AP PHYSICS B SUMMER REVIEW PACKET 2011 - 2012

Table of Contents Page(s)

AP PHYSICS B

SUMMER REVIEW PACKET

OBJECTIVE:

A great deal of the AP Physics B curriculum was covered in your Honors Physics class. The purpose of this review packet is to allow you to review and where necessary, strengthen your knowledge of physics in some of the areas covered in Honors Physics. This packet includes 12 actual AP B Free Response questions from Past AP Exams. These problems should give you a good idea of the level of difficulty of problems you will need to do for homework and on tests in our AP class.

This review packet covers most of the Newtonian Mechanics Unit. This unit has six sub-topics. Each sub-topic will have the following sections:

1) STUDENT OBJECTIVES (This is the AP's own list of student objectives for the AP B course)
2) CONCEPT DEVELOPMENT QUESTIONS (*Similar* to AP multiple-choice questions)
3) PROCEDURE for SOLVING PROBLEMS INVOLVING *PHYSICS* (Basic steps to aid you in problem solving)
4) ACTUAL AP B FREE RESPONSE PROBLEMS (Actual AP problems for you to complete)

<u>You will keep the entire review packet, I will not be collecting it or grading it.</u> However, there may be test questions during the first marking period with similarities to some of the questions from the review packet. Having done these problems in advance will put you at an advantage on the day of the test.

Please bring this packet in a three ring binder or folder on the first day of class, and every day for the first marking period. We will spend time in class going over many of the questions.

If you have any questions do not hesitate to ask me. You can best get in touch with me by email.
My address: mr.twalsh@gmail.com (don't forget the period) or twalsh@livingston.org

Topics in RED are topics that have been covered nearly in their entirety in the Honors Physics course. In these areas, we will do a brief review and then be tested. This review packet is intended to help you review the NEWTONIAN MECHANICS unit. Other smaller review assignments will be distributed during the school year in order to go over the other areas that were covered in honors.

AP PHYSICS B

CONTENT OUTLINE

UNIT	TOPIC		PERCENT of EXAM
I.	NEWTONIAN MECHANICS		35%
	A. KINEMATICS	(7%)	
	B. NEWTON'S LAWS of MOTION	(9%)	
	C. WORK, ENERGY, and POWER	(5%)	
	D. SYSTEMS of PARTICLES, LINEAR MOMENTUM	(4%)	
	E. CIRCULAR MOTION and ROTATION	(4%)	
	F. OSCILLATIONS and GRAVITATION	(6%)	
II.	FLUID MECHANICS and THERMAL PHYSICS		15%
	A. FLUID MECHANICS	(5%)	
	B. TEMPERATURE and HEAT	(3%)	
	C. KINETIC THEORY and THERMODYNAMICS	(7%)	
III.	ELECTRICITY and MAGNETISM		25%
	A. ELECTROSTATICS	(5%)	
	B. CONDUCTORS and CAPACITORS	(4%)	
	C. ELECTRIC CIRCUITS	(7%)	
	D. MAGNETOSTATICS	(4%)	
	E. ELECTROMAGNETISM	(5%)	
IV.	ATOMIC and NUCLEAR PHYSICS		10%
	A. ATOMIC PHYSICS and QUANTUM EFFECTS	(7%)	
	B. NUCLEAR PHYSICS	(3%)	
V.	WAVES and OPTICS		15%
	A. WAVE MOTION	(5%)	
	B. PHYSICAL OPTICS	(5%)	
	C. GEOMETRIC OPTICS	(5%)	

NOTE: This is the material covered by this summer review packet

Material Covered in this Summer Review Packet:

I. NEWTONIAN MECHANICS

CONTENT OUTLINE

A. KINEMATICS

1. MOTION in ONE DIMENSION
2. MOTION in TWO DIMENSIONS

B. NEWTON'S LAWS of MOTION

1. STATIC EQUILIBRIUM
2. DYNAMICS of a SINGLE PARTICLE
3. SYSTEMS of TWO or MORE BODIES

C. WORK, ENERGY, and POWER

1. WORK and the WORK-ENERGY THEOREM
2. CONSERVATIVE FORCES and POTENTIAL ENERGY
3. CONSERVATION of ENERGY
4. POWER

D. SYSTEMS of PARTICLES, LINEAR MOMENTUM

1. IMPULSE and MOMENTUM
2. CONSERVATION of LINEAR MOMENTUM, COLLISIONS

E. CIRCULAR MOTION and ROTATION

1. UNIFORM CIRCULAR MOTION
2. TORQUE and ROTATIONAL STATICS

F. OSCILLATIONS and GRAVITATION

1. SIMPLE HARMONIC MOTION
2. MASS on a SPRING
3. The PENDULUM and OTHER OSCILLATIONS
4. NEWTON'S LAW of GRAVITY
5. CIRCULAR ORBITS of PLANETS and SATELLITES

A. STUDENT OBJECTIVES for KINEMATICS

1. MOTION in ONE DIMENSION

a. You should understand the general relationships among position, velocity, and acceleration for the motion of a particle along a straight line, so you can:

i. Given a graph of one of the kinematic quantities, position, velocity, or acceleration, as a function of time, you can recognize in what time intervals the other two are positive, negative, or zero, and can identify or sketch a graph of each as a function of time.

b. You should understand the special case of motion with constant acceleration so you can:

i. Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities.

ii. Use the equations of motion:

$$v = v_o + at$$

$$x = x_o + v_o t + (1/2)\, at^2$$

$$v^2 - v_o^2 = 2a(x - x_o)$$

to solve problems involving one-dimensional motion with constant acceleration.

2. MOTION in TWO DIMENSIONS

a. You should know how to deal with displacement and velocity vectors so you can:

i. Relate velocity, displacement, and time for motion with constant velocity.

ii. Calculate the component of a vector along a specified axis, or resolve a vector into components along two specified mutually perpendicular axes.

iii. Add vectors in order to find the net displacement of a particle that undergoes successive straight line displacements.

iv. Subtract displacement vectors in order to find the location of one particle relative to another, or calculate the average velocity of a particle.

v. Add or subtract velocity vectors in order to calculate the velocity change or average acceleration of a particle, or the velocity of one particle relative to another.

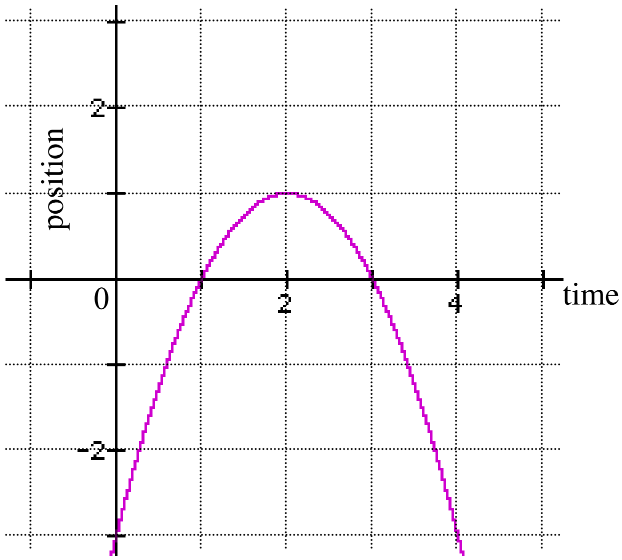
b. You should understand the motion of projectiles in a uniform gravitational field so you can:

i. Write down expressions for the horizontal and vertical components of velocity and position as functions of time, and sketch or identify graphs of these components.

ii. Use these expressions in analyzing the motion of a projectile that is projected above level ground with a specified initial velocity.

