

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.01 TEAL

Fall Term 2004

Exam 1: Equation Summary

One Dimensional Kinematics:

$$\vec{v} = d\vec{r} / dt, \quad \vec{a} = d\vec{v} / dt$$

$$v_x(t) - v_{x,0} = \int_{t'=0}^{t'=t} a_x(t') dt' \quad x(t) - x_0 = \int_{t'=0}^{t'=t} v_x(t') dt'$$

Constant Acceleration:

$$x(t) = x_0 + v_{x,0}(t-t_0) + \frac{1}{2} a_x(t-t_0)^2 \quad v_x(t) = v_{x,0} + a_x(t-t_0)$$
$$y(t) = y_0 + v_{y,0}(t-t_0) + \frac{1}{2} a_y(t-t_0)^2 \quad v_y(t) = v_{y,0} + a_y(t-t_0)$$

where $x_0, v_{x,0}, y_0, v_{y,0}$ are the initial position and velocities components at $t = t_0$

Newton's Second Law: Force, Mass, Acceleration

$$\vec{F} \equiv m\vec{a} \quad \vec{F}^{total} = \vec{F}_1 + \vec{F}_2 \quad F_x^{total} = ma_x \quad F_y^{total} = ma_y \quad F_z^{total} = ma_z$$

Newton's Third Law:

$$\vec{F}_{1,2} = -\vec{F}_{2,1}$$

Force Laws:

Universal Law of Gravity: $\vec{F}_{1,2} = -G \frac{m_1 m_2}{r_{1,2}^2} \hat{r}_{1,2}$, attractive

Gravity near surface of earth: $\vec{F}_{grav} = m_{grav} \vec{g}$, towards earth

Contact force: $\vec{F}_{contact} = \vec{N} + \vec{f}$, depends on applied forces

Static Friction: $0 \leq f_s \leq f_{s,max} = \mu_s N$ direction depends on applied forces

Kinetic Friction: $f_k = \mu_k N$ opposes motion

Hooke's Law: $F = k|\Delta x|$, restoring

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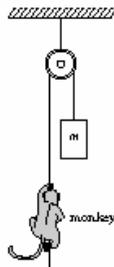
Physics 8.01T

Fall Term 2004

Practice Exam 1

Concept Questions: Briefly answer the following questions.

1. When a car accelerates forward, which force is responsible for this acceleration? State clearly which body exerts this force, and on which body the force acts.
2. A weightlifter and a barbell are both at rest on a large scale. The weightlifter begins to lift the barbell, ultimately holding it motionless above her head. Does the scale reading ever differ from the combined weight of the two bodies at any time during the lift? Explain.
3. As a space shuttle burns up its fuel after take-off, it gets lighter and lighter and its acceleration larger and larger. Between the moment it takes off and the time at which it has consumed nearly all of its fuel, is its average speed larger than, equal to, or smaller than half its final speed? Explain why.
4. Can astronauts floating in orbit tell which objects within their space-ship would be heavy or light on Earth even though everything in the ship is effectively weightless? Explain.
5. A monkey clings to a rope that passes over a pulley. The monkey's weight is balanced by the mass m of a block hanging at the other end of the rope; both monkey and block are motionless. In order to get to the block, the monkey climbs a distance L (measured along the rope) up the rope.
 - (a) Does the block move as a result of the monkey's climbing?
 - (b) If so, in which direction and by how much?



6. A basketball player is jumping vertically upward in order to land a shot. Her legs are flexed and pushing on the floor so that her body is accelerated upward.

- a) Draw free-body diagrams of the player's body and Earth. Show the relative magnitudes of the various forces and describe each in words (i.e., contact, gravitational, etc., and indicate which object exerts that force and on what). Identify the action-reaction pairs.
- b) Repeat this exercise for the situation immediately after the player's body breaks contact with the floor.
- c) Finally, consider, in the same manner, the situation at the top of the jump.

Analytic Questions: Show all your work.

