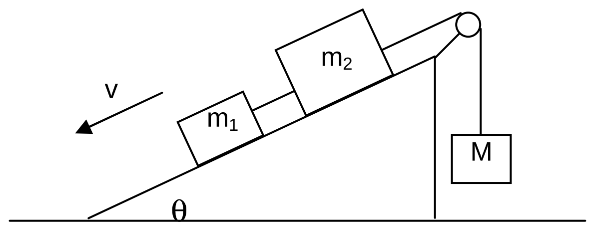
Final Test Review
- Free Response -

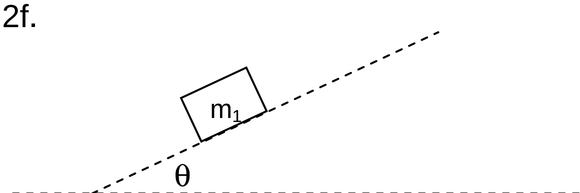
On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Show all work, because partial credit will be given. Circle your final answer(s) to each problem.

Problem #1:



Blocks 1 and 2 of masses m_1 and m_2, respectively, are connected by a light string. These blocks are further connected to a block of mass M by another light string that passes over a pulley of negligible mass and friction. Blocks 1 and 2 move with a constant velocity v down the inclined plane, which makes an angle θ with the horizontal. The kinetic frictional force on block 1 is f and that on block 2 is 2f.

a. On the given figure, draw and label all the forces on block m_1.



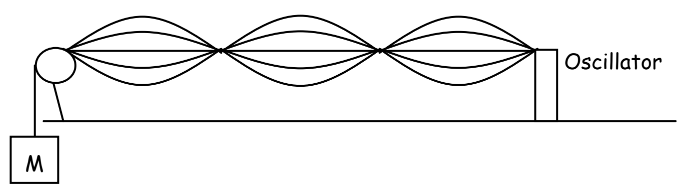
Express your answers to each of the following in terms of m_1, m_2, g, θ, f.

b. Determine the coefficient of kinetic friction between the inclined plane and block 1.

c. Determine the value of the suspended mass M that allows blocks 1 and 2 to move with constant velocity down the plane.

d. The string between blocks 1 and 2 is now cut. Determine the acceleration of block 1 while it is on the inclined plane.

Problem #2:



A string of length 3.2m is connected at one end to a mechanical oscillator with a variable frequency. The other end runs over a pulley to a mass M that hangs vertically. When the oscillator frequency is set to 200Hz, the standing wave in the diagram is set up on the string.

a. What is the wavelength of the wave in the diagram?

b. What is the wave speed on the string?

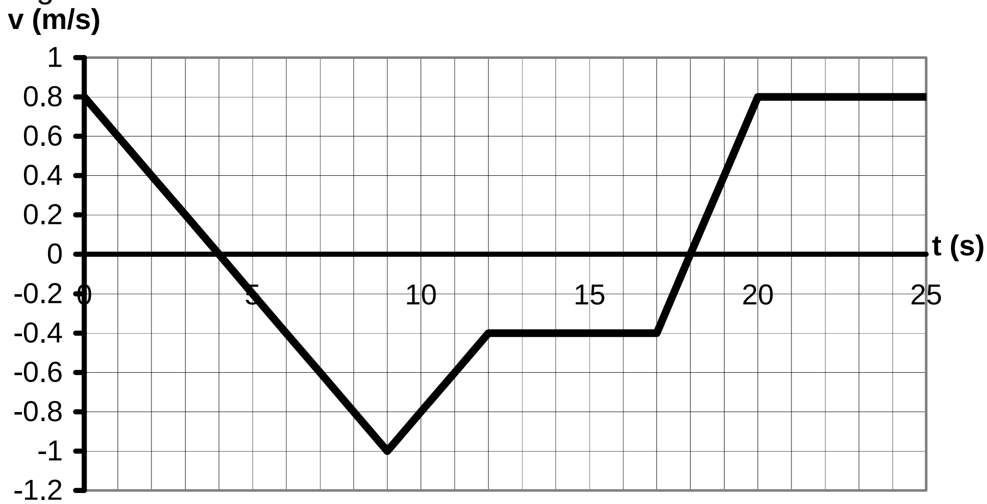
c. What is the lowest oscillation frequency that will produce a standing wave on this string?

