CHAPTER 7 KINETIC ENERGY

If an informal poll were taken among scientists to discover what they consider to be the most fundamental of physical quantities, the answer in all probability would be that energy is the most fundamental. You might then ask why we waited until this point in the course to introduce the concept of energy. This is because that which is most fundamental is often very subtle, and it is often best to first introduce quantities which appeal more to the intuition: such quantities being mass, velocity, acceleration, force, etc.

Specifically, this chapter introduces KINETIC ENERGY - a property of bodies in motion - and a related concept called WORK. Just how these quantities interrelate will be clarified in the readings. We will then examine how energy figures into the "interaction" of material bodies. The interaction of two objects "bumping into" one another is of rather narrow and limited usefulness in physics, and the law of conservation of kinetic energy is limited by the fact that it hardly ever is valid in real physical situations. Of greater importance in physics are the general concepts of "interaction" and the conservation of TOTAL ENERGY (which is valid in many more cases than conservation of kinetic energy). Why then, are we studying these seemingly limited concepts? This is because we're sticking to the approach of taking one step at a time, starting with the simple and specific and later tackling the more difficult and fundamental. In chapter 8 we will study the concept of potential energy which will aid us in learning about the more general law of conservation of TOTAL energy.

CHAPTER 7 PERFORMANCE OBJECTIVES

Upon completion of this chapter, you should:

1. be able to deduce work as a measure of energy transfer.

2. be able to define the joule as the unit of work.

3. be able to calculate the work done on an object.

4. be able to recognize a situation in which the component of a force is perpendicular to the displacement and recognize that no work is being done.

5. be able to define kinetic energy as energy due to the motion of an object.

6. be able to state the relation between work and kinetic energy.

7. be able to recognize that kinetic energy is conserved in an elastic collision but not conserved in an inelastic collision.

8. be able to calculate the kinetic energy, mass, or velocity given all but one of the variables.

9. be able to use the principles of conservation of momentum and kinetic energy in a one dimensional elastic collision to determine the velocities of the two masses after the collision, given their masses and velocities before the collision.

10. be able to recognize that analyzing kinetic energy from a center of mass point of view can simplify the analysis.

1. Read: Section 7-1 Work and Kinetic Energy page 133
   Section 7-2 Work: A Generalization page 134

   a. Define work (purely from a physicists point of view).

   b. The equation for finding work is: W = ________. Work has the units of _______________ which is called a __________.

   c. Is work a vector or a scalar quantity? How can we find out?

   d. Upon what does the amount of work accomplished depend?

   e. How can we calculate the work done when the force applied is not constant?

2. Vector algebra says that when a vector quantity is multiplied by another vector quantity, and the product is a scalar quantity, the product of the two vector quantities is called a DOT product. Since work (a scalar) is the product of force (a vector) and displacement (a vector), one would express the DOT product equation as: $W = \vec{F} \cdot \vec{\Delta x}$. The magnitude of this equation can be found using the equation: $W = F \Delta x \cos \theta$, where θ represents the angle between F and Δx.

   a. When would the quantity ($\cos \theta$) not be needed to find the work done?

   b. Calculate the work done by a boy who pulls a sled a distance of 20 meters while exerting a 100 Newton force on a rope that makes an angle of 45 degrees relative to the horizontal.

   c. How much work do you do when you hold a 60 kg mass above your head for 15 seconds.?

   d. How much work is required to carry a 15 kg suitcase a horizontal distance of 50 meters?

   e. How much work do you do if you swing an object (tangential speed of 14 m/s) in a circle exerting a centripetal force of 12 Newtons for 10 seconds?

   f. How much work do you do when you take a 7.5 kg bowling ball and bag from a shelf 2 meters high and lower it to the floor?

Note...See Study Notes I: MORE ON KINETIC ENERGY AND WORK.

3. Knowing that $W = F \Delta x$, we can say that $W = m \cdot a \cdot d$.

   a. Using two kinematic equations solved for 'a' and 'd', show that $W = 1/2\ mv_f\hat{}2 - 1/2\ mv_i\hat{}2$.

   b. 1/2 mv^2 is known as _______________with units of ______________ and is represented by symbol _______

   c. Does the amount of work done to an object ever equal the kinetic energy that an object possesses? Why or why not?

   d. Is kinetic energy a vector or scalar quantity? How do we know?