GRAPHICAL ANALYSIS of MOTION

1. The figure below is a graph of the position (y) vs. time (x) for a particle confined to one-dimensional motion.



(i) At time t = 0, what is the sign of the particle's position?

Is the particle's velocity positive, negative, or zero at
(ii) t = 1 s
(iii) t = 2 s
(iv) t = 3 s?
(v) How many times does the particle go through the point x = 0?

2. At t = 0, a particle moving along the x axis is at position X_0 = -20 m. The signs of the particle's initial velocity v_0 (at time t_0) and constant acceleration, a are, respectively, for four situations:

(1) +, +   (2) +, -   (3) -, +   (4) -, -

In which situation or situations will the particle
(i) Undergo a momentary stop
(ii) Definitely pass through the origin (given enough time)
(iii) Definitely not pass through the origin?

3. The initial and final velocities, respectively, of a particle in four situations are:

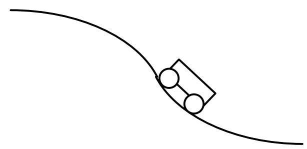
(i) v_o = 2 m/s, v_f = 3 m/s   (ii) v_o = - 2 m/s, v_f = 3 m/;
(iii) v_o = - 2 m/s, v_f = - 3 m/s   (iv) v_o = 2 m/s, v_f = - 3 m/s

The magnitude of the particle's constant acceleration is the same in all four situations. Rank the situations according to the magnitude of the particle's displacement, greatest first, during the change from initial to final velocity.

1. A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown

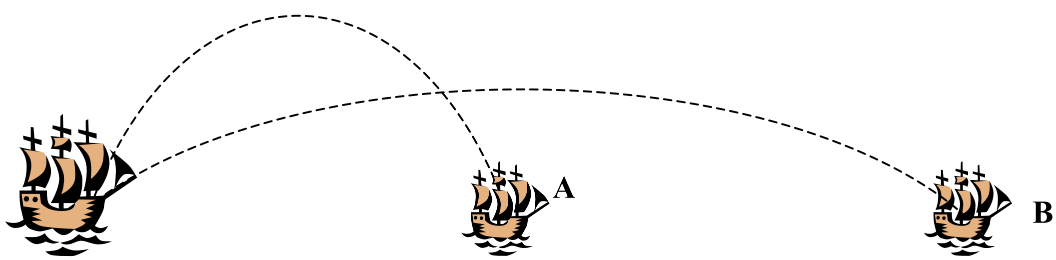
a. Upward. b. Downward. c. Neither they both hit at the same speed.

2. A cart on a roller coaster rolls down the track shown below. As the cart rolls beyond the point shown, what happens to its speed and acceleration in the direction of motion?



a. Both decrease. b. The speed decreases, but the acceleration increases.
c. Both remain constant. d. The speed increases, but acceleration decreases.
e. Both increase. f. Other

3. A ship simultaneously fires two cannonballs at enemy ships. If the balls follow the parabolic trajectories shown, which ship gets hit first?



a. A b. B
c. Both hit at the same time d. Need more information

4. Consider this situation. A gun is accurately aimed at a dangerous criminal hanging from the gutter of a building. The target is well within the guns range, but the instant the gun is fired and the bullet moves with a speed v_0, the criminal lets go and drops to the ground. What happens?

The bullet:

a. Hits the criminal regardless of the value of v_0.
b. Hits the criminal only if v_0 is large enough.
c. Misses the criminal.

PROCEDURE for SOLVING PROBLEMS INVOLVING KINEMATICS

The kinematic equations of motion may be used to solve any problem in one dimensional motion with constant acceleration. The best way to gain confidence in the use of these equations is to work a number of problems. Many times you will discover that there is more than one method for solving a given problem.

To be successful in a physics course it is necessary to be able to solve problems.
The following procedure should prove helpful in solving the physics problems assigned.
First, as a preliminary step, read the appropriate topic in the textbook.
Do not attempt to solve the problems before doing this.
Look at the appropriate illustrative examples to see how they are solved.
With this background, now read the assigned problem.
Now continue with the following procedure.

1. Draw a small picture showing the details of the problem. This is very useful so that you do not lose sight of the problem that you are trying to solve.
2. List all the information that you are given.
3. List all the answers you are expected to find.
4. From the summary of important equations, list the equations that are appropriate to this topic.
5. Pick the equation that relates the variables that you are given.
6. Place a check mark over each variable that is given and a question mark over each variable that you are looking for.
7. Solve the equation for the unknown variable on the LHS of the equation.
8. Plug in the known variables.
9. Compute the answer.
10. When the answer is obtained, check to see if the answer is reasonable.

Problem-Solving Strategy Accelerated Motion

The following procedure is recommended for solving problems involving accelerated motion:

1. Make sure all the units in the problem are consistent. That is, if distance is measured in meters, be sure that velocities have units of meters per second and accelerations have units of meters per second per second.
2. Chose a coordinate system.
3. Make a list of all the quantities given in the problem and a separate list of those to be determined.
4. Select from the list of kinematic equations the one or ones that will enable you to determine the unknowns.
5. Construct an appropriate motion diagram, and check to see if your answers are consistent with the diagram.

PROCEDURE for SOLVING PROBLEMS INVOLVING 2D KINEMATICS

Problem-Solving Strategy Adding Vectors

When two or more vectors are to be added, the following steps are used.

1 Select a coordinate system.

2. Draw a sketch of the vectors to be added (or subtracted), with a label on each vector.

3. Find the x and y components of all vectors.

4. Find the resultant components (the algebraic sum of the components) in both the x and y directions.

5. Use the Pythagorean theorem to find the magnitude of the resultant vector.

6. Use a suitable trigonometric function to find the angle the resultant vector makes with the x axis.

Projectile Motion

I suggest that you use the following approach to solving projectile motion problems:

1. Select a coordinate system.

2. Resolve the initial velocity vector into x and y components.

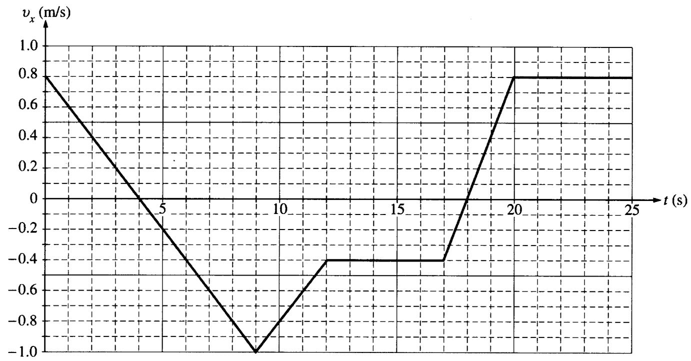
3. Treat the horizontal motion and the vertical motion independently.

4. Follow the techniques for solving problems with constant velocity to analyze the horizontal motion of the projectile.

5. Follow the techniques for solving problems with constant acceleration to analyze the vertical motion of the projectile.

1) Free Response Problem 1

A 1.50 kg cart moves on a straight horizontal track. The graph of velocity *v* versus time *t* for the cart is given below.