d. Assuming the speed of sound in air to be 343m/s, what is the frequency of the sound waves created by the string when vibrating as shown in the diagram?

e. Assuming the speed of sound in air to be 343m/s, what is the wavelength of the sound waves created by the string when vibrating as shown in the diagram?

Problem #3:

A 0.5kg cart moves on a straight horizontal track. The graph of velocity v versus time t for the cart is given below.

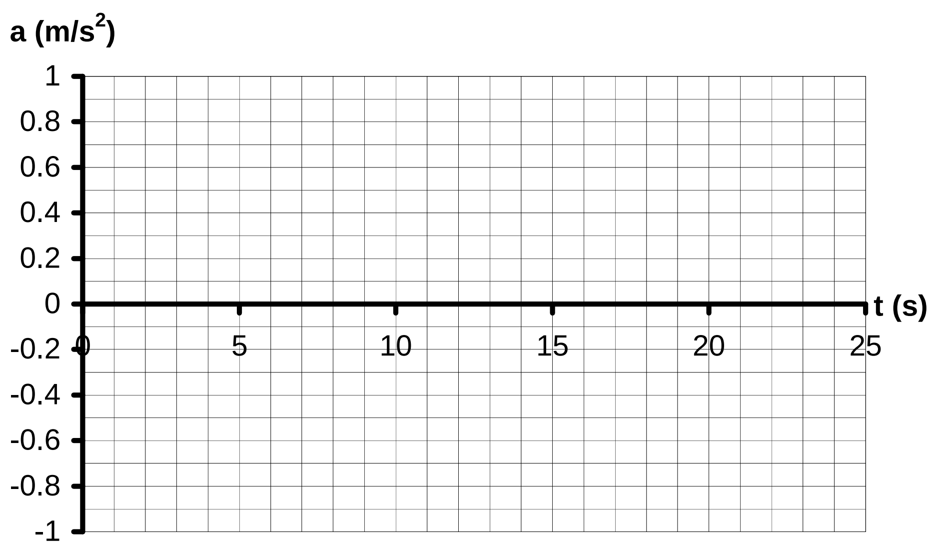


a. Indicate every time t for which the cart is at rest.

b. Indicate every time interval for which the speed (magnitude of velocity) of the cart is increasing.

c. Determine the horizontal position x of the cart at t=9.0s if the cart is located at x=2.0m at t=0.

d. On the given axes, sketch the acceleration a versus time t graph for the motion of the cart from t=0 to t=25s.

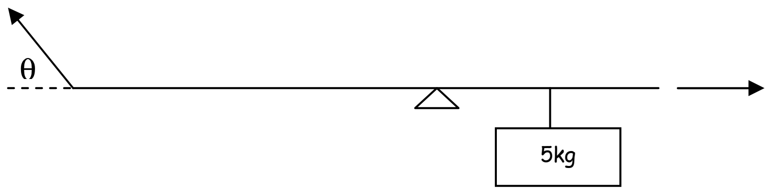


e. From t=25s until the cart reaches the end of the track, the cart continues with constant horizontal velocity. The cart then leaves the end of the track and hits the floor, which is 0.40m below the track. Neglecting air resistance, determine each of following:

i. The time from when the cart leaves the track until it first hits the floor.

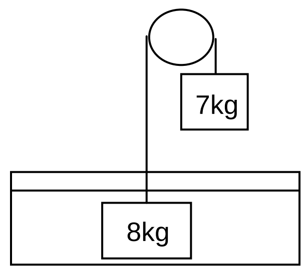
ii. The horizontal distance from the end of the track to the point at which the cart first hits the floor.

