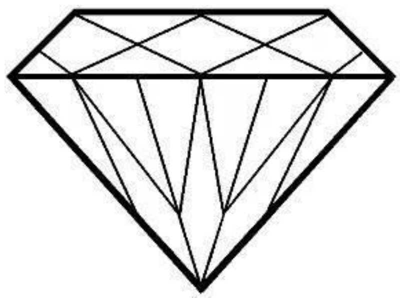
18- Physics

A. Mass, Force and Gravity

Before attempting to understand force, we need to look at *mass* and *acceleration*.

a) What does mass measure?

b) What is the ratio of atoms in the two diamonds?

	
0.100 kg	0.001 kg (5 carat diamond)

c) What is the ratio of atoms if we compare the number of atoms in the big diamond to those found in 0.100 kg of gold?

d) If you bring the 0.100 kg diamond to Mars, where gravity is 0.38*[1] of what it is on the Earth, what will its mass be? Why?

e) What is acceleration?

[1] The relative gravity(g_p/g_e) is calculated from $g_p/g_e = m_p/r_p^2$, where m_p is the planet's relative mass and r_p is the planet's relative size. For Mars m_p =0.107 and r_p= 0.532. The formula comes from Newton's Law of Gravitation which mathematically looks like Coulomb's Law.

f) The Ferrari Scuderia can go from 0 to 100 km/h (27.78 m/s) in 3.7 s. What is its acceleration?

g) **Force is a push or pull equal to the product of mass and acceleration**.

$$F = ma$$

A force is what's needed to move a mass from rest to a certain speed. It is also what's needed to decelerate (negative acceleration) a mass.

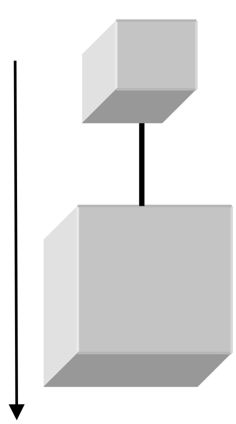
Find the force needed to accelerate a 1250 kg Scuderia from rest to 27.78 m/s in 3.7 s.

h) Relate fuel consumption and the ecological footprint to F = ma and the Ferrari.

i) If a rock is dropped from a window, it will also accelerate. It will do so at about 9.8 m/s^2. Would the acceleration due to gravity change if the rock was bigger?

j) What is responsible for the false notion that heavier objects fall faster?

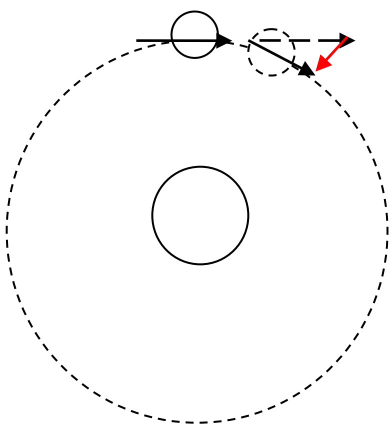
k) How does the following thought experiment (Galileo's) dispel the myth about heavier objects?



l) The product of mass and gravitational acceleration is known as weight. Weight is the gravitational force given by F = mg.
If you bring the 0.1000 kg diamond to Mars, where gravity is 0.38 of what it is on the Earth, what will its ***weight*** be?

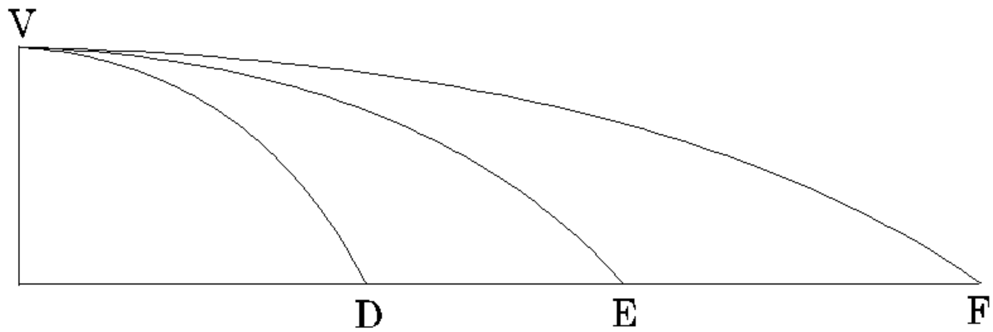
Weight on Earth	**Weight on Mars**

m) How does this diagram help us realize that gravity keeps the moon in orbit?