4. Problems: page 134: #1 #2 #3 #4
   page 135: #5 #6 #7 #8
   page 148: #23 #24 #25

5. The following activities are to be conducted using a two page work sheet titled MOMENTUM AND KINETIC ENERGY which is included in this packet.

   a. Complete the first column of item #1. When you have completed this column, check your answers with the ones given on the answer sheet. Any questions? If so, see your instructor.

   b. Next complete the second column following the directions given below question 'f'.

   c. Write a brief summary as to why the change in kinetic energy is the same for both intervals while the change in momentum is not the same for both intervals.

   d. Complete item #2. Why do two objects with the same speed possess the same momentum but not the same kinetic energy?

   e. Complete item #3. Why is the change in momentum the same from both points of view while the change in kinetic energy is not the same?

6. Read: Sec 7-3 Transfer of Kinetic Energy From One Mass to Another p 136
   Sec 7-4 Another Look at A Simple Collision page 138

   a. Note...Read Study Notes II: THE TRANSFER OF KINETIC ENERGY FROM ONE MASS TO ANOTHER which further explains the material in these sections.

   b. A distance 'd' is used. What distance does this 'd' represent?

   c. When are the speeds of both objects equal?

   d. What information do we need, and what method(s) will we use to calculate this speed?

   e. Ask instructor for a demonstration of two carts colliding.

7. Read: Section 7-5 Elastic Collisions page 140

8. Problems: page 142: #12 #14

9. Read: Section 7-6 Conservation of Kinetic Energy and Momentum page 142

10. Optional...On page 144, two formulae are introduced which give the velocities of two masses after a totally elastic collision. You need not memorize these formulae, but you should be familiar with the conservation laws from which they are derived. An alternative derivation is included in this packet. Answering the following questions correctly should provide you with the necessary restricted conditions under which the formulae can be used and the information they will give.

    a. What type of collision must take place?

    b. What must be conserved?

c. Complete the table at the bottom of the sheet.

d. Demonstration apparatus is available to check your answers.

11. Problems: page 145: #15 #16

12. Complete enclosed quiz and then have it evaluated.

13. Film: MOVING WITH THE CENTER OF MASS (25 min)

14. Read: Sec 7-7 Kinetic Energy and the Center of Mass page 145
Sec 7-8 Loss of Kinetic Energy in a Frictional Interaction p 146

15. Problems: page 146: #18 #19 #20
page 148: #27 #30 #32

16. Following is a conclusion taken from the 2nd Edition text.

What are the main things that we have found out in this chapter? In the first place, when a force is applied to a moving body, the transfer of energy to the body is given by the work done; that is, by the distance the body moves times the component of the force in the direction of the motion. If the force is opposite to the motion, energy is taken from the body. If the force is in the direction of motion, energy is fed into the body. When more than one force acts on a body the net force changes the motion of the body: and correspondingly the total work measures the change in its kinetic energy.

When two bodies interact and the force of interaction depends only on the distance between the bodies, the total kinetic energy after a completed interaction is the same as the total kinetic energy before the interaction. The collision of the two bodies is elastic.

We can make the same kind of statement when many bodies interact. If they all start so far apart that the forces of interaction are zero and all end up far apart again, the kinetic energy at the beginning and at the end is the same. Some bodies may have gained kinetic energy, others may have lost it, but the total comes back to what it was. This statement about the equality of the total kinetic energy at the beginning and at the end of a completed interaction will be proved in general in the next chapter. Here we should emphasize that the statement is correct only if the interaction forces are functions of the separation of the bodies alone. In other words, the forces must be the same whether the bodies are approaching each other or moving apart.

Forces of interaction are not always functions of separation alone. Recall the examples of the mass rubbing on the table and the putty ball bouncing on the floor. They show that when the forces depend on other things the kinetic energy of bulk motion seems to change permanently. But when this kinetic energy disappears a temperature rise is usually observed. Later we shall find how this temperature increase indicates that the kinetic energy has been transferred to another form.

Even in the course of an elastic collision, the total kinetic energy of the bodies may appear to be lost temporarily. We have found that this lost kinetic energy can be eventually regained. As long as the forces of interaction depend only on the relative positions of the bodies, the 'lost' kinetic energy is actually stored in the system. This stored energy is called potential energy. It is the subject of the next chapter.