PROBLEM #4:



A 900g meterstick is placed on a pivot point, and a 5kg mass is hung from the 72cm mark. A string is tied to the left end (0cm mark), and pulls at an angle to the meterstick. One additional force acts at the right end of the meterstick (1m mark), pulling to the right. This force has the same magnitude as if it were a gravitational force between two 30kg objects separated by a distance of 3.65×10^{-5} meters. What does the tension (magnitude and direction) in the string need to be to keep this system in equilibrium, and where should the pivot point be placed, if the pivot point is to only support 80% of the weight of the system? (Note: The drawing may not have all objects/forces in the correct locations.)

PROBLEM #5:

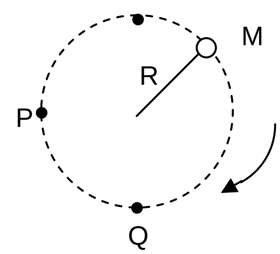


An 8kg block and a 7kg block are hung over a frictionless, massless pulley, as shown. The 8kg mass is fully submerged in a container of a fluid. The dimensions of the 8kg block are 8cm×30cm×10cm.

a. If the fluid is water, what is the acceleration of the 7kg block as it falls? (Ignore water resistance as the 8kg block moves upward through the water.)

b. What would the density of the fluid need to be in order for the system to be in equilibrium?

PROBLEM #6:



A ball of mass M is attached to a string of length R and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point P, the string is horizontal. Point Q is at the bottom of the circle and point Z is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

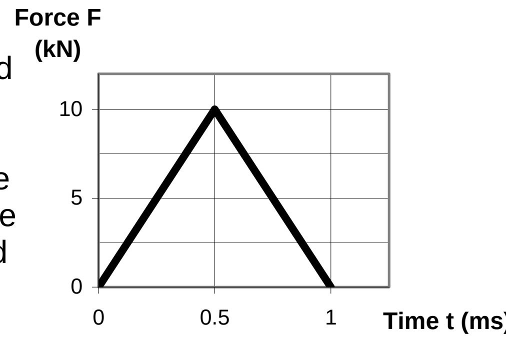
a. Derive an expression for v_{min}, the minimum speed the ball can have at point Z without leaving the circular path.

b. The maximum tension the string can have without breaking is T_{max}. Derive an expression for v_{max}, the maximum speed the ball can have at point Q without breaking the string.

c. Suppose that the string breaks at the instant the ball is at point P. Describe the motion of the ball immediately after the string breaks.

PROBLEM #7:

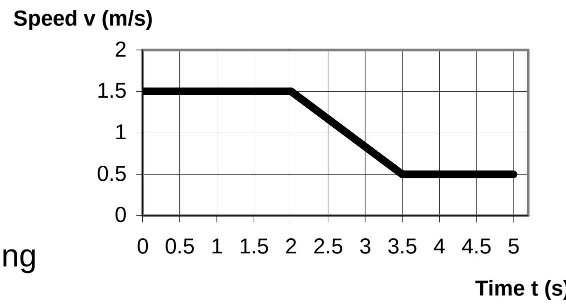
A 2.0kg frictionless cart is moving at a constant speed of 3.0m/s to the right on a horizontal surface, as shown above, when it collides with a second cart of undetermined mass M that is initially at rest. The force F of the collision as a function of time t is shown in the graph to the right, where t=0 is the instant of initial contact. As a result of the collision, the second cart acquires a speed of 1.5m/s to the right. Assume that friction is negligible before, during, and after the collision.



a. Calculate the magnitude and direction of the velocity of the 2.0kg cart after the collision.

b. Calculate the mass M of the second cart.

After the collision, the second cart eventually experiences a ramp, which it transverses with no frictional losses. The graph below shows the speed v of the second cart as a function of time t for the next 5s, where t=0 is now the instant at which the carts separate.



c. Calculate the acceleration of the cart at t=3.0s.

d. Calculate the distance traveled by the second cart during the 5.0s interval after the collision.

e. State whether the ramp goes up or down and calculate the maximum elevation (above or below the initial height) reached by the second cart during the 5.0s interval after the collision.