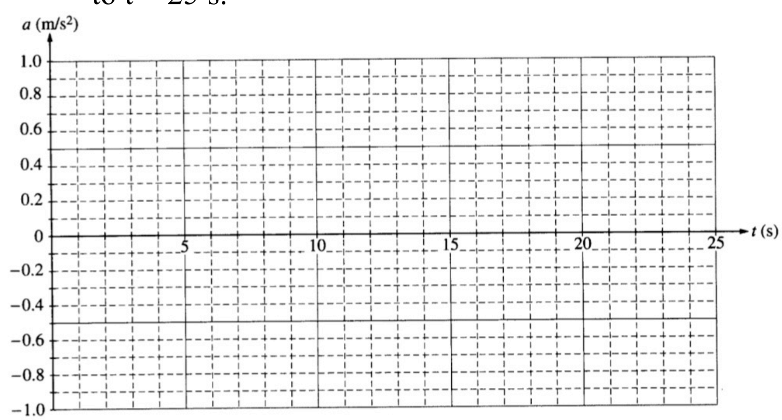


a. Indicate every time t for which the cart is at rest.

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 = 9.0 s if the cart is located at x = 2.0 m at t = 0.

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



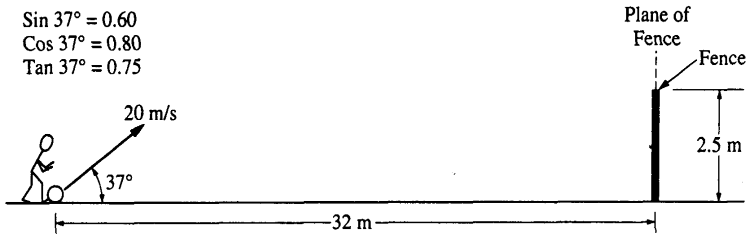
e. From t = 25 s until the cart reaches the end of the track, the cart continues with constant horizontal velocity. The cart leaves the end of the track and hits the floor, which is 0.40 m below the track. Neglecting air resistance, determine each of the following:

   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

   iii. The kinetic energy of the cart immediately before it hits the floor

Free Response Problem 2



Note: Diagram not drawn to scale.

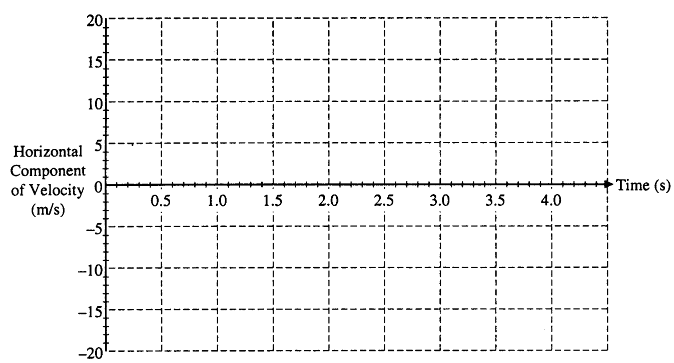
2) A ball of mass 0.5 kilogram, initially at rest, is kicked directly toward a fence from a point 32 meters away, as shown above. The velocity of the ball as it leaves the kicker's foot is 20 meters per second at an angle of 37° above the horizontal. The top of the fence is 2.5 meters high. The kicker's foot is in contact with the ball for 0.05 second. The ball hits nothing while in flight and air resistance is negligible.

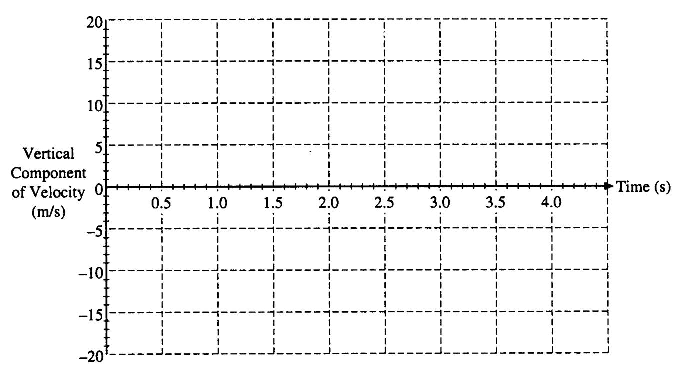
a. Determine the magnitude of the average net force exerted on the ball during the kick.

b. Determine the time it takes for the ball to reach the plane of the fence.

c. Will the ball hit the fence? If so, how far below the top of the fence will it hit? If not, how far above the top of the fence will it pass?

d. On the axes below, sketch the horizontal and vertical components of the velocity of the ball as functions of time until the ball reaches the plane of the fence.





B. STUDENT OBJECTIVES for NEWTON'S LAWS of MOTION

1. STATIC EQUILIBRIUM (First Law)

   a. You should be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

2. DYNAMICS of a SINGLE PARTICLE (Second Law)

   a. You should understand the relation between the force that acts on a body and the resulting change in the body's velocity so you can:

      i. Calculate, for a body moving in one direction, the velocity change that results when a constant force F acts over a specified time interval.

      ii. Determine, for a body moving in a plane whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the body.

   b. You should understand how Newton's Second Law, F = ma, applies to a body subject to forces such as gravity, the pull of strings, or contact forces, so you can:

      i. Draw a well-labeled diagram showing all real forces that act on the body

      ii. Write down the vector equation that results from applying Newton's Second Law to the body, and take components of this equation along appropriate axes.

   c. You should be able to analyze situations in which a body moves with specified acceleration under the influence of one or more forces so you can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as:

      i. Motion up or down with constant acceleration (e.g. in an elevator)

      ii. Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).

      iii. Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).

   d. You should understand the significance of the coefficient of friction so you can:

      i. Write down the relationship between the normal and frictional forces on a surface.

      ii. Analyze situations in which a body slides down a rough inclined plane or is pulled or pushed across a rough surface.

      iii. Analyze static situations involving friction to determine under what circumstances a body will start to slip, or to calculate the magnitude of the force of static friction.

3. SYSTEMS of TWO or MORE BODIES (THIRD LAW)

   a. You should understand Newton's Third Law so that, for a given force, you can identify the body on which the reaction force acts and state the magnitude and direction of this reaction.

   b. You should be able to apply Newton's Third Law in analyzing the force of contact between two bodies that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another.

1. A constant force is exerted on a cart that is initially at rest on an air track.
Friction between the cart and the track is negligible. The force acts for a short time interval and gives the cart a certain final speed. To reach the same final speed with a force that is only half as big, the force must be exerted on the cart for a time interval

a. Four times as long as

b. Twice as long as

c. Equal to

d. Half as long as

e. A quarter of that for the stronger force.

2. A constant force is exerted for a short time interval on a cart that is initially at rest on an air track. This force gives the cart a certain final speed. The same force is exerted for the same length of time on another cart, also initially at rest, that has twice the mass of the first one.
The final speed of the heavier cart is

a. One-fourth

b. Four times

c. Half

d. Double

e. The same as that of the lighter cart.

3. A constant force is exerted for a short time interval on a cart that is initially at rest on an air track. This force gives the cart a certain final speed. Suppose we repeat the experiment but, instead of starting from rest, the cart is already moving with constant speed in the direction of the force at the moment we begin to apply the force. After we exert the same constant force for the same short time interval, the increase in the cart's speed

a. Is equal to two times its initial speed.

b. Is equal to the square of its initial speed.

c. Is equal to four times its initial speed.

d. Is the same as when it started from rest.

e. Cannot be determined from the information provided.

4. Consider a person standing in an elevator that is accelerating upward. The upward normal force N exerted by the elevator floor on the person is

   a. Larger than

   b. Identical to

   c. Smaller than the downward weight W of the person.

