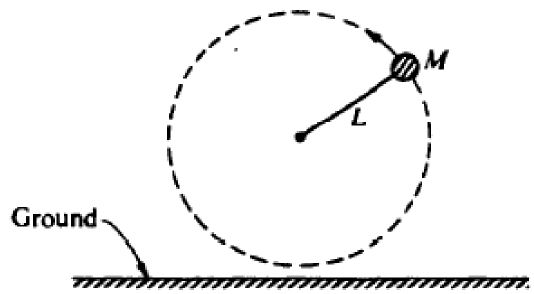


1. A ball of mass M attached to a string of length L moves in a circle in a vertical plane as shown above. At the top of the circular path, the tension in the string is twice the weight of the ball. At the bottom, the ball just clears the ground. Air resistance is negligible. Express all answers in terms of M, L, and g.

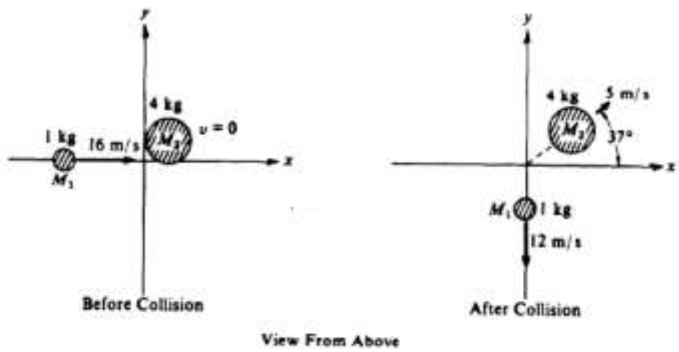
(a) Determine the magnitude and direction of the net force on the ball when it is at the top.

(b) Determine the speed v_0 of the ball at the top.

The string is then cut when the ball is at the top.

(c) Determine the time it takes the ball to reach the ground.

(d) Determine the horizontal distance the ball travels before hitting the ground.



2. Two objects of masses M_1 = 1 kilogram and M_2 = 4 kilograms are free to slide on a horizontal frictionless surface. The objects collide and the magnitudes and directions of the velocities of the two objects before and after the collision are shown on the diagram above. (sin 37° = 0.6, cos 37° = 0.8, tan 37° = 0.75)

(a) Calculate the x and y components (p_x and p_y, respectively) of the momenta of the two objects before and after the collision, and write your results in the proper places in the following table.

	M_1 = 1 kg		M_2 = 4 kg	
	$p_x\left(\frac{\text{kg}\cdot\text{m}}{\text{s}}\right)$	$p_y\left(\frac{\text{kg}\cdot\text{m}}{\text{s}}\right)$	$p_x\left(\frac{\text{kg}\cdot\text{m}}{\text{s}}\right)$	$p_y\left(\frac{\text{kg}\cdot\text{m}}{\text{s}}\right)$
Before Collision				
After Collision				

(b) Show, using the data that you listed in the table, that linear momentum is conserved in this collision.

(c) Calculate the kinetic energy of the two-object system before and after the collision.

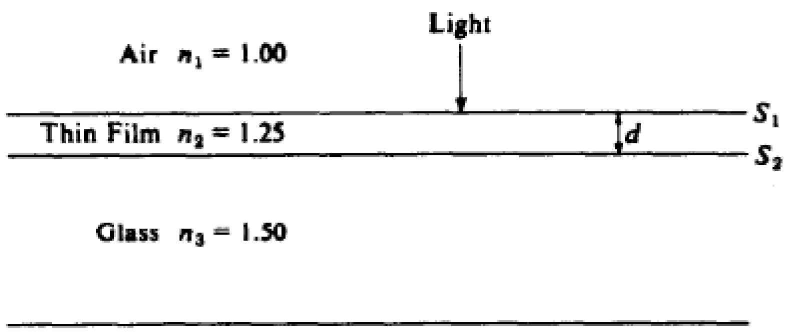
(d) Is kinetic energy conserved in the collision?

3. A heating coil is placed in a thermally insulated tank of negligible heat capacity. The tank contains 0.1 kilogram of water and 0.01 kilogram of ice, both initially at a temperature of 0° C. The resistance of the coil is 25 ohms, independent of temperature, and there is a current of 2 amperes in the coil. Calculate each of the following quantities.