PROBLEM #8:

While exploring a sunken ocean liner, the principal researcher found the absolute pressure on the robot observation submarine at the level of the ship to be about 413 atmospheres. The density of seawater is 1025kg/m^3.

a. Calculate the gauge pressure on the sunken ocean liner.

b. Calculate the depth D of the sunken ocean liner.

c. Calculate the magnitude F of the force due to the water on a viewing port of the submarine at this depth, if the viewing port has a surface area of 0.01m^2.

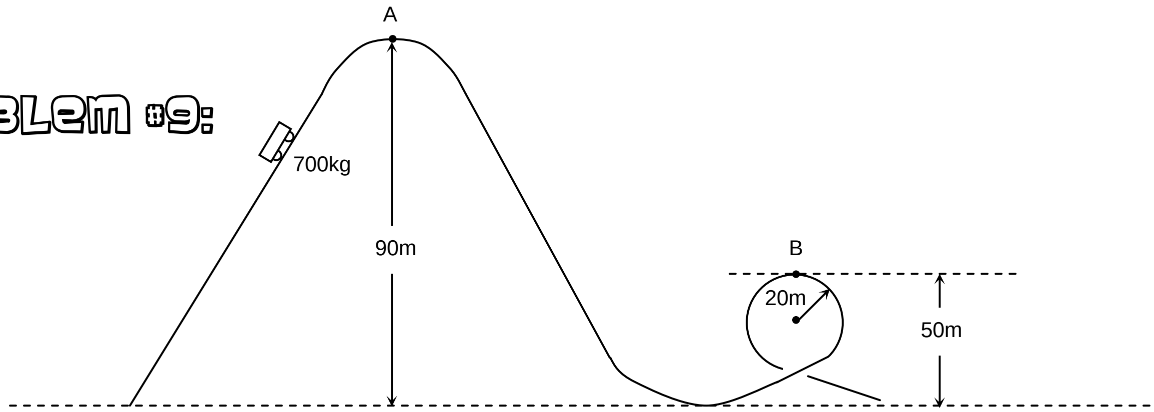
Suppose that the ocean liner had come to rest at the surface of the ocean before it had started to sink. Due to the resistance of the seawater, the sinking ocean liner then reached a terminal velocity of 10m/s after falling for 30s.

d. Determine the magnitude a of the average acceleration of the ocean liner during this period of time.

e. Assuming the acceleration was constant, calculate the distance d below the surface at which the ocean liner reached this terminal velocity.

f. Calculate the time t it took the ocean liner to sink from the surface to the bottom of the ocean.

PROBLEM #9:



A roller coaster ride at an amusement park lifts a car of mass 700kg to point A at a height of 90m above the lowest point on the track, as shown. The car starts from rest at point A, rolls with negligible friction down the incline and follows the track around a loop of radius 20m. Point B, the highest point on the loop, is at a height of 50m above the lowest point on the track.

a. Indicate on the figure the point P at which the maximum speed of the car is attained.

b. Calculate the value v_{max} of this maximum speed.

c. Calculate the magnitude of all the forces acting on the car when it is upside down at point B.

d. In order to stop the car at point B, some friction must be introduced. Calculate the work that must be done by the friction force in order to stop the car at point B.

PROBLEM #10:

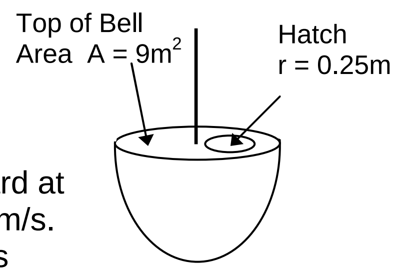
A 0.42kg mass is pressed against a horizontal spring (k=130N/m), compressing it by 55 cm. The mass is released, and the spring pushes it forward along a horizontal, frictionless surface with an average force of 35.75N. As the block slides, it encounters a rough, inclined plane tilted 30° above the horizontal. Friction on the incline slows down the mass by pushing back on it with a force of 0.25N. Use energy, work, and impulse ideas to find the following:

a. For how long is the spring in contact with the block, after it is released?

b. How fast is the mass going when it hits the bottom of the incline?

c. How far along the incline does the mass travel before coming to a stop?