5. A locomotive pulls a series of wagons. Which is the correct analysis of the situation?

   a. The train moves forward because the locomotive pulls forward slightly harder on the wagons than the wagons pull backward on the locomotive.

   b. Because action always equals reaction, the locomotive cannot pull the wagons the wagons pull backward just as hard as the locomotive pulls forward, so there is no motion.

   c. The locomotive gets the wagons to move by giving them a tug during which the force on the wagons is momentarily greater than the force exerted by the wagons on the locomotive.

   d. The locomotive's force on the wagons is as strong as the force of the wagons on the locomotive, but the frictional force on the locomotive is forward and large while the backward frictional force on the wagons is small.

   e. The locomotive can pull the wagons forward only if it weighs more than the wagons.

6. A car rounds a curve while maintaining a constant speed.

   Is there a net force on the car as it rounds the curve?

   a. No, its speed is constant.

   b. Yes.

   c. It depends on the sharpness of the curve and the speed of the car.

PROCEDURE for SOLVING PROBLEMS INVOLVING NEWTON'S LAWS of MOTION

It is neither possible nor desirable to follow blindly a prescribed set of rules in solving problems involving Newton's laws. Nevertheless, the following procedure is generally useful.

1. Draw a simple, clear diagram.

2. Choose the object whose motion is to be analyzed. It is often helpful to draw this object, isolated from its surroundings, on a separate diagram. This drawing is called a force diagram, or a free-body diagram.

3. Draw all the forces acting on the chosen object, for example, the body's weight, forces applied by objects with which the chosen object is in contact, and noncontact forces (in addition to the weight), such as electric and magnetic forces which may act on the body. (Remember that when we apply Newton's second law, we are concerned only with the external forces acting on the chosen object. It is true, of course, that the chosen body exerts forces on its surroundings, but such forces are irrelevant because they do not act on the chosen object.) Indicate on the force diagram the magnitude and direction of each force, if known; otherwise, choose symbols to represent the unknown forces.

4. Choose appropriate axes for finding the components of the forces. By a judicious choice of axes one can often simplify the computation of force components. Then resolve each force vector into its components along the chosen axes.

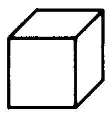
5. Use the component form of Newton's second law, to solve algebraically for the unknowns.

Actual AP B PROBLEMS for the STUDY of NEWTON'S LAWS of MOTION

Free Response Problem 3

A helicopter holding a 70-kilogram package suspended from a rope 5.0 meters long accelerates upward at a rate of 5.2 m/s^2. Neglect air resistance on the package.

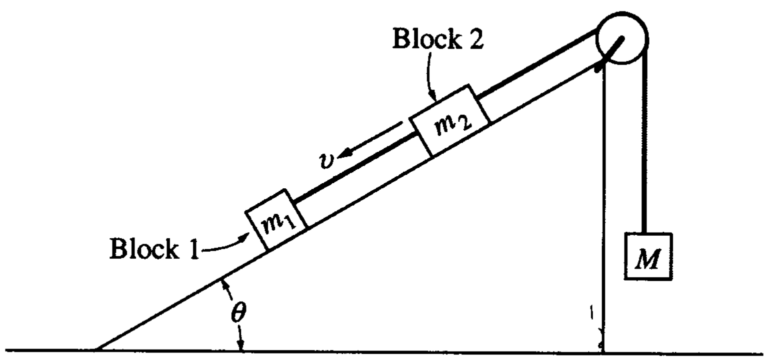
a. On the diagram below, draw and label all of the forces acting on the package.



b. Determine the tension in the rope.

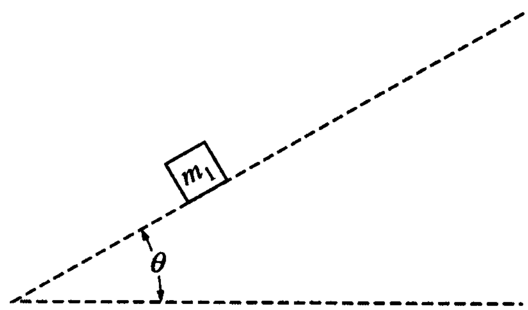
c. When the upward velocity of the helicopter is 30 meters per second, the rope is cut and the helicopter continues to accelerate upward at 5.2 m/s^2. Determine the distance between the helicopter and the package 3.0 seconds after the rope is cut.

Free Response Problem 4



Blocks 1 and 2 of masses m_1 and m_2, respectively, are connected by a light string, as shown above. 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 l 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 figure below, 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, and 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.

C. STUDENT OBJECTIVES for WORK, ENERGY, and POWER

1. WORK and the WORK-ENERGY THEOREM

 a. You should understand the definition of work so you can:

  i. Calculate the work done by a specified constant force on a body that undergoes a specified displacement.

  ii. Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position.

 b. You should understand the work-energy theorem so you can:

  i. Calculate the change in kinetic energy or speed that results from performing a specified amount of work on a body.

  ii. Calculate the work performed by the net force, or by each of the forces that makes up the net force, on a body that undergoes a specified change in speed or kinetic energy.

  iii. Apply the theorem to determine the change in a body's kinetic energy and speed that results from the application of specified forces, or to determine the force that is required in order to bring a body to rest in a specified distance.

2. CONSERVATIVE FORCES and POTENTIAL ENERGY

 a. You should understand the concept of potential energy so you can:

  i. Write an expression for the force exerted by an ideal spring and for the potential energy stored in a stretched or compressed spring.

  ii. Calculate the potential energy of a single body in a uniform gravitational field.

3. CONSERVATION of ENERGY

 a. You should understand conservation of energy so you can:

  i. Identify situations in which mechanical energy is or is not conserved.

  ii. Apply conservation of energy in analyzing the motion of bodies that are moving in a gravitational field and are subject to constraints imposed by strings or surfaces.

  iii. Apply conservation of energy in analyzing the motion of bodies that move under the influence of springs.

4. POWER

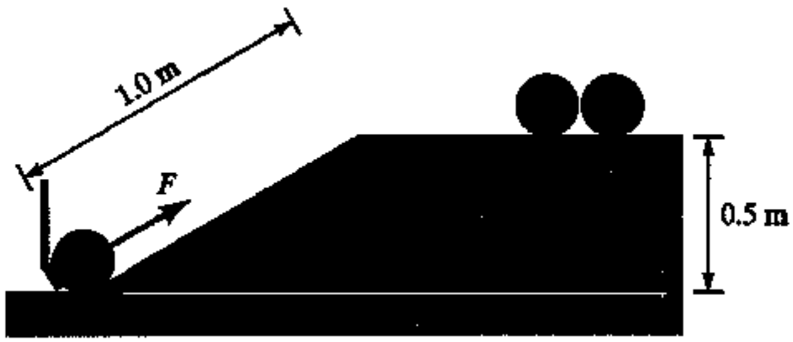
 a. You should understand the definition of power so you can:

  i. Calculate the power required to maintain the motion of a body with constant acceleration. (e.g., to move a body along a level surface, to raise a body at a constant rate, or to overcome friction for a body that is moving at a constant speed)

  ii. Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work.

