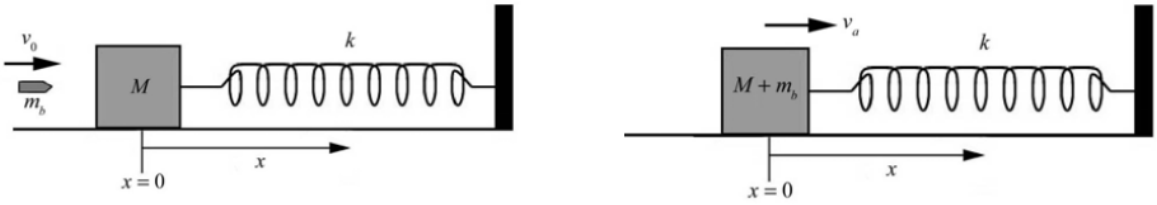
Tutorial Sheet - 4

FIRST SEMISTER 2014
PHYSICS-101

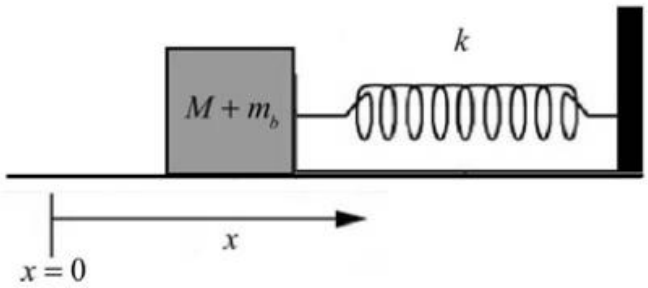
Date: 02.09.2014 Tut. Sheet **04**

1. An instrument-carrying projectile accidentally explodes at the top of its trajectory. The horizontal distance between the launch point and the point of explosion is L. The projectile breaks into two pieces which fly apart horizontally. The larger piece has three times the mass of the smaller piece. To the surprise of the scientist in charge, the smaller piece returns to earth at the launching station. How far away does the larger piece land? Neglect air resistance and effects due to the earth's curvature.

2. A massless spring with spring constant *k* is attached at one end of a block of mass *M* that is resting on a frictionless horizontal table. The other end of the spring is fixed to a wall. A bullet of mass m_b is fired into the block from the left with a speed v_0 and comes to rest in the block. (Assume that this happens instantaneously). How fast is the block moving immediately after the bullet comes to rest?



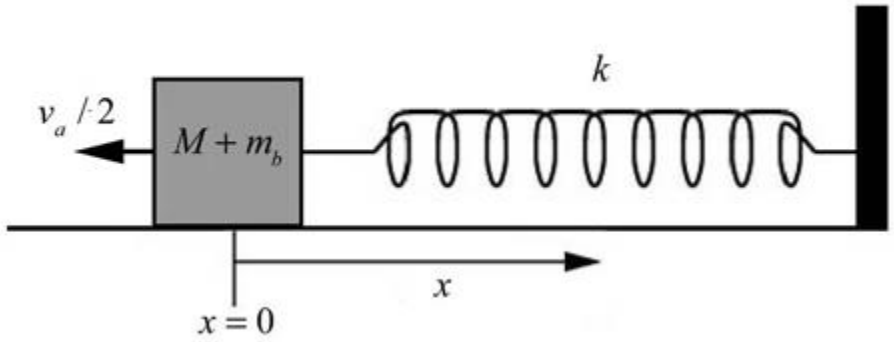
The resulting motion of the block and bullet is simple harmonic motion



a) Find the amplitude of the resulting simple harmonic motion.
b) How long does it take the block to first return to the position x = 0?

c) What fraction of the original kinetic energy of the bullet is stored in the harmonic oscillator?

d) Now suppose that instead of sliding on a frictionless table during the resulting motion, the block is acted on by the spring and a weak friction force of constant magnitude *f*. Suppose that when the block first returned to the position x = 0, the speed of the block was found to be one half the speed immediately after the collision that you found in part (a). How far did the block travel? (Your answer may include the symbol v_a, the speed of the block immediately after the bullet comes to rest, whether or not you have answered part (a) correctly.)