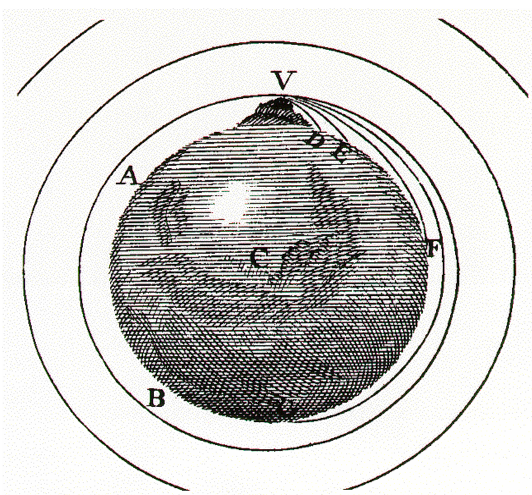
From: http://galileoandeinstein.physics.virginia.edu/lectures/newton.html

Let us now turn to the central topic of the *Principia*, the universality of the gravitational force. The legend is that Newton saw an apple fall in his garden in Lincolnshire, thought of it in terms of an attractive gravitational force towards the earth, and realized the same force might extend as far as the moon. He was familiar with Galileo's work on projectiles, and suggested that the moon's motion in orbit could be understood as a natural extension of that theory. To see what is meant by this, consider a gun shooting a projectile horizontally from a very high mountain, and imagine using more and more powder in successive shots to drive the projectile faster and faster.



The parabolic paths would become flatter and flatter, and, if we imagine that the mountain is so high that air resistance can be ignored, and the gun is sufficiently powerful, *eventually the point of landing is so far away that we must consider the curvature of the earth in finding where it lands.*

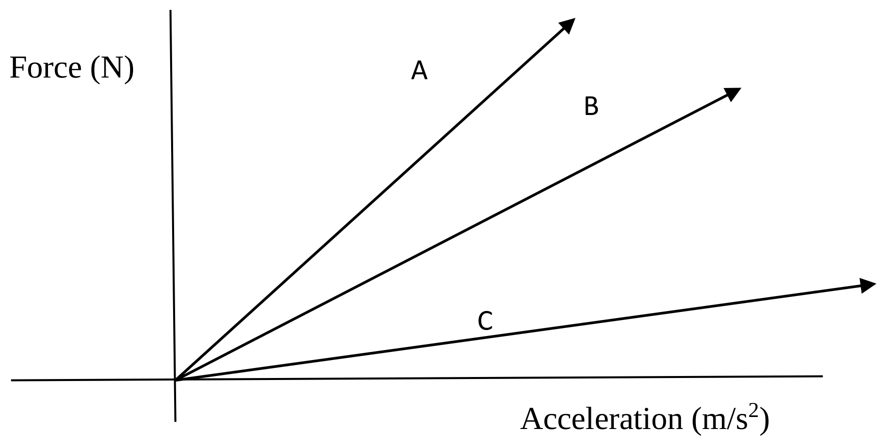
In fact, the real situation is more dramatic—the earth's curvature may mean the projectile *never lands at all.* This was envisioned by Newton in the *Principia*. The following diagram is from his later popularization, *A Treatise of the System of the World*, written in the 1680's:



The mountaintop at V is supposed to be above the earth's atmosphere, and for a suitable initial speed, the projectile orbits the earth in a circular path. In fact, the earth's curvature is such that the surface falls away below a truly flat horizontal line by about five meters in 8,000 meters (five miles). Recall that five meters is just the vertical distance an initially horizontally moving projectile will fall in the first second of motion. But this implies that if the (horizontal) muzzle velocity were 8,000 meters per second, the downward fall of the cannonball would be just matched by the earth's surface falling away, and it would never hit the ground! This is just the motion, familiar to us now, of a satellite in a low orbit, which travels at about 8,000 meters (five miles) a second, or 18,000 miles per hour. (Actually, Newton drew this mountain impossibly high, no doubt for clarity of illustration. A satellite launched horizontally from the top would be far above the usual shuttle orbit, and go considerably more slowly than 18,000 miles per hour.)

Exercises

1. If you go on a diet and lose weight, will you also lose mass? Explain.
2. John weighed 980 N on Earth where gravity = 9.8 m/s^2. Before leaving for the moon, his wife cooked lots of pasta for him. When he reached the moon he weighed 167 N. How much mass did he gain from the pasta? Gravitational acceleration on the moon is 1.6 m/s^2.
3. What force is required to accelerate a 3.0 kg mass by 2.0 /s^2?
4. Which of the following graphs corresponds to the greatest mass? Explain.



5. A loose leaf and a lead weight are dropped from the same height in a vacuum. Which, if any, hits the floor first?

6. The different masses and radii of different planets account for different gravitational accelerations.

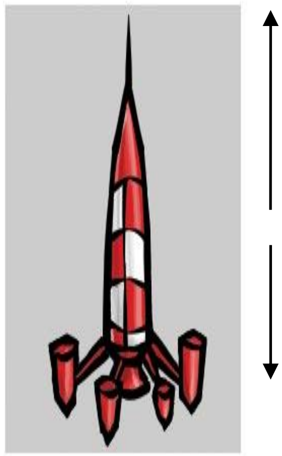
$$F = m_o g_p = \frac{G m_o m_p}{r^2}$$

where m_o = mass of the object on surface of planet
g_p = gravitational acceleration on planet
G = gravitational constant
m_p = mass of planet
r_p = radius of planet

a) Simplify the above formula to get a formula for g. What term cancels?
b) Let $g_n = \frac{Gm_n}{r_n^2}$ = gravitational acceleration on planet Neptune. Write a similar expression for Earth's gravity in terms of its radius r_e and mass m_e.
c) Divide g_n by g_e to get a formula for how much stronger gravitational acceleration is on planet Neptune. What term cancels?

