length l and a bob of mass m. We release the bob (without speed) when the string is at an angle θ_0 with respect to the vertical. A pin is located a distance L below the top of the string. When the pendulum swings down, the string hits the pin.

a) What is the maximum angle α that the string below the pin makes with the vertical after hitting the pin?

b) If the bob had been released with an initial tangential velocity v_0, what would then be the maximum angle α. Does the direction of this tangential velocity matter?

4.14 *Drop suitcase on conveyor belt.*

a) A stationary suitcase is placed on a moving conveyor belt. Is the friction static or kinetic?

b) The belt is moving to the right. Thus, relative to the belt, the suitcase is moving to the left, thus there is a force on the suitcase to the right. The suitcase accelerates to the right until it reaches the speed of the belt. Is the work that friction does on the suitcase positive, negative, or zero?

c) After the suitcase reaches the speed of the belt, what is the horizontal component of the force acting on the suitcase?

Reminder.
There are 25 recitation sections. If you want to change, for whatever reason, please go to the physics education office (4-352).