Problem 1 *One dimensional kinematics: track event*

During a track event two runners, Bob, and Jim, round the last turn and head into the final stretch with Bob a distance d in front of Jim. They are both running with the same velocity v_0 . When the finish line is a distance s away from Jim, Jim accelerates at a constant a_j until he catches up to Bob and passes him. Jim then continues at a constant speed until he reaches the finish line.

- a) How long did it take Jim to catch Bob?
- b) How far did Jim still have to run when he just caught up to Bob?
- c) How long did Jim take to reach the finish line after he just caught up to Bob?

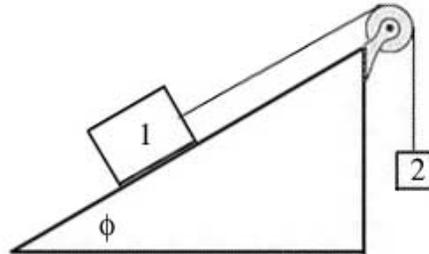
Bob starts to accelerate at a constant a_B at the exact moment that Jim catches up to him, and accelerates all the way to the finish line and crosses the line exactly when Jim does. Assume Bob's acceleration is constant.

- d) What is Bob's acceleration?
- e) What is Bob's velocity at the finish line? Who is running faster?

Problem 2: *Second Law and projectile motion*

An object with mass m slides down a roof a distance d that is inclined at an angle of ϕ to the horizontal. The contact surface between the roof and object has a coefficient of kinetic friction μ_k . The edge of the bottom of the roof is at a height h above the ground. What is the horizontal displacement from the edge of the roof to the point where the object hits the ground?

Problem 3 A block 1 of mass m_1 , constrained to move along a plane inclined at angle ϕ to the horizontal, is connected via a massless inextensible string that passes over a massless pulley, to a second block 2 of mass m_2 . Assume the coefficient of static friction on the between the block and the inclined plane is μ_s and the coefficient of kinetic friction is μ_k . Assume the gravitational constant is g .



- a) What is the relation between the masses of block 1 and block 2 such that the system just starts to slip.

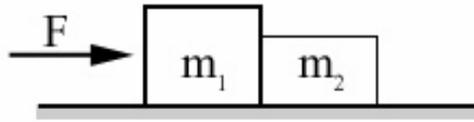
For the following questions suppose block 2 has a mass greater than the value you found in part a).

- b) Calculate the acceleration of the blocks.
- c) Calculate the tension in the rope.
- d) If the block 2 starts out at a height h above the bottom of the inclined plane and is released at rest. How long does it take to fall a distance s ? Note that block 1 starts off a distance greater than s from the pulley.

Problem 4: Suppose a MIT student wants to row across the Charles river. Suppose the water is moving downstream at a constant rate of 1.0 m/s. A second boat is floating downstream with the current. From the second boat's viewpoint, the student is rowing perpendicular to the current at 0.5 m/s. Suppose the river is 800 m wide.

- a) What is the direction and magnitude of the velocity of the student as seen from an observer at rest along the bank of the river?
- b) How far down river does the student land on the opposite bank?
- c) How long does the student take to reach the other side?

Problem 5: Two blocks sitting on a frictionless table are pushed from the left by a horizontal force, as shown below.



- a) Draw a free-body diagram for each of the blocks.
- b) What is the acceleration of the blocks?
- c) Express, in terms of the quantities given in the figure, the force of contact between the two blocks.

Problem 6: In the projectile motion experiment, a ball of diameter D is projected upwards at an angle θ with respect to the horizontal. The ball leaves the tube at a height h above the ground. Just as it leaves the tube, the ball passed a photogate which measures the voltage across a photo-transistor. The width of the graph of voltage vs. time at half maximum is ΔT . The ball has diameter D . How long will it take the ball to return to the same height that it left the tube? How far in the horizontal direction has it traveled at that point. What is the direction and magnitude of the velocity at that point?