Continued from page 97

n) What is the net upward force acting on the rocket?

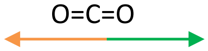


120 000 N of upward thrust
provided by expanding gases

10 000 kg rocket

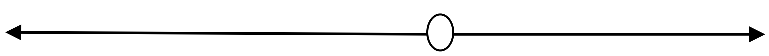
o) What is the net force acting on the carbon atom within the CO_2 molecule for this specific stretch?

O=C=O



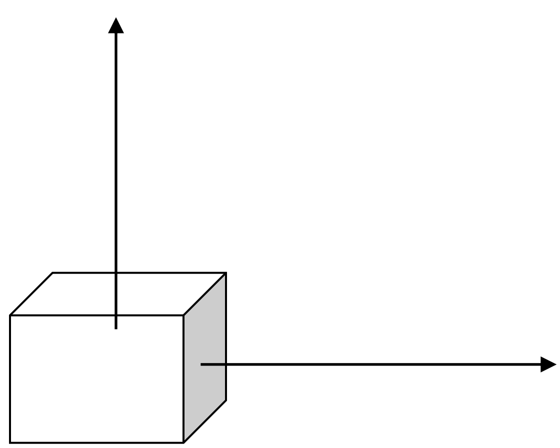
CASE 1

p) What is the net force in the following:



100 N 40 N

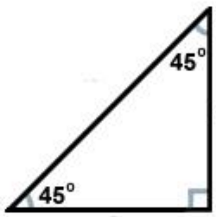
q) Find the effective force acting on the block. The upward and horizontal forces are equal.