   (a) The heat transferred to the water and ice by the heating coil in time t

   (b) The time t_1 necessary to melt all the ice (The latent heat of fusion of ice is 3.34×10^5 joules per kilogram.)

   (c) The additional time t_2 necessary to bring the water to a boil (The specific heat of water is 4.19×10^3 joules per kilogram·Kelvin.)



5. The surface of a glass plate (index of refraction $n_3 = 1.50$) is coated with a transparent thin film (index of refraction $n_2 = 1.25$). A beam of monochromatic light of wavelength 6.0×10^{-7} meter traveling in air (index of refraction $n_1 = 1.00$) is incident normally on surface S_1 as shown above. The beam is partially transmitted and partially reflected.

   (a) Calculate the frequency of the light.

   (b) Calculate the wavelength of the light in the thin film.

   The beam of light in the film is then partially reflected and partially transmitted at surface S_2.

   (c) Calculate the minimum thickness d_1 of the film such that the resultant intensity of the light reflected back into the air is a minimum.

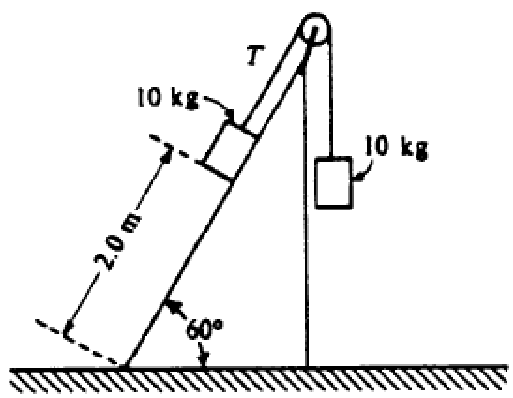
   (d) Calculate the minimum nonzero thickness d_2 of the film such that the resultant intensity of the light reflected back into the air is a maximum.

1. A 2-kilogram block initially hangs at rest at the end of two 1-meter strings of negligible mass as shown on the left diagram above. A 0.003-kilogram bullet, moving horizontally with a speed of 1000 meters per second, strikes the block and becomes embedded in it. After the collision, the bullet/block combination swings upward, but does not rotate.

   (a) Calculate the speed v of the bullet/block combination just after the collision.

   (b) Calculate the ratio of the initial kinetic energy of the bullet to the kinetic energy of the bullet/block combination immediately after the collision.

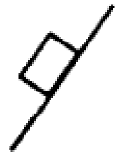
   (c) Calculate the maximum vertical height above the initial rest position reached by the bullet/block combination.



2. Two 10-kilogram boxes are connected by a massless string that passes over a massless frictionless pulley as shown above. The boxes remain at rest, with the one on the right hanging vertically and the one on the left 2.0 meters from the bottom of an inclined plane that makes an angle of 60° with the horizontal. The coefficients of kinetic friction and static friction between the left-hand box and the plane are 0.15 and 0.30, respectively. You may use $g = 10\ m/s^2$, $\sin 60° = 0.87$, and $\cos 60° = 0.50$.

   (a) What is the tension T in the string?

   (b) On the diagram below, draw and label all the forces acting on the box that is on the plane.



(c) Determine the magnitude of the frictional force acting on the box on the plane.

The string is then cut and the left-hand box slides down the inclined plane.

(d) Determine the amount of mechanical energy that is converted into thermal energy during the slide to the bottom.

(e) Determine the kinetic energy of the left-hand box when it reaches the bottom of the plane.

5. Light of wavelength 5.0×10^{-7} meter in air is incident normally on a double slit. The distance between the slits is 4.0×10^{-4} meter, and the width of each slit is negligible. Bright and dark fringes are observed on a screen 2.0 meters away from the slits.

 (a) Calculate the distance between two adjacent bright fringes on the screen.

 The entire double-slit apparatus, including the slits and the screen, is submerged in water, which has an index of refraction 1.3.

 (b) Determine each of the following for this light in water.

  i. The wavelength

  ii. The frequency

 (c) State whether the distance between the fringes on the screen increases, decreases, or remains the same. Justify your answer.