3. A rocket ascends from rest in a uniform gravitational field (with acceleration of gravity g) by ejecting exhaust with a constant speed *u*. Assume that the rate at which mass is expelled is given by $dm/dt = \Upsilon m$, where *m* is the instantaneous mass of the rocket and Υ is a positive constant. In addition, the rocket is retarded by air resistance with a force *mbv*, where *b* is another positive constant. Find the velocity of the rocket as a function of time.

4. The compressive force per area necessary to break the tibia in the lower leg is about $F/A = 1.6\times10^{-8} N.m^{-2}$. The smallest cross sectional area of the tibia, about 3.2 cm^2, is slightly above the ankle. Suppose a person of mass *m* = 60 kg jumps to the ground from a height h_0 = 2.0 m and absorbs the shock of hitting the ground by bending the knees.

Assume that there is constant deceleration during the collision. During the collision, the person lowers his center of mass by an amount Δd = 1.0 cm .

a) What is the collision time $\Delta tcol$?

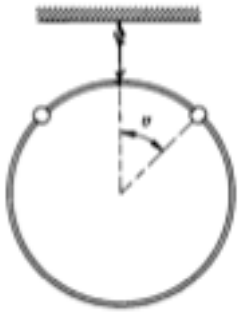
b) Find the average force of the ground on the person during the collision.

c) What is the ratio of average force of the ground on the person to the gravitational force on the person? Can we effectively ignore the gravitational force during the collision?

d) Will the person break his ankle?

5. A rain drop falling vertically down accumulates moisture due to which its radius increases at a constant rate K. Assuming that the moisture being accumulated is stationary in the atmosphere and neglecting air drag, calculate the speed of the rain drop after it has fallen for a time t. The drop starts with an initial radius r_0 with zero speed.

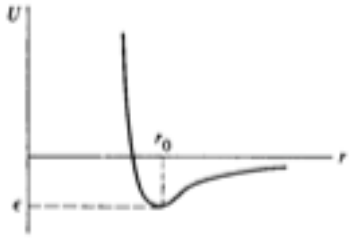
6. A ring of mass M hangs from a thread, and two beads of mass m slide on it without friction as shown below. The beads are released simultaneously from the top of the ring and slide down opposite sides. Show that the ring will start to rise if $m > \frac{3M}{2}$, and find the angle at which this occurs.



7. A commonly used potential energy function to describe the interaction between two atoms is the Lennard-Jones 6,12 potential

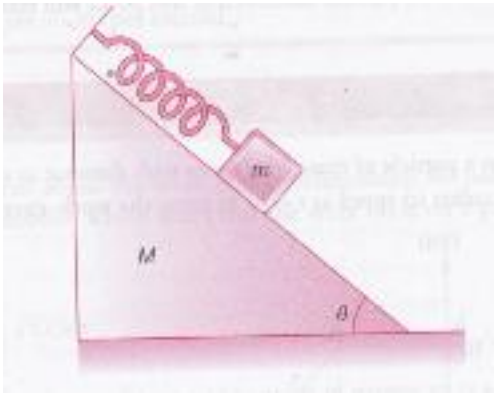
$$U = \varepsilon\left[\left(\frac{r_0}{r}\right)^{12} - 2\left(\frac{r_0}{r}\right)^{6}\right]$$

   a. Show that the radius at the potential minimum is r_0, and that the depth of the potential well is ε.
   b. Find the frequency of small oscillations about equillibrium for 2 identical atoms of mass m bound to each other by the L-J interaction.



8. A block of mass m is attached to a light spring of spring constant k whose other end is attached to a triangular block of mass M kept on a smooth horizontal surface as shown in figure below. If the initial elongation in the spring is $x_0 > \frac{2mg\sin\theta}{k}$, find velocity of

the block having mass M when spring attains its unstretched length. Assume all surfaces to be smooth.



9. A block of mass M on a horizontal frictionless table is connected to a spring (spring constant k). The block is set in motion so that it oscillates about its equilibrium point with a certain amplitude A_0. The period of motion is $T_0 = 2\pi\sqrt{M/k}$
    a. A lump of sticky putty of mass m is dropped onto the block. The putty sticks without bouncing. The putty hits M at the instant when the velocity of M is zero. Find 1) the new period, 2) the new amplitude and 3) the change in the mechanical energy of the system.
    b. Repeat a) but assume that the sticky putty hits M at the instant when M has its maximum velocity.

10. A particle A of mass m has initial velocity v_0. After colliding with particle B of mass 2m initially at rest, the particles follow the paths shown in the sketch at right below. Find θ