Question 1. [23 marks]

A ball of mass m=215g is released from rest at a height 1.50m above the ground. A wind blows, imparting a constant horizontal force of 0.260N. Ignore wind resistance in the vertical direction.

(a) Draw a free-body diagram for the ball, indicating the forces acting.

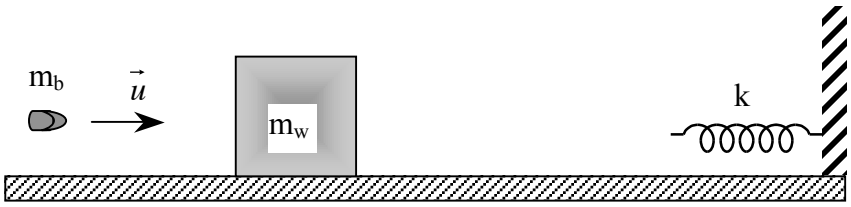
(b) Find the resultant acceleration of the ball, expressing your answer in terms of components along the horizontal and vertical directions ($\vec{i}$ and $\vec{j}$, respectively).

(c) Derive the trajectory of the ball (i.e., vertical position *y* as a function of horizontal position *x*) AND sketch it.

(d) Find the horizontal distance travelled by the ball before impact with the ground AND find the angle of impact.

(e) Determine the speed of the ball immediately before impact.

Question 2. [25 marks]



An experiment is designed to measure the speed of a bullet. The bullet is to be fired into a wooden block which is free to move on a horizontal surface, finally compressing a spring. The masses of the bullet and block are m_b=3.62g and m_w=1.43kg, respectively. The spring is found to conform to Hooke's law (F=-kx) when it is compressed or stretched up to 14.6cm.

(a) First, the spring constant *k* has to be determined. It is found that the spring is stretched 8.32cm when the wooden block hangs from it. Use this information to calculate the value of *k*.

(b) Next, the coefficient of kinetic friction μ_k between the block and surface should be determined. The block is pushed against the spring, compressing it 10.0cm. On release, the block travels 66.2cm along the horizontal surface before coming to rest. Find μ_k.

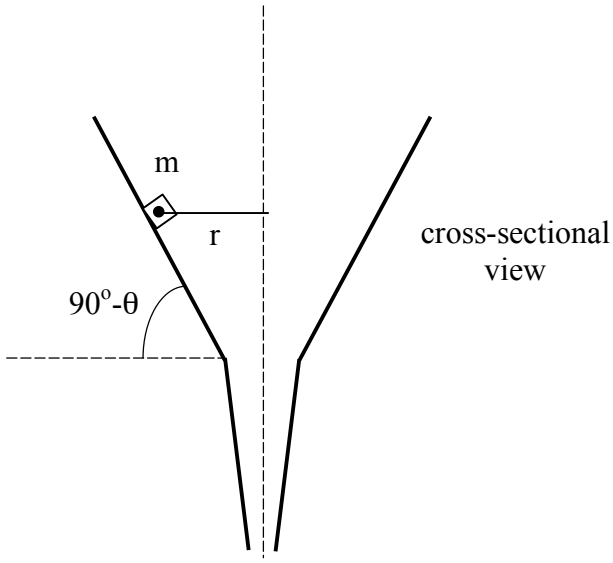
(c) The bullet is fired into the block, becoming lodged in it, and the combined block+bullet moves a distance 33.2cm before compressing the spring a maximum of 12.3cm. Giving reasons for your working, find:

(i) the speed of the combined block+bullet immediately after the bullet hits the block;

(ii) the initial speed of the bullet.

Question 3. [18 marks]

A very small block of mass m moves with constant angular velocity ω in a horizontal circle of radius r on the inside wall of a funnel, as shown in the figure. The wall of the funnel makes an angle θ with the vertical. Assuming frictionless contact between the funnel and the block:



(a) Draw a free-body diagram for the block, clearly indicating the forces acting.

(b) Which of the forces from (a) is responsible for keeping the block moving in a circle?

(c) Derive an expression for the angular velocity ω in terms of the acceleration due to gravity g, the angle θ, and the radius r.

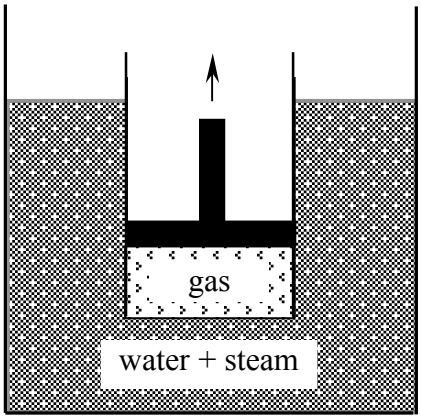
Question 4. [14 marks]

Europa is a satellite of the planet Jupiter. Its radius is 1569km and its free-fall acceleration at the surface is $1.30 ms^{-2}$. Showing all working:

(a) find the mass of Europa;

(b) derive the escape speed on Europa.

Question 5. [20 marks]



An ideal gas is enclosed by a cylinder with a movable piston. The cylinder is submerged in a mixture of water and steam at 100 ^{o}C. The piston is pulled rapidly, increasing the volume of the gas. The piston is held still until the temperature of the gas is again100 ^{o}C. Then it is slowly pushed back to the original position. 52.0g of water in the mixture vaporise in the process.

(a) Sketch the process on a PV diagram.

(b) Find the heat transferred to the gas.

(c) Find the change in internal energy of the gas.

(d) Find the work done on the gas.