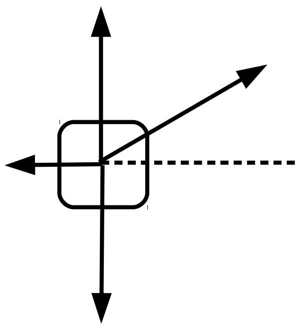
Midterm 3 for Calculus-Based Physics-1: Mechanics (PHYS150-01)

Dr. Jordan Hanson - Whittier College Dept. of Physics and Astronomy

November 6th, 2017

1 Definition of Work

1. *In each of the following three questions, determine whether work is being performed* ***on the backpack*** by the student.
   - A student lifts her backpack. (a) No work is done on backpack (b) Positive work is done on backpack (c) Negative work is done on backpack **(b)**
   - A student lowers her backpack. (a) No work is done on backpack (b) Positive work is done on backpack (c) Negative work is done on backpack **(c)**
   - A student walks horizontally with her backpack at constant height (a) No work is done on backpack (b) Positive work is done on backpack (c) Negative work is done on backpack **(a)**
2. For this problem, use the work formula $W = \vec{F}_{\rm Net} \cdot \vec{x}$, where $\vec{F}_{\rm Net}$ is the net force on a system that is moved a displacement $\vec{x}$. (a) Draw the correct free-body diagram for a crate being pushed horizontally against friction by some applied force $\vec{F}$, which makes a 30 degree angle with the horizontal.



(b) Calculate the work done on the the system if the mass is 100 kg, $\vec{x} = 1\hat{i}$ m, the friction force is $-100\hat{i}$ N, and the magnitude of $\vec{F}$ is 400 N. **Solution**: The net force in the x-direction (the direction of the displacement) is $-100 + 200\sqrt{3}$ N, so the force times the displacement is $100(2\sqrt{3} - 1)$ J.

2 Kinetic Energy

1. What is the kinetic energy of a system with mass 2 kg moving at $\sqrt{10}$ m/s? **Solution**: $KE = \frac{1}{2}mv^2 = \frac{1}{2}(2)(\sqrt{10})^2 = 10$ J.
2. What would be the kinetic energy if the speed doubled? **Solution**: Kinetic energy is proportional to the square of the speed, so if we double speed the kinetic energy quadruples: KE = 40 J. *This is an example of a* ***scaling*** *problem*.

3 Work-Energy Theorem

1. How much work is required to compress a spring with spring constant $k = 500$ N/m by a displacement 0.1 m? How high will an object go if we use the spring to shoot something straight up, if it has 0.1 kg mass? **Solution 1**: (This is actually energy conservation) $W_{\rm s} = \frac{1}{2}kx^2 = \frac{1}{2}(500)(0.1)^2 = \frac{5}{2}$ J. As for the height, we can solve it kinematically, but it's much easier to use gravitational potential energy: $PE = mgh$, so $\frac{5}{2} = 0.1 * 10h$, or $h = \frac{5}{2}$ m. **Solution 2**: Use work-energy theorem to get initial velocity: $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$, so $v_{\rm i}^2 = \frac{k}{m}x^2$. Kinematically, $v_{\rm f}^2 = v_{\rm i}^2 - 2g\Delta y$, and at the top of the trajectory we have $v_{\rm f} = 0$. Combining the equation for $v_{\rm i}$ with the kinematic one, we arrive at the same answer: $\Delta y = \frac{kx^2}{2mg} = \frac{5}{2}$ m.

4 Gravitational Potential Energy

1. What is the maximum velocity achieved by an object if we drop it from 300 m? (No drag). **Solution**: Set gravitational potential energy equal to kinetic energy and solve for speed, so $mgh = \frac{1}{2}mv^2$, or $v = \sqrt{2gh} = \sqrt{2 * 10 * 300} = \sqrt{6000}$ m/s (about 80 m/s).

5 Conservative Forces

1. Be able to describe, in your own words, what is a conservative force. Which of these forces is conservative? (a) Friction, kinetic (b) Drag, air (c) Stoke's Law (drag in viscous liquids) (d) Hooke's Law