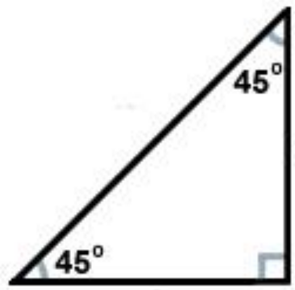
r) Introduction to Trigonometry

1. Special Triangles

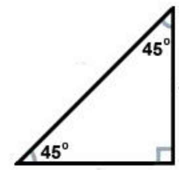
A- 45-45-90 Triangle



A 45-45-90 triangle

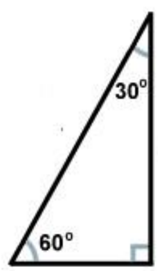


A 45-45-90 triangle

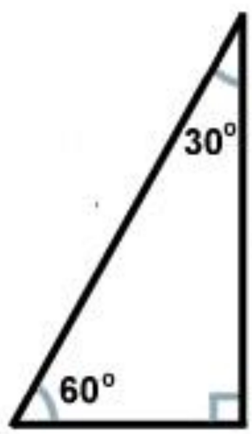


A 45-45-90 triangle

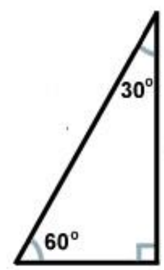
B- 30-60-90 Triangle



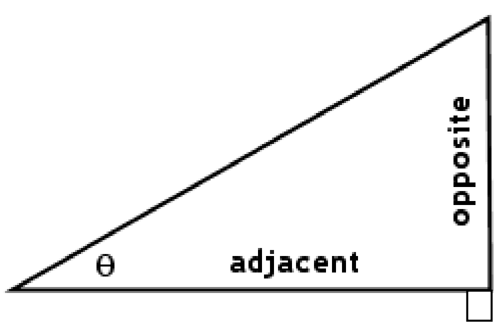
A 30-60-90 triangle



A 30-60-90 triangle

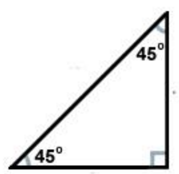


A 30-60-90 triangle

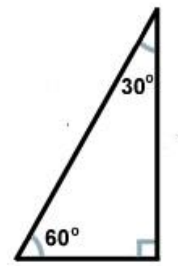


2. The Basic Trigonometric Ratios

3. Relating Trig Ratios to Special Triangles



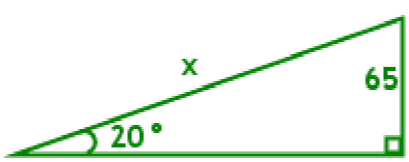
A 45-45-90 triangle



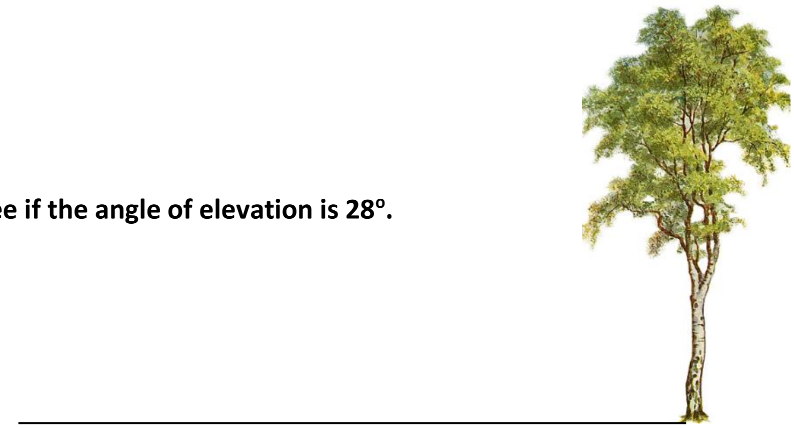
A 30-60-90 triangle

Example 1

In the triangle shown below, find the value of x, accurate to three decimal places.



<u>Example 2:</u> **a)Find the height of the tree if the angle of elevation is 28°.**



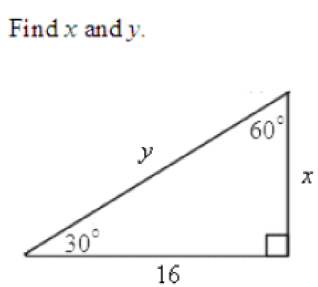
30 m

b) Use the Pythagorean theorem to find the hypotenuse, and verify your answer with the cosine ratio.

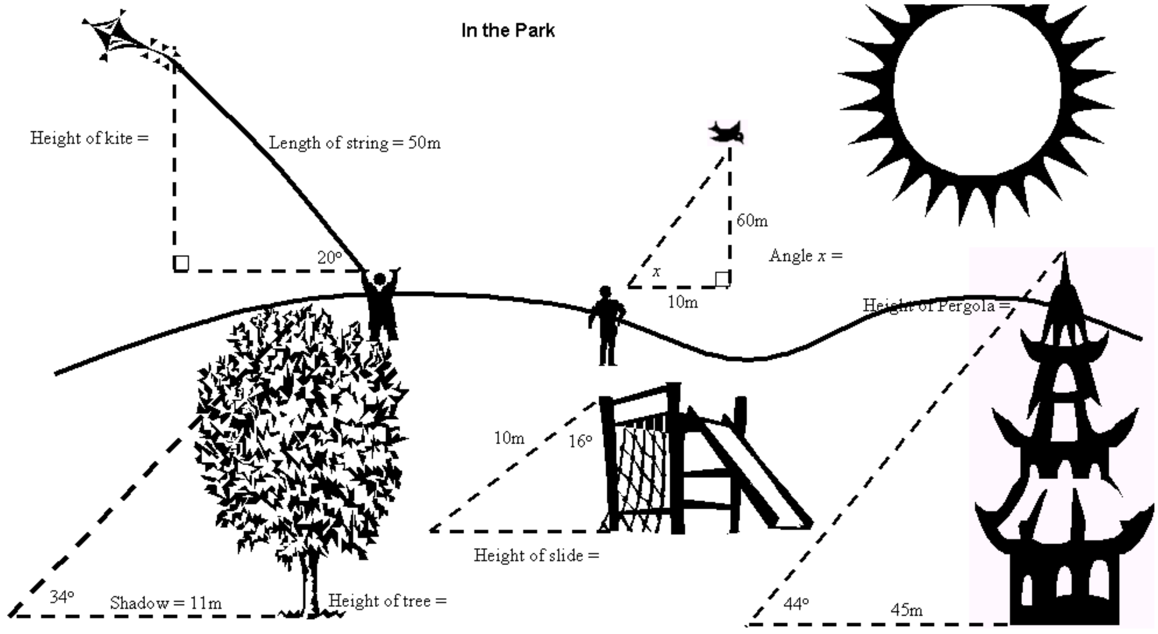
<u>Example 3</u> **Find the angles in a 3 cm- 4 cm- 5 cm triangle.**

<u>Exercises</u>

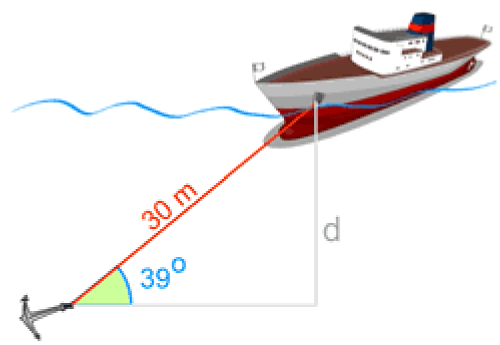
1.