17. A two page test is enclosed. Complete and then have it evaluated.

Thought for the chapter:

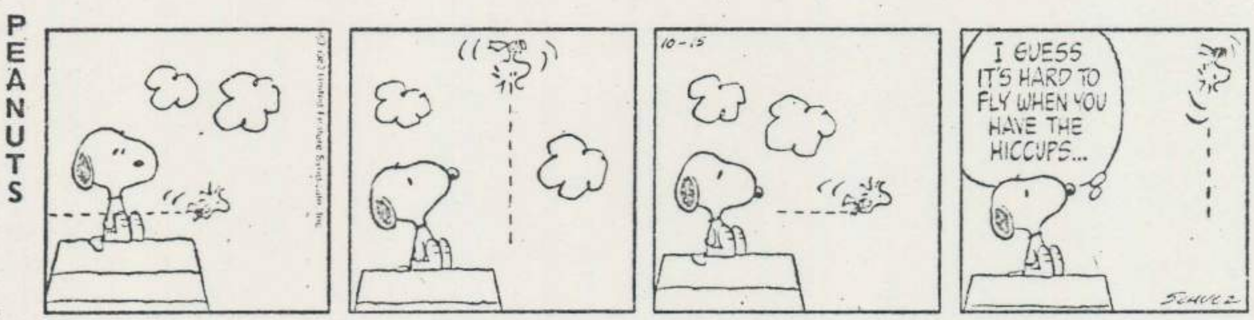
Many a woman who can get a 17.8 centimeter foot into a 15.2 centimeter shoe cannot get a 1.83 meter car into a 2.44 meter garage.

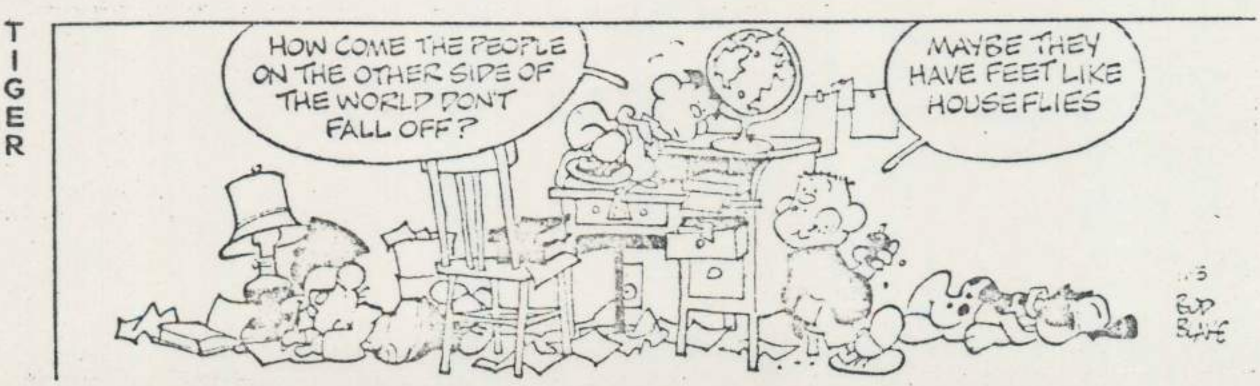
Can you see through this?

Since d = 1/2 at^2 , then a = 2d/t^2 .

But we know that a = v/t , so v/t = 2d/t^2, or v = 2d/t .

Therefore v = 2v or 1 = 2 !





ANSWERS Chapter 7

1. (b) F x, Newton-meter, Joule
   (c) scalar (only experimental evidence will provide the answer)
   (d) force applied and distance object (to which force is applied) moves
   (e) find area under the force vs displacement graph

2. (a) When both F and x are in the same direction (0 = 0 degrees)
   (b) 1414 Joules (c) 0 (d) 0 (e) 0 (f) - 147 Joules

3. (b) kinetic energy, kg-m^2/sec^2 = Newton-meter = Joule, E_K
   (c) be careful here, it equals the change in E_K, however it will equal the final kinetic energy if the initial kinetic energy is zero.
   (d) scalar (only by experimental evidence)