PROBLEM #11:



The experimental diving bell shown in the diagram is lowered from rest at the ocean's surface and reaches a maximum depth of 80m. Initially it accelerates downward at a rate of $0.1 m/s^2$ until it reaches a terminal velocity of 2m/s. During the descent, the pressure inside the bell remains constant at 1 atmosphere (1.01×10^5 Pa). The top of the bell has a cross-sectional area $A = 9.0 m^2$, and on top of the bell there is a circular hatch of radius 0.25m. The density of seawater is $1025 kg/m^3$.

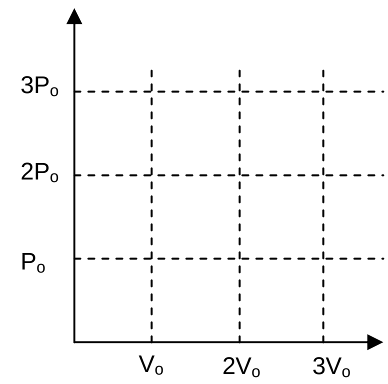
a. Calculate the total time it takes the bell to reach the maximum depth of 80m.

b. Calculate the weight of the water on top of the bell when it is at the maximum depth.

c. Calculate the absolute pressure on the top of the bell at the maximum depth.

d. Calculate the net force acing on the circular hatch of the bell at the maximum depth.

PROBLEM #12:



1 mole of ideal gas is to be used as a working substance in a heat engine. Initially, the gas is at a pressure P_o and volume V_o. It then undergoes the following set of processes:

I. $3P_oV_o$ Joules of heat is added to the gas, as its pressure increases at constant volume to $3P_o$.

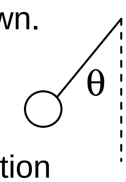
II. With the addition of $Q = 3.3P_oV_o$ of heat, the gas now expands isothermally to a volume of $3V_o$.

III. Then the gas is compressed at constant pressure back to its initial state.

a. Draw the PV diagram for this cycle. Label each vertex with the appropriate temperature.
b. Determine the work done on the gas in process II.
c. Determine the work done on the gas in process III.
d. Determine the change in internal energy for the entire cycle.
e. Determine the efficiency of the engine.

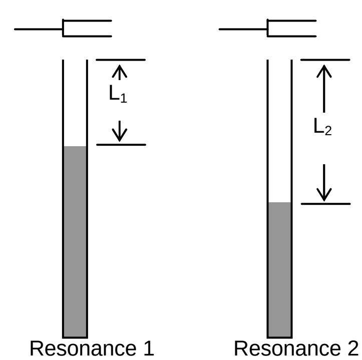
PROBLEM #13:

An airplane accelerates uniformly from rest. A physicist passenger holds up a thin string of negligible mass to which she has tied her ring of mass m, notices that as the plane accelerates down the runway, the string makes an angle θ with the vertical, as shown.



a. Draw a free-body diagram of the ring, showing and labeling all forces present.
The plane reaches a takeoff speed of 65m/s after accelerating for a total of 30s.
b. Determine the length of runway needed.
c. Determine the angle θ that the string makes with the vertical during the acceleration of the plane before it leaves the ground.
d. What additional information would be needed in order to estimate the mechanical energy of the airplane at the instant of takeoff?