2. Find all 5 unknowns in the figures below.

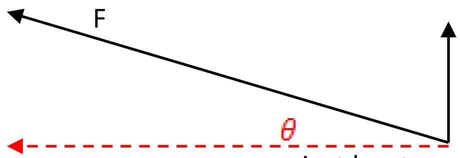


3. Find the distance *d* and then find the third side with and without the Pythagorean theorem.



B- **Effective Force**

r) What is the effective force of pulling on a wagon with a 53 N force acting at 30.0 ^{0} to the horizontal? Effective force is in the direction of movement observed



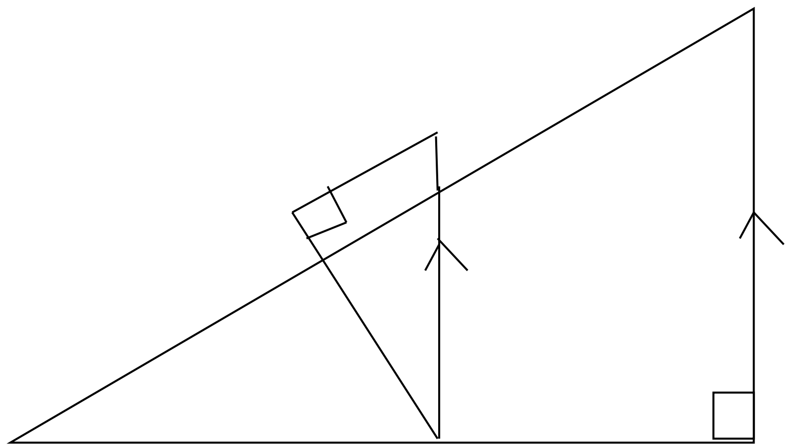
__________: has to overcome weight

_________: just has to overcome friction

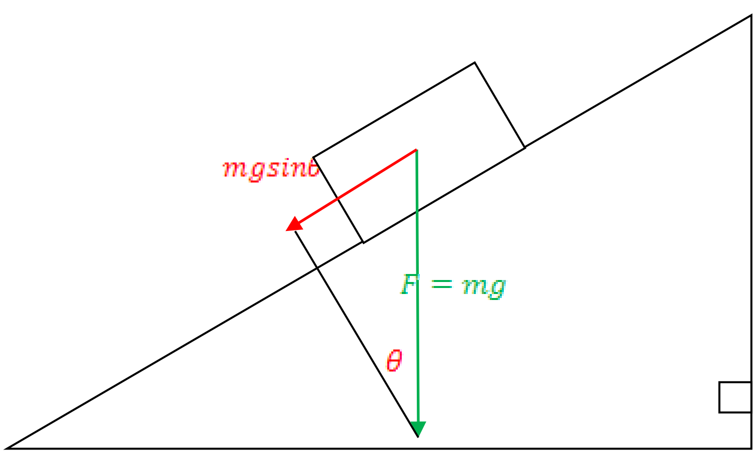
In this case the effective force is along the horizontal and is _____________________________

s) Review of similar triangles:

Show that the two triangles are similar

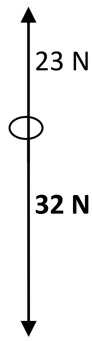


t) Find the effective force acting on the 10.0 kg mass accelerating down the 30.0^{o} ramp.

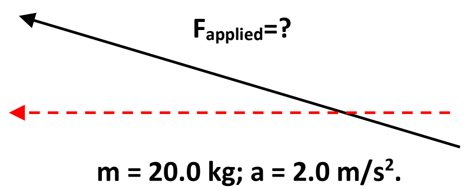


<u>More In-class examples</u>:

1. Find the net force:



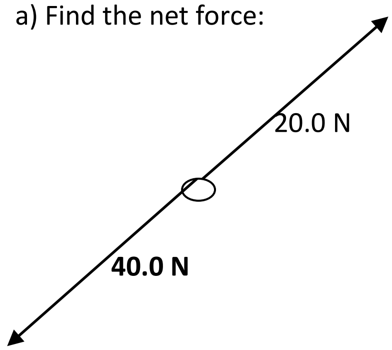
2. a) Find the applied force (it's applied 25.0° with horizontal) if a 20.0 kg wagon is accelerating along the horizontal at 2.0 m/s².



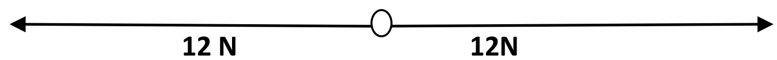
b) First find *mg* for the wagon and then show that there is not enough force to lift the wagon off the ground as it's being pulled.