CONCEPT DEVELOPMENT for WORK, ENERGY, and POWER

1. At the bowling alley, the ball-feeder mechanism must exert a force to push the bowling balls up a 1.0 m long ramp The ramp leads the balls to a chute 0.5 m above the base of the ramp. Approximately how much force must be exerted on a 5.0 kg bowling ball?



   a. 200 N
   b. 50N
   c. 25N
   d. 5.0 N
   e. Impossible to determine

2. Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. Just before hitting the ground, the heavier marble has

   a. As much kinetic energy as the lighter one.
   b. Twice as much kinetic energy as the lighter one.
   c. Half as much kinetic energy as the lighter one.
   d. Four times as much kinetic energy as the lighter one.
   e. Impossible to determine

3. Suppose you want to ride your mountain bike up a steep hill. Two paths lead from the base to the top, one twice as long as the other. Compared to the average force exerted along the short path, F_{av} the average force you exert along the longer path is

   a. $F_{av}/4$
   b. $F_{av}/3$
   c. $F_{av}/2$
   d. F_{av}
   e. Undetermined, it depends on the time taken

PROCEDURE for SOLVING PROBLEMS INVOLVING WORK, ENERGY and POWER

Conservation of Energy

Take the following steps in applying the principle of conservation of energy:

1. Draw an accurate diagram locating all of the forces, both conservative and nonconservative. acting on the object.
2. Define your system, which may consist of more than one object.
3. Select a reference position for the zero point of gravitational potential energy.
4. Determine whether or not nonconservative forces are present.
5. If mechanical energy is conserved (that is, if only conservative forces are present), you can write the total initial energy at some point as the sum of the kinetic and potential energies at that point. Then, write an expression for the total final energy, $KE_f + PE_f$, at the final point of interest. Because mechanical energy is conserved, you can equate the two total energies and solve for the unknown.

Conservation of Energy Revisited

If nonconservative forces such as friction act on a system, mechanical energy is not conserved. Hence, the problem-solving strategy given before must be modified as follows.
First, write expressions for the total initial and total final mechanical energies.
In this case, the difference between the two total energies is equal to the work done by the nonconservative force(s).

For problems involving the work-energy theorem:

1. Draw an accurate diagram locating all of the forces, both conservative and nonconservative, acting on the object.
2. Determine the magnitude and direction of the net force acting on the object and then determine the net work done on the object.
3. Apply the work energy theorem and solve the problem.

For problems involving power:

1. Draw an accurate diagram locating all of the forces, both conservative and nonconservative, acting on the object.
2. Apply the formulas for power and solve the problem.

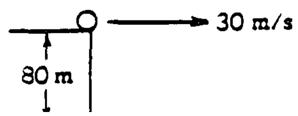
Free Response Problem 5

A ball thrown vertically downward strikes a horizontal surface with a speed of 20 meters per second. It then bounces, and reaches a maximum height of 8 meters. Neglect air resistance on the ball.

a. What is the speed of the ball immediately after it rebounds from the surface?

b. What fraction of the ball's initial kinetic energy is apparently lost during the bounce?

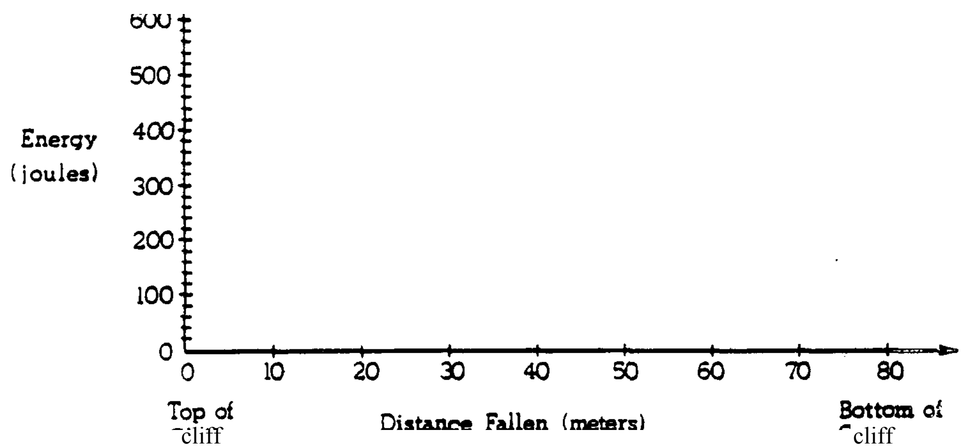
Free Response Problem 6



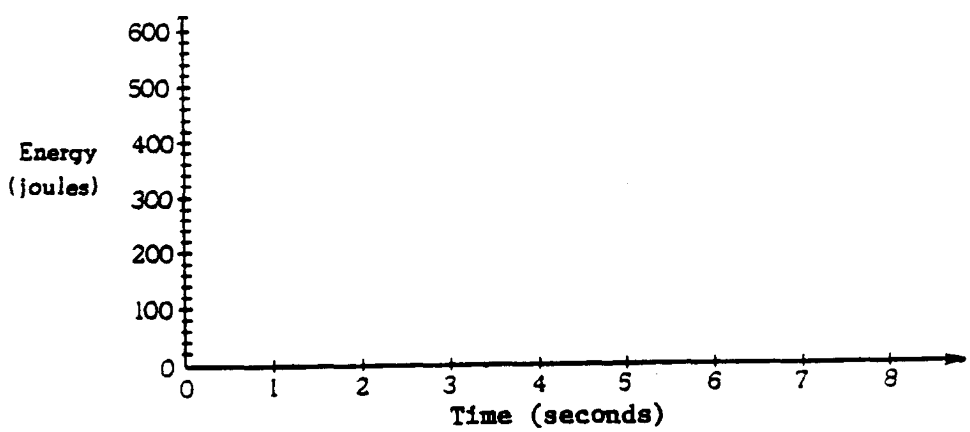
From the top of a cliff 80 meters high, a ball of mass 0.5 kilogram is launched horizontally with a velocity of 30 meters per second at time t = 0 as shown above. The potential energy of the ball is zero at the bottom of the cliff. Use g = 10 meters per second squared.

a. Calculate the potential, kinetic, and total energies of the ball at time t = O.

b. On the axes below, sketch and Label graphs of the potential, kinetic, and total energies of the ball as functions of the distance fallen from the top of the cliff



c. On the axes below sketch and label the kinetic and potential energies of the ball as functions of time until the ball hits



STUDENT OBJECTIVES for SYSTEMS of PARTICLES, LINEAR MOMENTUM

1. IMPULSE and MOMENTUM

    a. You should understand impulse and linear momentum so you can:

    i. Relate mass, velocity, and linear momentum for a moving body, calculate the total linear momentum of a system of bodies.

    ii. Relate impulse to the change in linear momentum and the average force acting on a body.

2. CONSERVATION of LINEAR MOMENTUM, COLLISIONS

    a. You should understand linear momentum conservation so you can:

    i. Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.

    ii. Apply linear momentum conservation to determine the final velocity when two bodies that are moving along the same line, or at right angles, collide and stick together, and calculate how much kinetic energy is lost in such a situation.

    iii. Analyze collisions of particles in one or two dimensions to determine unknown masses or velocities, and calculate how much kinetic energy is lost in a collision.

CONCEPT DEVELOPMENT of LINEAR MOMENTUM

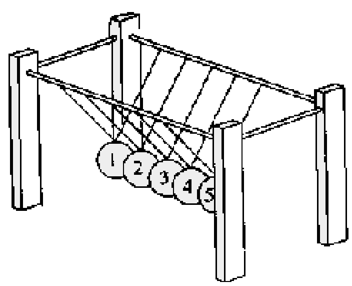
1. An astronaut floating weightlessly in orbit attempts to shake a large iron anvil rapidly back and forth. She reports back to Earth that

   a. The shaking costs her no effort because the anvil has no inertial mass in space.
   b. The shaking costs her some effort but considerably less than on Earth.
   c. Although weightless, the inertial mass of the anvil is the same as on Earth.