4. (1) (a) 37.5 Joules (b) 2500 Newton
   (2) times 4
   (3) (a) 4 times (b) equal (c) equal (d) equal
   (4) equal
   (5) S.A.B.
   (6) (a) 20 Joules (b) 20 Joules (c) 28 Joules
   (7) 120 Joules (b) 11 m/sec
   (8) (a) 20 Joules (b) 3 meters (c) S.A.B.
   (23) (a) 50 kg-m/sec (b) 250 Joules (c) S.A.B.
   (24) S.A.B.
   (25) (a) 39 Joules (b) 160 Newton (c) zero

5. (1) (a) 3.0×10^5 Joules (b) 20 m/s (c)(d) 3×10^4 kg-m/s
   (e)(f) 3×10^5 Joules
   (a) 3.0×10^5 Joules (b) 28.3 m/s (c) 4.24×10^4 kg-m/s
   (d) 1.24×10^4 kg-m/s (e) 6.0×10^5 Joules (f) 3×10^5 Joules
   (2) (a)(b) 30 kg-m/sec (c) 4500 Joules (d) 0.30 Joules
   (3) (a) 0 (b) 50 Joules (c) 50 Joules (d) 50 Joules (e) 200 Joules
   (f) 150 Joules (g) 0 (h) 10 kg-m/s (i) 10 kg-m/s (j) 10 kg-m/s
   (k) 20 kg-m/s (l) 10 kg-m/s

6. (b) the max. distance between carts when there is a mutual repelling force
   (c) when the distance between the carts is a minimum
   (d) mass of both carts and the velocity of the cart that is moving

8. (12) yes
   (14) S.A.B.

10. (a) elastic, head on, with one mass at rest
    (b) both momentum and kinetic energy

11. (15) m_1 is less than m_2
    (16) (a) 0.10 m/s and -0.10 m/s (b) S.A.B.

15. (18) S.A.B.
    (19) zero
    (20) (a) 0.4 m/s (b) 0.48 Joules (c) 0.48 Joules
    (27) both with 1×10^4 kg-m/s, shell with 5×10^6 Joules, car with 5000 Joules
    (30) (32) S.A.B.

Chapter 7 STUDY NOTES

I. More on Kinetic Energy and Work

You should remember that quantities like force, velocity, momentum, and acceleration are vector quantities because they have both a magnitude and a direction. On the other hand, quantities such as mass or speed are said to be scalar because they have only a magnitude and not a direction. In this chapter the new quantities introduced, work and kinetic energy, are both scalars.

In general, scalar quantities can have both positive and negative values, although most of the scalar quantities we have studied have only positive values. For example, mass and volume are quantities which are scalar and always positive in magnitude. Kinetic energy is such a quantity as well - its value is always positive too. To see this, look at the formula for kinetic energy:

$$\text{kinetic energy} = \tfrac{1}{2}mv^2$$

The quantity $\frac{1}{2}$ is certainly positive, mass is always positive, and the square of speed is always positive. Thus, the kinetic energy of any object is always positive.

Work, however, is a scalar which can be positive or negative. One simple way of seeing this is to examine the formula relating work to the change in an object's kinetic energy:

$$\text{work} = \text{change in kinetic energy (or work)} = \tfrac{1}{2}mv^2_{final} - \tfrac{1}{2}mv^2_{initial}$$

If an object's kinetic energy increases, then the work done on the object is positive; if an object's kinetic energy decreases, then the work done on the object is negative. A force acting in a manner such that it speeds an object up does positive work; a force acting to slow an object down does negative work. Thus, work is positive when the force acts along the displacement; the work is negative when the force acts against the displacement.

Physicists call kinetic energy a "state" quantity because it describes the condition of a physical system at any particular time. On the other hand, work is known as a "transfer" quantity since it describes a way of changing the state of an object.

Suppose an object has 20 Joules of kinetic energy. That is a description of its state. If +20 Joules of work are done on the object, its state changes such that it now has 40 Joules of kinetic energy. It is meaningless to say that an object has 20 Joules of work, just as it is meaningless to say that 20 Joules of kinetic energy is performed on a body.

In the previous chapter, we saw another example of a state quantity and its associated transfer quantity. Momentum describes the state (a body has so much momentum) while impulse is the means of transferring momentum. Note the analogy:

State Quantities	Transper Quantities	Formulae
Momentum (p)	Impulse	Impulse = Δp
Kinetic Energy (E_K)	Work	Work = ΔE_K

II. The Transfer of Kinetic Energy from one Mass to Another

Section 7-3 is attempting to show that kinetic energy is conserved in collisions where the repulsive interaction force between two bodies depends <u>only</u> on the separation distance between the two bodies. Since the text's example assumes one mass to be initially stationary, kinetic energy is conserved if the lost kinetic energy of the initially moving mass is entirely transferred into kinetic energy of the mass which was originally stationary.