PROBLEM #14:

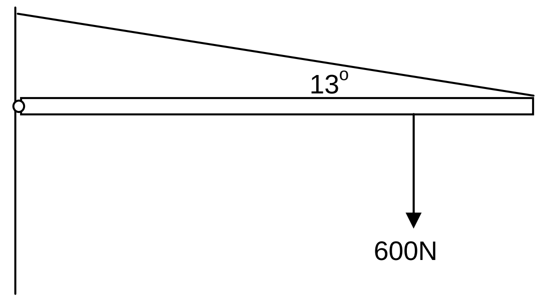


A vibrating tuning fork is held above a column of air, as shown in the diagrams to the right. The water level is raised and lowered to change the length of the column of air. The shortest length of air-column that produces a resonance is $L_1 = 0.25$m, and the next resonance is heard when the air column has length $L_2 = 0.75$m. The speed of sound in air at 20^oC is 343m/s, and the speed of sound in water is 1490m/s.

a. Calculate the wavelength of the standing sound wave produced by this tuning fork.
b. Calculate the frequency of the tuning fork that produces the standing wave, assuming the air is at 20^oC.
c. Calculate the wavelength of the sound waves produced by this tuning fork in the water.
d. The water level is lowered again until a third resonance is heard. Calculate the length L_3 of the air column that produces this third resonance.
e. The student performing this lab notices that the temperature in the room is actually slightly higher than 20^oC. Is the calculation of the frequency found in part b too high, too low, or still correct? Justify your answer.

PROBLEM #15:

A 600N person hangs from a rope that is tied 80cm from the right end of a 3m-long horizontal beam. The weight of the beam is 200N. The left end of the rod is supported by a hinge and the right end is supported by a thin cable making a 13^o angle with the horizontal, as shown in the picture. Find the tension in the cable, and the horizontal and vertical components of force exerted on the left end of the rod by the hinge.

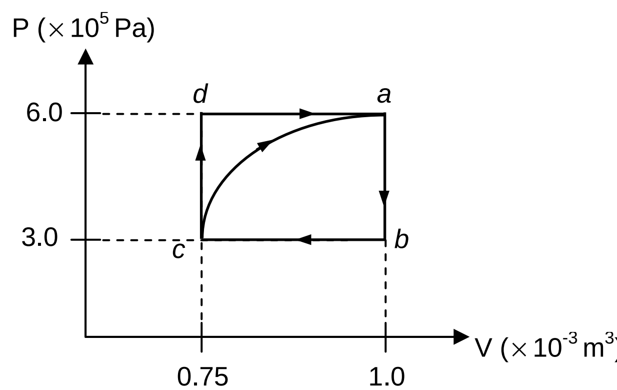


PROBLEM #16:

A cylinder with a movable piston contains 0.1 mole of a monatomic ideal gas. The gas, initially at state *a*, can be taken through either of two cycles, *abca* or *abcda*, as shown on the PV diagram above. The following information is known about this system…

$Q_{c\to a} = 685\text{J}$ along the curved path. $U_a - U_b = 450\text{J}$

$W_{c\to a} = -120\text{J}$ along the curved path $W_{a\to b\to c} = 75\text{J}$



a. Calculate the temperature of the gas when it is at state *a*.
b. Determine the change in internal energy, $U_a - U_c$, between states *a* and *c*.
c. Calculate the work done by the gas in the process *cda*.
d. i. Is heat added to or removed from the gas when the gas is taken along path *cda*? Explain your reasoning.
ii. Calculate the amount of heat added or removed along the path *cda*.
e. After one complete cycle along the path *abca*, is the internal energy of the gas greater, less, or the same as before? Justify your answer.

PROBLEM #17:

A large rectangular raft (density 650kg/m^3) is floating on a lake. The surface area of the top of the raft is 8.2m^2 and its volume is 1.80m^3. The density of the lake water is 1000kg/m^3.
a. Calculate the height of the portion of the raft that is above the surrounding water.
b. Calculate the magnitude of the buoyant force on the raft, and state its direction.
c. If the average mass of a person is 75kg, calculate the maximum number of people that can be on the raft without the top of the raft sinking below the surface of the water. (Assume that the people are evenly distributed on the raft.)