Exercises

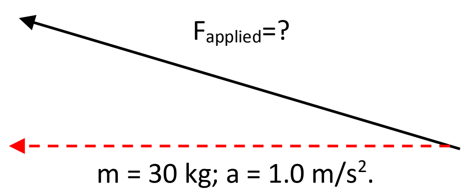
1. a) Find the net force:



b)

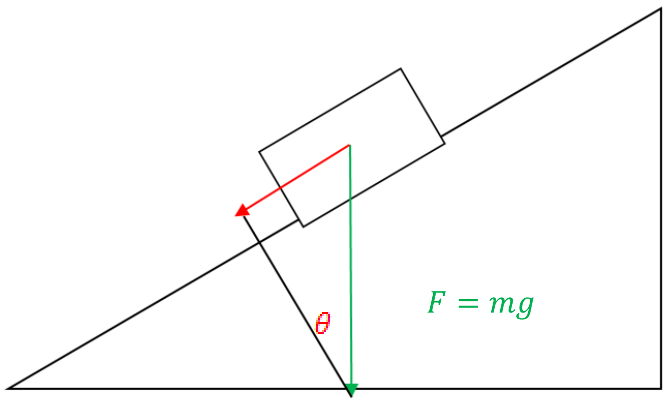


2. a) Find the applied force (it's applied 25° with horizontal) if a 30.0 kg wagon is accelerating along the horizontal at 1.0 m/s^2.



b) Show that there is not enough force to lift the wagon off the ground as it's being pulled.

c) Find the effective force acting on the 20.0 kg mass accelerating down the 35.0° ramp.



$$\text{Effective force} =$$

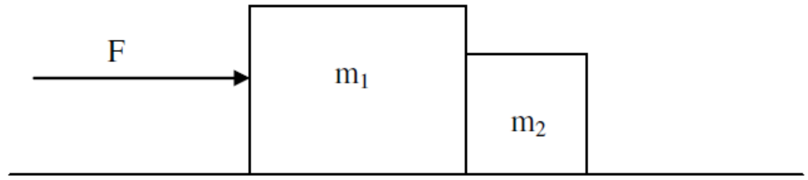
3. If gravitational acceleration on the moon is 1/6th of what it is on Earth, find the weight of a 100.0 kg man on the moon.

4. You fill a box with 100.0 g of carbon and a second box with 100.0 g of Al.

a) Which will have more atoms?

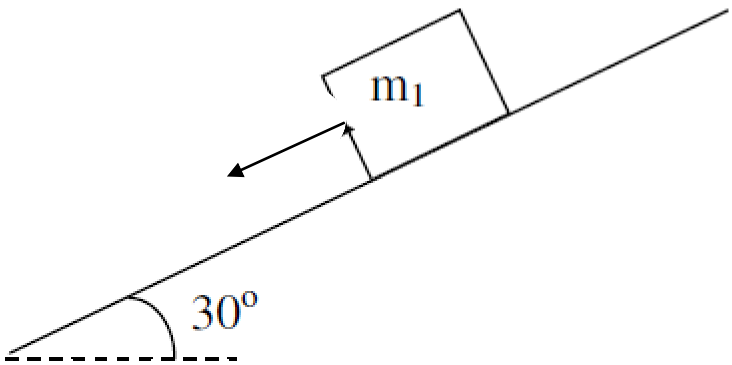
b) Which, if any will hit the ground first? Why?

Extra Physics Practice



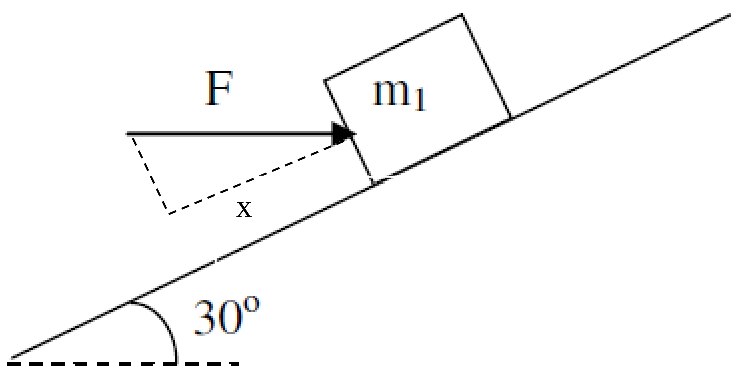
1. Two blocks are in contact on a frictionless table. A horizontal force is applied to one block, as shown below. (a) If $m_1 = 2.3$ kg, $m_2 = 1.2$ kg, and F = 3.2 N, find the acceleration of the two blocks.

2. A 100 kg crate is sliding down the frictionless 30° ramp shown below.



a) With what force is it sliding down?
b) Calculate its acceleration without using 100 kg.

c) Suppose you wanted to apply a horizontal force to this block to stop it from sliding down. How big would the force have to be? (Hint: use trig to find an expression for x and equate it to its opposite force)

