AP Physics C: Mechanics
1999 Free-Response Questions

1999

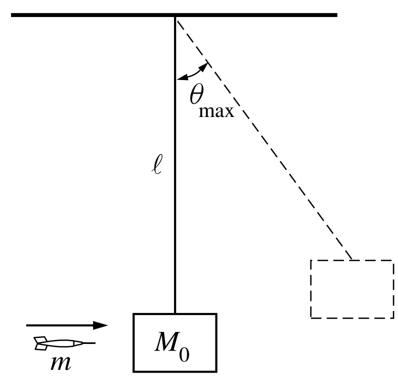
PHYSICS C

SECTION II, MECHANICS

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.



Mech 1. In a laboratory experiment, you wish to determine the initial speed of a dart just after it leaves a dart gun. The dart, of mass m, is fired with the gun very close to a wooden block of mass M_0, which hangs from a cord of length ℓ and negligible mass, as shown above. Assume the size of the block is negligible compared to ℓ, and the dart is moving horizontally when it hits the left side of the block at its center and becomes embedded in it. The block swings up to a maximum angle θ_{max} from the vertical. Express your answers to the following in terms of m, M_0, ℓ, θ_{max}, and g.

(a) Determine the speed v_0 of the dart immediately before it strikes the block.

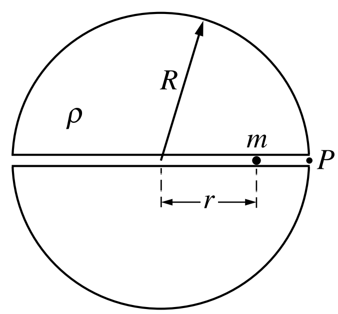
(b) The dart and block subsequently swing as a pendulum. Determine the tension in the cord when it returns to the lowest point of the swing.

(c) At your lab table you have only the following additional equipment.

Meter stick	Stopwatch	Set of known masses
Protractor	5 m of string	Five more blocks of mass M_0
Spring		

Without destroying or disassembling any of this equipment, design another practical method for determining the speed of the dart just after it leaves the gun. Indicate the measurements you would take, and how the speed could be determined from these measurements.

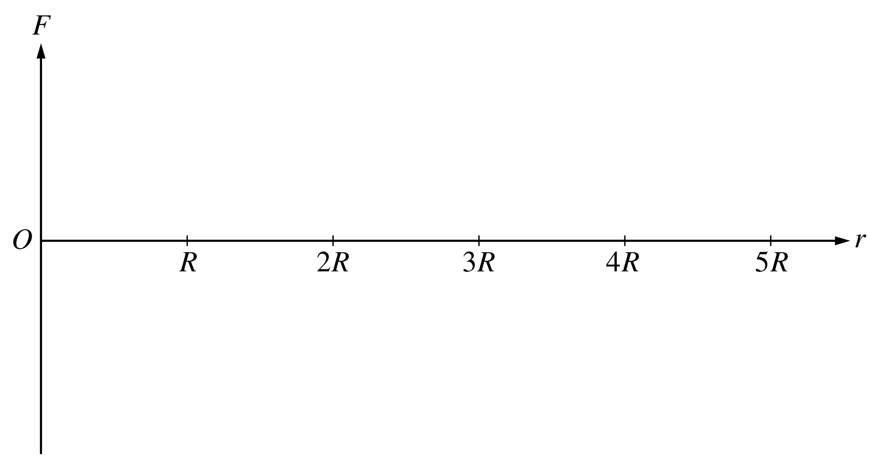
(d) The dart is now shot into a block of wood that is fixed in place. The block exerts a force $\mathbf{F}$ on the dart that is proportional to the dart's velocity $\mathbf{v}$ and in the opposite direction, that is $\mathbf{F} = -b\mathbf{v}$, where b is a constant. Derive an expression for the distance L that the dart penetrates into the block, in terms of m, v_0, and b.