2. You are given two carts, A and B.They look identical, and you are told that they are made of the same material. You place A at rest on an air track and give B a constant velocity directed to the right so that it collides elastically with A. After the collision, both carts move to the right, the velocity of B being smaller than what it was before the collision. What do you conclude?

   a. Cart A is hollow.
   b. The two carts are identical.
   c. Cart B is hollow.
   d. Need more information

3. If ball 1 in the arrangement shown here is pulled back and then let go, ball 5 bounces forward. If balls 1 and 2 are pulled back and released, balls 4 and 5 bounce forward, and so on. The number of balls bouncing on each side is equal because



   a. Of conservation of momentum.
   b. The collisions are all elastic.
   c. Neither of the above

4. A car accelerates from rest. In doing so the absolute value of the car's momentum changes by a certain amount and that of the Earth changes by

   a. A larger amount.
   b. The same amount.
   c. A smaller amount.
   d. The answer depends on the interaction between the two.

PROCEDURE for SOLVING PROBLEMS INVOLVING LINEAR MOMENTUM

For problems involving impulse-change of momentum.

1. Draw an accurate diagram locating all of the forces acting on the system.
2. If a net external force acts on the object(s) then the momentum of the system will change. Determine the magnitude and direction of the net force.
3. Apply the impulse-momentum equation taking note that force and velocity are vectors and that direction of the vector plays an important part in the solution.

For problems involving no external force acting on the system:

1. Use the law of conservation of momentum to solve the problem. Take note that momentum is a vector quantity and must be considered in the solution.

For problems involving graphical integration:

1. Determine the sum of the partial and complete blocks that lie under the curve.
2. Determine the magnitude of the impulse represented by one block.
3. Determine the magnitude of the total impulse by multiplying the impulse represented by one block by the total number of blocks found in step 2.
4. Use the impulse-momentum equation and solve the problem.

For problems involving perfectly elastic and completely inelastic collisions:

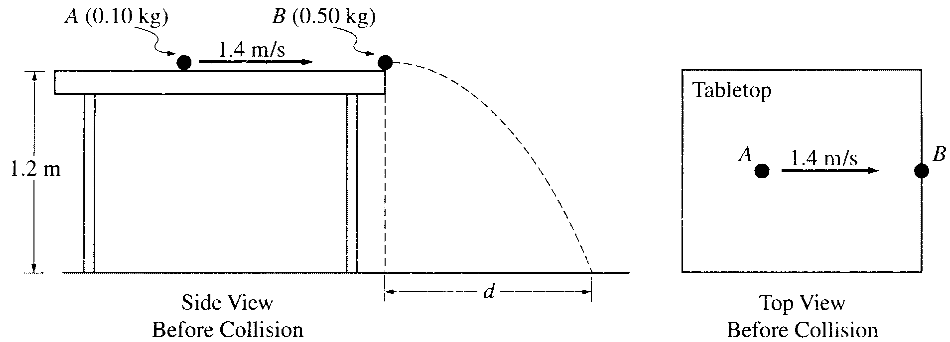
1. Determine which type of collision is described in the problem.
2. If the collision is completely inelastic and the objects stick together, use the law of conservation of momentum to solve the problem.
3. If the collision is perfectly elastic, use both conservation of momentum and conservation of mechanical energy. Each law produces an algebraic equation with two unknowns. The final velocity of each object can be determined by applying standard algebraic techniques.

Conservation of Momentum

The following procedure is recommended for problems involving collisions between two objects:

1. Set up a coordinate system and define your velocities with respect to that system. That is objects moving in the direction selected as the positive direction of the x axis are considered to have a positive velocity, and those moving in the negative x direction, a negative velocity. It is convenient to make the x axis coincide with one of the initial velocities.
2. In your sketch of the coordinate system, draw all velocity vectors with labels and include all the given information.
3. Write expressions for the momenta of each object before and after the collision. (In two-dimensional collision problems, write expressions for the x and y components of momentum before and after the collision.) Remember to include the appropriate signs for the velocity vectors.
4. Now write expressions for the total momentum before and after the collision and equate the two. (For two-dimensional collisions, this expression should be written for the momentum in both the x and y directions.) Remember, it is the momentum of the system (the two colliding objects) that is conserved, not the momenta of the individual objects.
5. If the collision is inelastic, kinetic energy is not conserved. Proceed to solve the momentum equations for the unknown quantities.
6. If the collision is elastic, kinetic energy is conserved, so you can equate the total kinetic energies before and after the collision. This gives an additional relationship between the velocities.

Free Response Problem 7



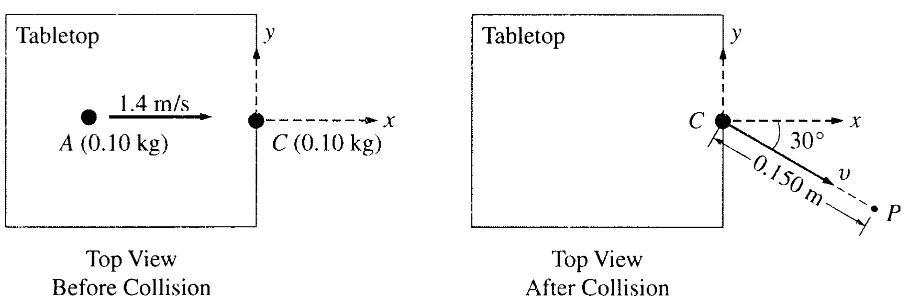
Note: Figures not drawn to scale.

An incident ball A of mass 0.10 kg is sliding at 1.4 m/s on the horizontal tabletop of negligible friction shown above. It makes a head-on collision with a target ball B of mass 0.50 kg at rest at the edge of the table. As a result of the collision, the incident ball rebounds, sliding backwards at 0.70 m/s immediately after the collision.

a. Calculate the speed of the 0.50 kg target ball immediately after the collision.

The tabletop is 1.20 m above a level, horizontal floor. The target ball is projected horizontally and initially strikes the floor at a horizontal displacement d from the point of collision.

b. Calculate the horizontal displacement d.

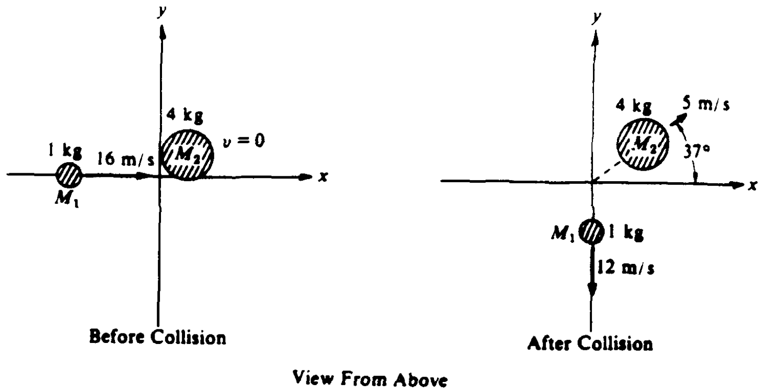


In another experiment on the same table, the target ball B is replaced by target ball C of mass 0.10 kg. The incident ball A again slides at 1.4 m/s, as shown above left, but this time makes a glancing collision with the target ball C that is at rest at the edge of the table. The target ball C strikes the floor at point P, which is at a horizontal displacement of 0.15 m from the point of the collision, and at a horizontal angle of 30° from the +x-axis, as shown above right.

c. Calculate the speed v of the target ball C immediately after the collision.

d. Calculate the y-component of incident ball A's momentum immediately after the collision.

Free Response Problem 8



1984B2. 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	
	$p_x\left(\frac{kg\cdot m}{s}\right)$	$p_y\left(\frac{kg\cdot m}{s}\right)$	$p_x\left(\frac{kg\cdot m}{s}\right)$	$p_y\left(\frac{kg\cdot m}{s}\right)$
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?

