

Study Guide for Test 2

Newton's first law: An isolated object (with no outside influences acting on it) moves in a straight line at constant speed.

Newton's second law: The acceleration of an object is determined by the vector sum of all the forces acting on it. More precisely,

$$\sum F_x = ma_x \quad \sum F_y = ma_y \quad \sum F_z = ma_z$$

Newton's third law: When two objects, A and B , interact, the forces they exert on each other are always equal in magnitude and opposite in direction. Written as an equation,

$$\vec{F}_{\text{on } A \text{ from } B} = -\vec{F}_{\text{on } B \text{ from } A}$$

Newton's laws work only in an inertial reference frame, that is, when all measurements are made with respect to a reference frame that is not itself accelerating.

Every force on an object arises from an interaction with some other nearby object (called the "agent" of the force). If a force has no agent, it's not a real force.

Types of forces:

- Contact forces
 1. compression (including "normal")
 2. tension (same at each end of an ideal string)
(for a stretched or compressed spring, $F_x = -k_s x$)
 3. friction (gripping, $|\vec{F}_f| \leq \mu_s |\vec{F}_N|$; slipping, $|\vec{F}_f| = \mu_k |\vec{F}_N|$; also air resistance, etc.)
- Long-range forces
 1. gravity or "weight", $|\vec{F}_g| = mg$, where $g = 9.8 \text{ N/kg}$ near earth's surface
 2. electromagnetic

$$(\text{Center of mass of a system}) = \vec{r}_{\text{cm}} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2 + \dots}{m_1 + m_2 + \dots} \quad (\text{weighted average of the positions})$$

$$\text{Motion of center of mass: } \sum \vec{F}_{\text{external}} = M \vec{a}_{\text{cm}}$$

$$\text{Momentum} = \vec{p} = m\vec{v}$$

Momentum conservation: $\sum \vec{p}_f = \sum \vec{p}_i$ (for any isolated system) *Note:* This is a vector equation, so it must be broken into components in solving problems: $\sum p_{f,x} = \sum p_{i,x}$, and similarly for y, z .

You should be able to do the following:

- Draw qualitatively accurate force diagrams, identify the type and agent of each force, identify third-law partners.
- Solve "constrained motion" problems involving straight-line or circular motion of a single object or multiple interacting objects.
- Recognize non-inertial reference frames (accelerating cars, elevators, etc.) and instead analyze problems from the viewpoint of an inertial reference frame.
- Solve momentum-conservation problems.

Although this test will cover mainly the ideas listed here (and covered on Problem Sets 4–6), you are still responsible for material covered on the first test (Problem Sets 1–3). Note that the equations for constant acceleration and for uniform circular motion tend to come up frequently in constrained motion problems.

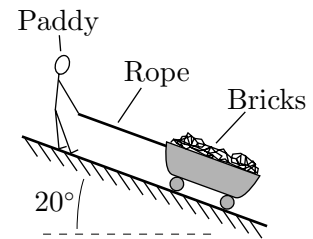
Practice Problems

(These problems are taken from tests that I gave in past years. They don't cover everything that could come up on the test, but I still recommend them as excellent practice.)

1. Because the earth spins once a day on its axis, the earth's surface is not quite an inertial reference frame. Consider a person whose mass is exactly 50.0 kg, standing on a bathroom scale in Ecuador (at the equator) in a location where the value of g is exactly 9.80 N/kg. The radius of the earth is 6.37×10^6 m. Please neglect all motions of the earth other than its daily spin.

- (a) (2 points.) What is this person's true weight (in newtons)?
- (b) (4 points.) Draw a force diagram for this person, assuming that she is motionless with respect to the scale and the ground beneath her. Label each force appropriately.
- (c) (14 points.) What is the person's apparent weight, that is, the reading on the scale? (The scale is calibrated in newtons, of course. Please assume that the person's mass and the value of g given above are exact; don't worry about keeping too many significant figures. Be sure to show all your work and make your logic clear.)

2. Paddy the bricklayer (mass 75 kg) needs to lower a wheelbarrow full of bricks (total mass 100 kg) down a roof inclined at 20° from horizontal. Fortunately, he is wearing rubber-soled shoes so that the coefficient of gripping (static) friction between his feet and the rooftop is 0.80. Paddy is connected to the wheelbarrow by an ideal, massless rope, held parallel to the rooftop; there is no friction between the rooftop and the wheelbarrow. For obvious reasons, Paddy prefers to descend at a constant velocity, slow enough for air resistance to be negligible.



- (a) (8 points.) Draw qualitatively accurate force diagrams for both Paddy and the wheelbarrow. Label all forces appropriately, and indicate any third-law partners.
- (b) (12 points.) Will Paddy begin to slip and accelerate down the rooftop? Please show your work and explain clearly.