Mech 2. A spherical, nonrotating planet has a radius R and a uniform density ρ throughout its volume. Suppose a narrow tunnel were drilled through the planet along one of its diameters, as shown in the figure above, in which a small ball of mass m could move freely under the influence of gravity. Let r be the distance of the ball from the center of the planet.

(a) Show that the magnitude of the force on the ball at a distance $r < R$ from the center of the planet is given by $F = -Cr$, where $C = \frac{4}{3}\pi G\rho m$.

(b) On the axes below, sketch the force F on the ball as a function of distance r from the center of the planet.



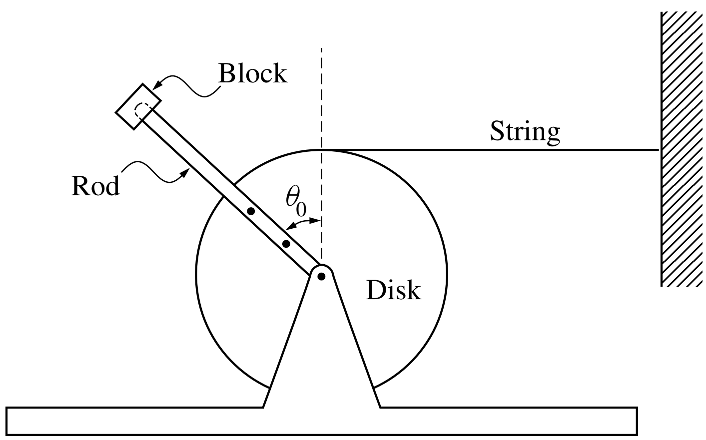
The ball is dropped into the tunnel from rest at point P at the planet's surface.

(c) Determine the work done by gravity as the ball moves from the surface to the center of the planet.

(d) Determine the speed of the ball when it reaches the center of the planet.

(e) Fully describe the subsequent motion of the ball from the time it reaches the center of the planet.

(f) Write an equation that could be used to calculate the time it takes the ball to move from point P to the center of the planet. It is not necessary to solve this equation.



Mech 3. As shown above, a uniform disk is mounted to an axle and is free to rotate without friction. A thin uniform rod is rigidly attached to the disk so that it will rotate with the disk. A block is attached to the end of the rod. Properties of the disk, rod, and block are as follows.

Disk: mass $= 3m$, radius $= R$, moment of inertia about center $I_D = \frac{3}{2}mR^2$

Rod: mass $= m$, length $= 2R$, moment of inertia about one end $I_R = \frac{4}{3}mR^2$

Block: mass $= 2m$

The system is held in equilibrium with the rod at an angle θ_0 to the vertical, as shown above, by a horizontal string of negligible mass with one end attached to the disk and the other to a wall. Express your answers to the following in terms of m, R, θ_0, and g.

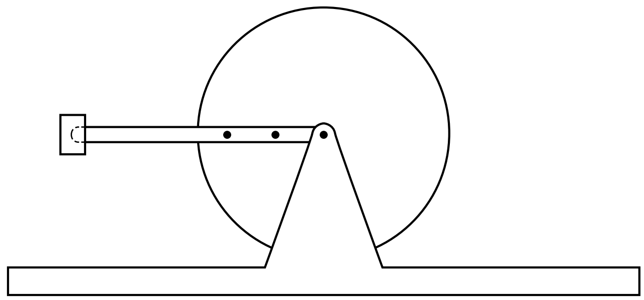
(a) Determine the tension in the string.

The string is now cut, and the disk-rod-block system is free to rotate.

(b) Determine the following for the instant immediately after the string is cut.

i. The magnitude of the angular acceleration of the disk

ii. The magnitude of the linear acceleration of the mass at the end of the rod



As the disk rotates, the rod passes the horizontal position shown above.

(c) Determine the linear speed of the mass at the end of the rod for the instant the rod is in the horizontal position.

S T O P

END OF SECTION II, MECHANICS