E. STUDENT OBJECTIVES for CIRCULAR MOTION and ROTATION

1. UNIFORM CIRCULAR MOTION

a. You should understand the uniform circular motion of a particle so you can:

i. Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.

ii. Describe the direction of the particle's velocity and acceleration at any instant during the motion.

iii. Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.

2. TORQUE and ROTATIONAL STATICS

a. You should understand the concept of torque so you can:

i. Calculate the magnitude and sense of the torque associated with a given force.

ii. Calculate the torque on a rigid body due to gravity.

b. You should be able to analyze problems in statics so you can:

i. State the conditions for translational and rotational equilibrium of a rigid body.

ii. Apply these conditions in analyzing the equilibrium of a rigid body under the combined influence of a number of coplanar forces applied at different locations.

CONCEPT DEVELOPMENT for CIRCULAR MOTION and ROTATION

ROTATIONAL KINEMATICS

1. A disk is rotating at a constant rate about a vertical axis through its center. Point Q is twice as far from the center of the disk as point P is. The angular velocity of Q at a given time is

a. Twice as big as P's.
b. The same as P's.
c. Half as big as P's.
d. None of the above.

2. When a disk rotates counterclockwise at a constant rate about a vertical axis through its center, the tangential acceleration of a point on the rim is

a. Positive.
b. Zero.
c. Negative.
d. Impossible to determine without more information.

3. A cockroach rides the rim of a rotating merry-go-round. If the angular speed of this system (merry-go-round + cockroach) is constant, does the cockroach have (yes or no)

(i) Radial acceleration

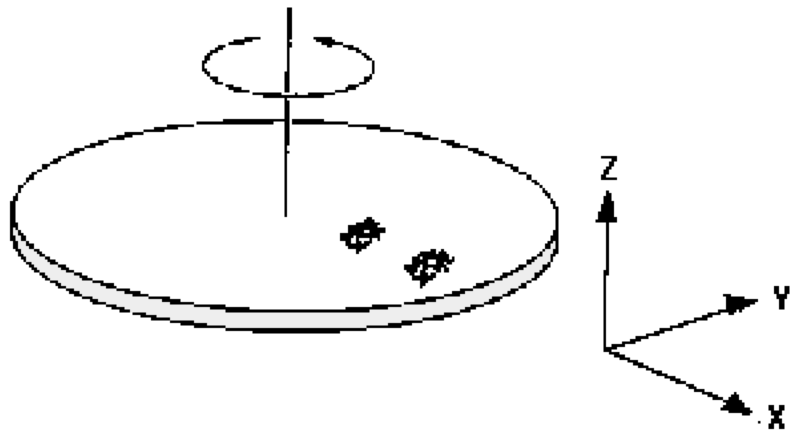
(ii) Tangential acceleration?

If the angular speed is decreasing, does the cockroach have

(iii) Radial

(iv) Tangential acceleration?

4. A ladybug sits at the outer edge of a merry-go-round, and a gentleman bug sits halfway between her and the axis of rotation. The merry-go-round makes a complete revolution once each second. The gentleman bug's angular speed is



a. Half the ladybug's.
b. The same as the ladybug's.
c. Twice the ladybug's.
d. Impossible to determine

PROCEDURE for SOLVING PROBLEMS INVOLVING CIRCULAR MOTION and ROTATION

Use the following steps when dealing with centripetal accelerations and forces that produce them:

1. Draw a free-body diagram of the object(s) under consideration showing and labeling all forces that act on it.
2. Choose a coordinate system that has one axis perpendicular to the circular path followed by the object and one axis tangent to the circular path.
3. Find the net force toward the center of the circular path. This is the force that causes the centripetal acceleration.
4. From here on the steps are virtually identical to those encountered when solving Newton's second law problems with F = ma. Also, note that the magnitude of the centripetal acceleration can always be written $a_C = v^2/r$.

Objects in Equilibrium/torque

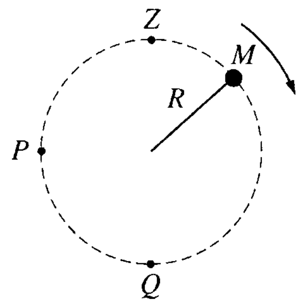
1. Draw a simple, neat diagram of the system.

2. Isolate the object that is being analyzed. Draw a free-body diagram showing all external forces that are acting on this object. For systems that contain more than one object, draw a separate diagram for each object. Do not include forces that the object exerts on its surroundings.

3. Establish convenient coordinate axes for each body and find the components of the forces along these axes. Now apply the first condition of equilibrium (the net force on the object in the x and y direction must be zero) for each object under consideration.

4. Choose a convenient origin for calculating the net torque on the object. Now apply the second condition of equilibrium (the net torque on the object about any origin must be zero). Remember that the choice of the origin for the torque equation is arbitrary: therefore, choose an origin that will simplify your calculation as much as possible. Note that a force that acts along a line passing through the point chosen as the axis of rotation gives zero contribution to the torque. The first and second conditions for equilibrium will give a set of simultaneous equations with, several unknowns. All that is left to complete your solution is to solve for the unknowns in terms of the known quantities.

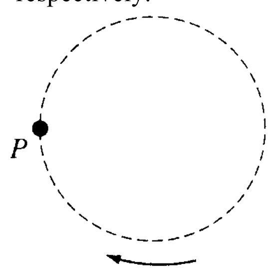
Free Response Problem 9

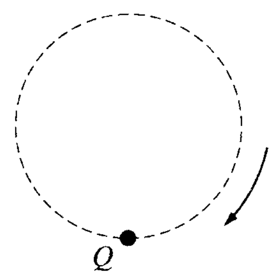


Side View

2001B1. 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. On the figures below, draw and label all the forces exerted on the ball when it is at points P and Q, respectively.



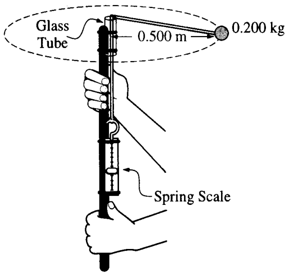


b. Derive an expression for v_{min} the minimum speed the ball can have at point Z without leaving the circular path.

c. 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.

d. 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.

Free Response Problem 10



To study circular motion, two students use the hand-held device shown above, which consists of a rod on which a spring scale is attached. A polished glass tube attached at the top serves as a guide for a light cord attached the spring scale. A ball of mass 0.200 kg is attached to the other end of the cord. One student swings the ball around at constant speed in a horizontal circle with a radius of 0.500 m. Assume friction and air resistance al negligible.

a. Explain how the students, by using a timer and the information given above, can determine the speed of the ball as it is revolving.

b. How much work is done by the cord in one revolution? Explain how you arrived at your answer.

c. The speed of the ball is determined to be 3.7 m/s. Assuming that the cord is horizontal as it swings, calculate the expected tension in the cord.

d. The actual tension in the cord as measured by the spring scale is 5.8 N. What is the percent difference between this measured value of the tension and the value calculated in part c. ?

e. The students find that, despite their best efforts, they cannot swing the ball so that the cord remains exactly horizontal.

i. On the picture of the ball below, draw vectors to represent the forces acting on the ball and identify the force that each vector represents.

ii. Explain why it is not possible for the ball to swing so that the cord remains exactly horizontal.

iii. Calculate the angle that the cord makes with the horizontal.