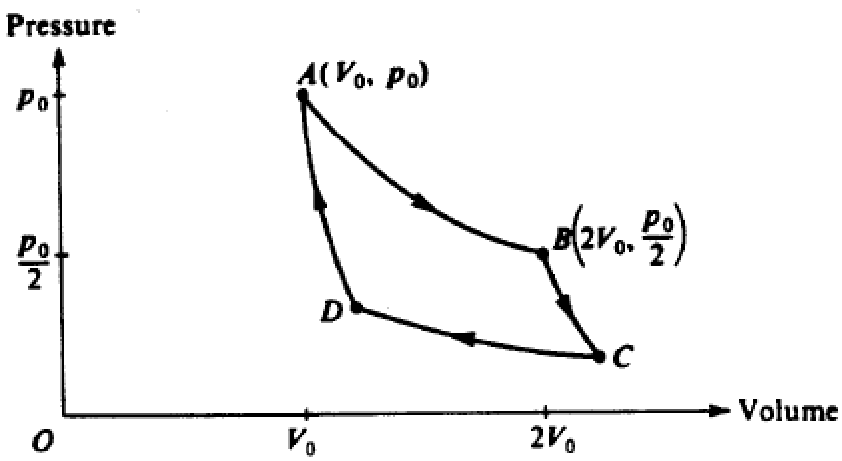
5. A proposed ocean power plant will utilize the temperature difference between surface seawater and seawater at a depth of 100 meters. Assume the surface temperature is 25° Celsius and the temperature at the 100-meter depth is 3° Celsius.

 (a) What is the ideal (Carnot) efficiency of the plant?

 (b) If the plant generates useful energy at the rate of 100 megawatts while operating with the efficiency found in part (a), at what rate is heat given off to the surroundings?

 (c) A nuclear power plant operates with an overall efficiency of 40 percent. At what rate must mass be converted into energy to give the same 100-megawatt output as the ocean power plant above? Express your answer in kilograms per second.

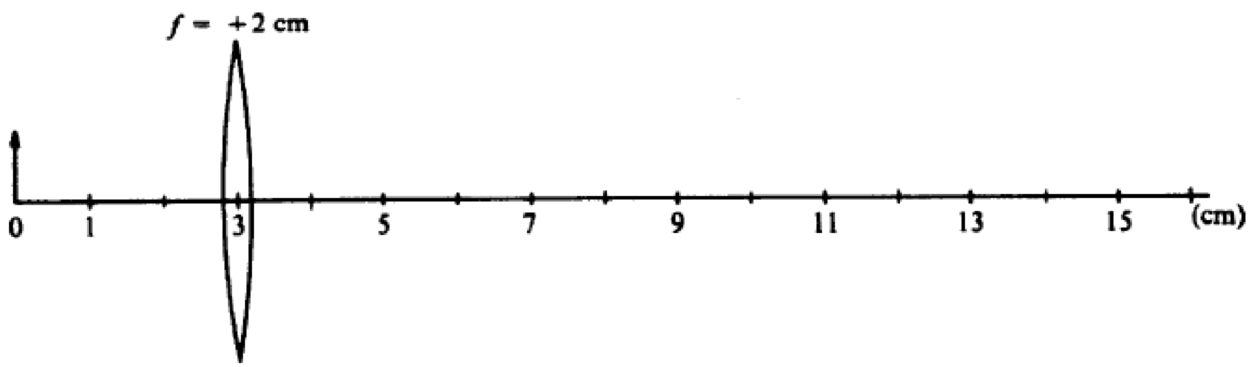
The diagram below represents the Carnot cycle for a simple reversible (Carnot) engine in which a fixed amount of gas, originally at pressure p_0 and volume V_0, follows the path $ABCDA$.



(d) In the chart below, for each part of the cycle indicate with +, −, or 0 whether the heat transferred Q and temperature change ΔT are positive, negative, or zero, respectively. (Q is positive when heat is added to the gas, and ΔT is positive when the temperature of the gas increases.)

	Q	ΔT
AB		
BC		
CD		
DA		

6. An object is placed 3 centimeters to the left of a convex (converging) lens of focal length $f = 2$ centimeters, as shown below.



(a) Sketch a ray diagram on the figure above to construct the image. It may be helpful to use a straight-edge such as the edge of the green insert in your construction.

(b) Determine the ratio of image size to object size.