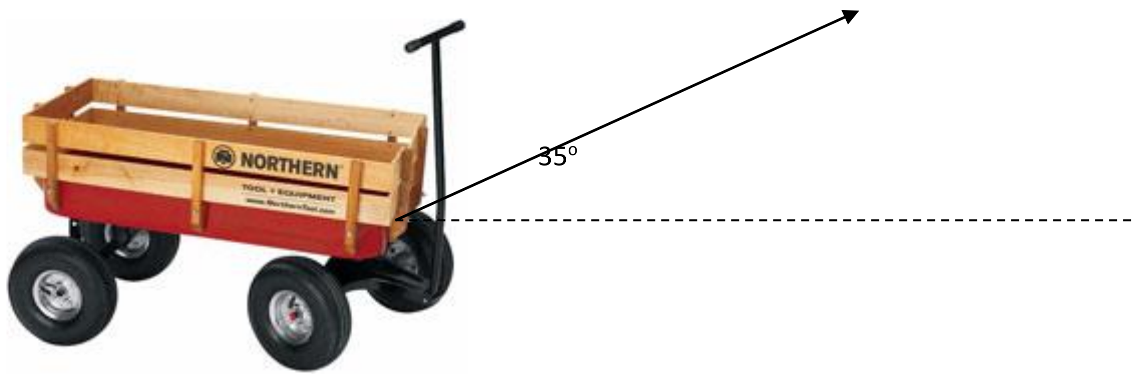


C- **Work and Energy**

Work is the product of a force and displacement, but the displacement has to be in the same direction (and angle) as the force.

$$W = F*d$$

a)



A 22 N force is applied at an angle of 35° with the horizontal. How much work is done if a wagon is pulled for a distance of 12 m?

b) If work is done to elevate a mass (raise it to a certain height), the energy as usual is not destroyed. The energy is stored as **gravitational potential energy**, E_p.

$$W = F_g*d$$

$$E_p = mgh$$

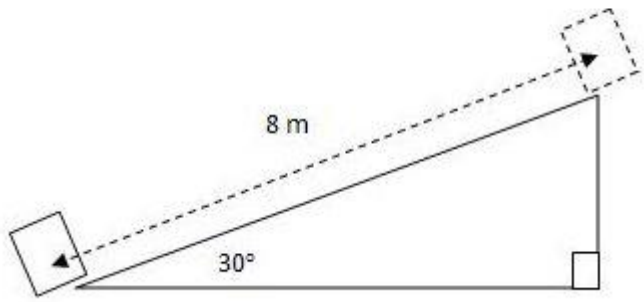
If a 10.0 kg mass is raised 3.0 m above the floor and rested on a shelf at that height, how much gravitational potential energy is gained?

c) If that same 10.0 kg mass is dropped from the 3.0 m shelf, it will hit the ground with a velocity of 7.668 m/s. At the point of impact, the gravitational potential energy that had been gained has *all* been transformed to **kinetic energy**(E_k), which is energy of motion.

$$E_k = 0.5\ mv^2$$

Calculate the kinetic energy of the mass to make sure that the above statement applies.

d) How much work is done to raise the 12 kg from the bottom of a ramp? The slanted distance travelled is 8.0 metres. Use the applied force to work it out. The angle is 30°.

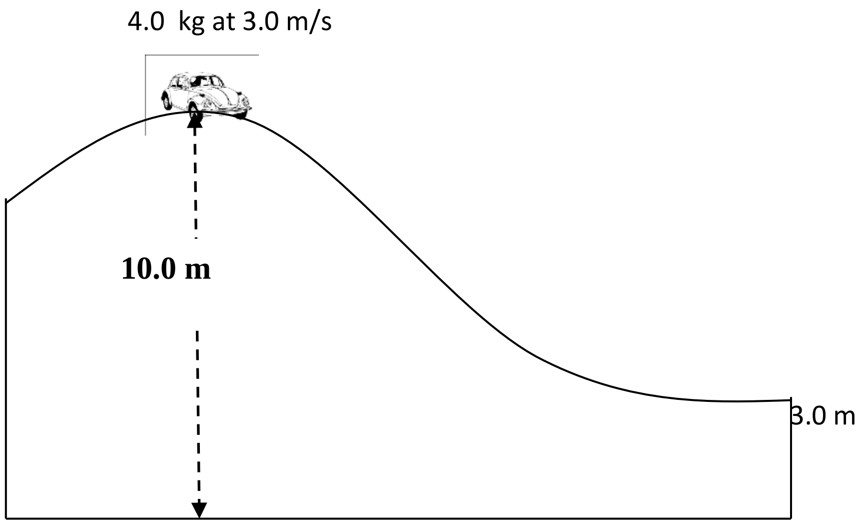


e) Redo (d) using the idea of potential energy.

f) If you let the mass slide down, how fast will it be travelling when it hits the flat surface? ***Hint***: how much kinetic energy will it have at that point?

g) Total mechanical energy = potential energy+ kinetic energy.

Use this idea to find the kinetic and potential energy just before the toy car goes off the ramp. Also find its velocity in km/h just before it goes off the ramp.