F. STUDENT OBJECTIVES for OSCILLATIONS and GRAVITATION

1. SIMPLE HARMONIC MOTION

a. You should understand the kinematics of simple harmonic motion so you can:

i. Sketch or identify a graph of displacement as a function of time, and determine from such a graph the amplitude, period, and frequency of the motion.

ii. Identify points in the motion where the velocity is zero or achieves its maximum positive or negative value.

iii. State qualitatively the relation between acceleration and displacement in simple harmonic motion.

iv. Identify points in the motion where the acceleration is zero or achieves its greatest positive or negative value.

v. State and apply the relation between frequency and period for simple harmonic motion.

vi. State how the total energy of an oscillating system depends on the amplitude of the motion, sketch or identify a graph of kinetic or potential energy as a function of time, and identify points in the motion where this energy is all potential or all kinetic.

2. MASS on a SPRING

a. You should be able to apply your knowledge of simple harmonic motion to the case of mass on a spring, so you can:

i. Apply the expression for the period of oscillation of a mass on a spring.

3. THE PENDULUM and OTHER OSCILLATIONS

a. You should be able to apply your knowledge of simple harmonic motion to the case of a pendulum, so you can:

i. Apply the expression for the period of a simple pendulum.

ii. State what approximation must be made in deriving the period.

4. NEWTON'S LAW of GRAVITY

a. You should know Newton's Law of Universal Gravitation so they can:

i. Determine the force that one spherically symmetrical mass exerts on another.

ii. Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.

5. CIRCULAR ORBITS of PLANETS and SATELLITES

a. You should understand the motion of a body in circular orbit under the influence of gravitational forces so they can:

i. Recognize that the motion does not depend on the body's mass, describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit, and derive expressions for the velocity and period of revolution in such an orbit.

CONCEPT DEVELOPMENT for OSCILLATIONS and GRAVITATION

GRAVITATION

1. Which of the following depends on the inertial mass of an object (as opposed to its gravitational mass)?

   a. The time the object takes to fall from a certain height

   b. The weight of the object on a bathroom-type spring scale

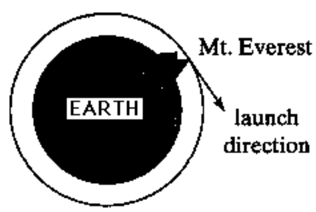
   c. The acceleration given to the object by a compressed spring

   d. The weight of the object on an ordinary balance

2. Two satellites A and B of the same mass are going around Earth in concentric orbits. The distance of satellite B from Earth's center is two times that of satellite A. What is the ratio of the centripetal force acting on B to that acting on A?

   a. 1:8 b. 1:4 c. 1:2 e. 2:1 f. 4:1

3. Suppose the Earth had no atmosphere and a ball were fired from the top of Mt. Everest in a direction tangent to the ground.



   If the initial speed were high enough to cause the ball to travel in a circular trajectory around Earth, the ball's acceleration would

   a. Be much less than g (because the ball doesn't fall to the ground).

   b. Be approximately g.

   c. Depend on the ball's speed.

OSCILLATIONS

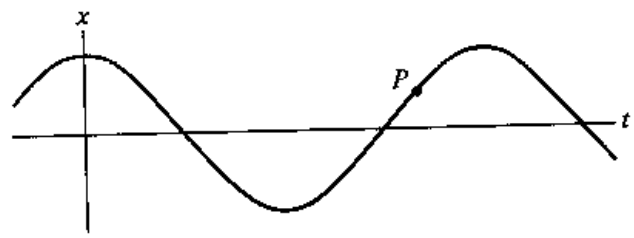
1. An object is in equilibrium when the net force and the net torque on it is zero. Which of the following statements is/are correct for an object in an inertial frame of reference?

   a. Any object in equilibrium is at rest.

   b. An object in equilibrium need not be at rest.

   c. An object at rest must be in equilibrium.

2. A mass attached to a spring oscillates back and forth as indicated in the position vs. time plot below. At point P, the mass has



   a. Positive velocity and positive acceleration.

   b. Positive velocity and negative acceleration.

   c. Positive velocity and zero acceleration.

   d. Negative velocity and positive acceleration.

   e. Negative velocity and negative acceleration.

   f. Negative velocity and zero acceleration.

   g. Zero velocity but is accelerating (positively or negatively).

   h. Zero velocity and zero acceleration.

PROCEDURE for SOLVING PROBLEMS INVOLVING OSCILLATIONS and GRAVITATION

For problems involving Newton's universal law of gravitation:

1. Complete a data table based on information both given and implied in the problem.

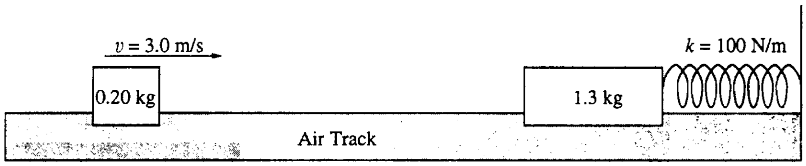
2. Use the universal law of gravitation and, if necessary, Newton's second law and the concept of centripetal acceleration to solve the problem.

For problems involving Kepler's third law:

1. Complete a data table based on information both given and implied in the problem.

2. Use Kepler's third law to solve the problem.

Free Response Problem 11

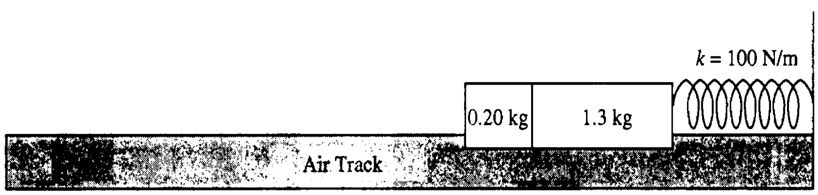


A 0.20 kilogram mass is sliding on a horizontal, friction less air track with a speed of 3.0 meters per second when it instantaneously hits and sticks to a 1.3 kilogram mass initially at rest on the track. The 1.3 kilogram mass is connected to one end of a massless spring, which has a spring constant of 100 newtons per meter. The other end of the spring is fixed.

(a) Determine the following for the *0.20 kilogram mass* immediately *before* the impact.

i. Its linear momentum

ii. Its kinetic energy



(b) Determine the following for the *combined masses* immediately *after* the impact.

i. The linear momentum

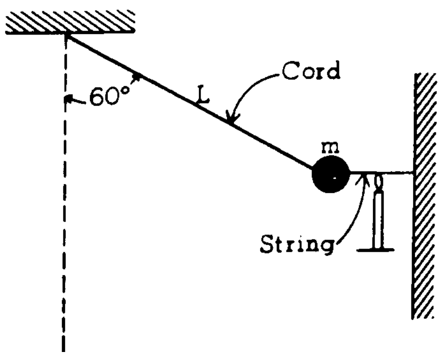
ii. The kinetic energy

After the collision, the two masses undergo simple harmonic motion about their position at impact.

(c) Determine the amplitude of the harmonic motion.

(d) Determine the period of the harmonic motion.

Free Response Problem 12



A pendulum consists of a small object of mass m fastened to the end of an inextensible cord of length L. Initially, the pendulum is drawn aside through an angle of 60° with the vertical and held by a horizontal string as shown in the diagram above. This string is burned so that the pendulum is released to swing to and fro.

a. In the space below draw a force diagram identifying all of the forces acting on the object while it is held by the string.

b. Determine the tension in the cord before the string is burned (express your answer in terms of m, L, and fundamental constants).

c. Show that the cord, strong enough to support the object before the string is burned, is also strong enough to support the object as it passes through the bottom of its swing.

d. The motion of the pendulum after the string is burned is periodic. Is it also simple harmonic? Why, or why not