Exercises: Work and Energy

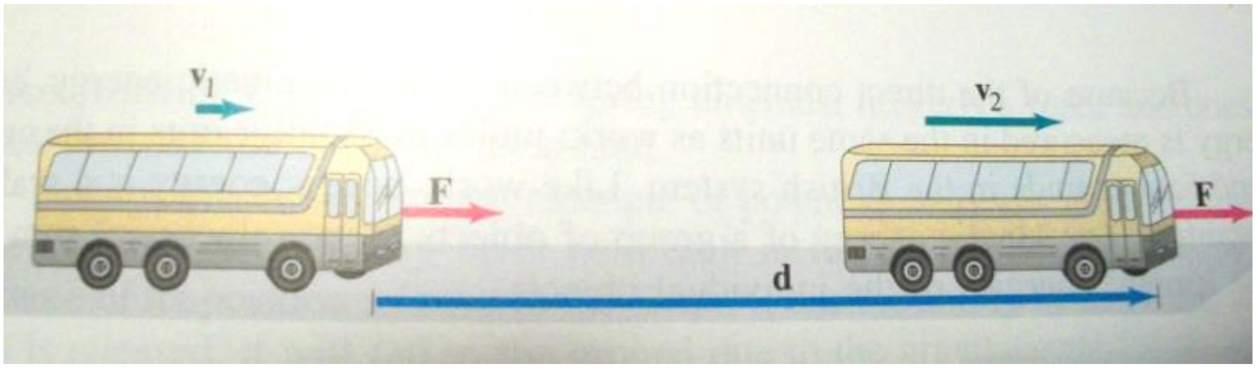
1. a) An Easter rabbit pulls the wagon with a force of 35 N, and the rope makes an angle of 30.0^o. Use the effective force and the acceleration of 2.0 m/s^2, to find the total mass of the Easter eggs and wagon.

b) Use the effective force to calculate the work done by the rabbit as he drags the wagon 2.00 m before reaching a constant speed.

2. While pushing a car, a boy exerts a 10.0 N force parallel to the ground for a distance of 230 cm. Find the work being done.

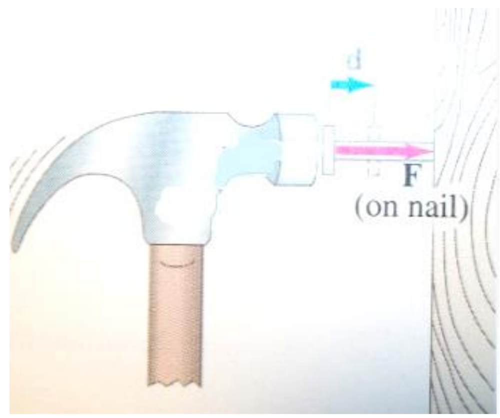
3. A mass is dropped from a height of 20.0 m. Find its velocity at a height of 10.0 m by using the conservation of energy principle.

Extra Work/Energy Problems

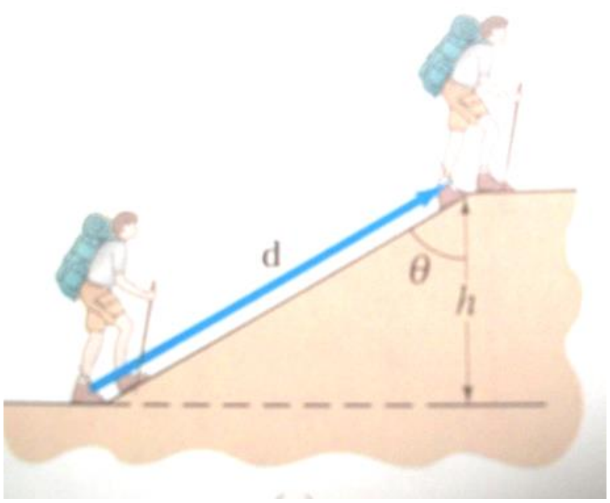


4. a) A constant force acts on a 2000.0 kg bus in order to accelerate it from 15 to 20 m/s in 5.00 seconds. (recall: $\frac{v_f - v_i}{t_f - t_i} = a$). The force is applied over a distance of 87.5 m. Find the work being done on the bus.

b) What is the change in the kinetic energy of the bus?

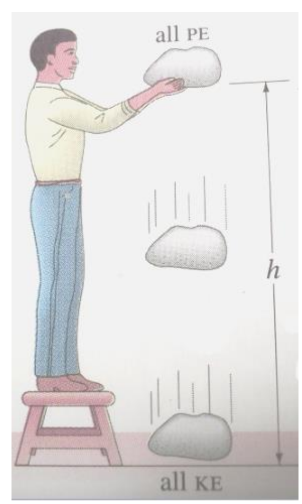


5. 3.6 J of work are done to drive a nail 2.00 cm deeper into a piece of wood. What force was applied?



6. a) If a 75 kg man walks up the hill, ignoring friction, what continuous force must he apply to climb the hill if the angle shown is 70.0°?

b) Show two ways of obtaining the work done by the man if d = 100.0 m.



7. How fast is the rock travelling when it is halfway down? Total height = 4.0 m.