The example cited is one where the mutual force of interaction between the bodies is <u>steplike</u> - see Figure 7-5. This is a simple case which serves the purposes of the argument. An outline of the text's argument follows:

1. Assume that the mutual interaction force is described by this <u>steplike</u> graph. Then since the force has limited range, we can define a beginning and an end to the interaction. The interaction begins when the separation becomes less than d; it ends when the separation becomes greater than d.
2. A moving mass collides with another mass initially at rest. We wish to show that the <u>total</u> kinetic energy before and after the collision is the same. This is equivalent to showing that all the kinetic energy lost by the initially moving mass during the collision is eventually gained by the mass which was initially stationary.
3. The change in an object's kinetic energy is equal to the work done on the object. Thus, if the positive work done during the entire collision on the initially stationary object is equal in magnitude to the negative work done during the entire collision on the initially moving object, then the initially stationary object will have gained exactly as much kinetic energy as the initially moving object lost. This would mean that kinetic energy is conserved.

   Remember: Work done = [force] x [distance traveled].
4. The forces exerted by each object on the other during the interaction are equal and opposite. Thus, to show that the work done on both objects is equal and opposite, we simply must show that the objects travel the same distance during the interaction.
5. They <u>must</u> travel the same distance during the interaction because they are the same distance apart both at the instant the interaction begins and at the instant the interaction ends. In one dimension, any two objects which are a given distance apart at some time, and the same distance apart at a later time, must have travelled the same distance during the ensuing time interval. The reasoning here is a bit tricky - think about it. You might spend some time looking at Figure 7-8 until it is clear.
6. Now if the two objects travel the same distance during the interaction and the interaction forces are equal and opposite, then the positive work done on the initially stationary object is equal in magnitude to the negative work done on the initially moving object. Thus, the kinetic energy gained by the initially stationary object is equal in magnitude to the kinetic energy lost by the initially moving object. Thus, the kinetic energy is conserved.
7. In the section "Conservation of Kinetic Energy in Elastic Interactions", this argument is generalized to show that it doesn't matter what the range of the force or the magnitude of the force as a function of distance happen to be kinetic energy is still conserved if the repulsive interaction force depends on separation distance only. The crux of the argument is the same as described above.

1. Let a force of 1500 Newtons act through a distance of 200 meters on a 1500 kg car which starts from rest.

   a. What is the work done? __________ __________

   b. What is the final velocity? __________ __________

   c. What is the car's momentum? __________ __________

   d. What is the car's change in momentum? __________ __________

   e. What is the car's kinetic energy? __________ __________

   f. What is the car's change in kinetic energy? __________ __________

Now let the 1500 Newton force continue to act on the car, in the same direction, through an additional 200 meters. Calculate the quantities asked for after the car had gone 200 meters and place the answers in the second set of blanks.

What do you note about the change in kinetic energy and change in momentum when comparing the results of the first half vs the second half intervals. What reason can you give for the results?

2. A 100 gram bullet and a 1500 kg car, each strike a block of wood. The bullet has an initial speed of 300 m/sec; the car, 0.02 m/sec. Find:

   a. the initial momentum of the bullet __________

   b. the initial momentum of the car __________

   c. the kinetic energy of the bullet __________

   d. the kinetic energy of the car __________

What does the difference in kinetic energy represent or suggest what might happen to the block?

3. A man is riding on a flatcar of a freight train moving at 10 m/sec. He throws a baseball in the direction of the train's motion, exerting a 50 Newton force throughout a 1 meter motion of his hand. The ball attains a speed of 10 m/sec relative to the flatcar. Calculate:

Relative to the flatcar;

a. Kinetic Energy of the ball before the throw ____________

b. Kinetic Energy of the ball after the throw ____________

c. change in Kinetic Energy ____________

Relative to the observer on the ground;

d. Kinetic Energy of the ball before the throw ____________

e. Kinetic Energy of the ball after the throw ____________

f. change in Kinetic Energy ____________

Is the additional work done fictitious or not? Explain.

Relative to the flatcar;

g. Momentum of ball before the throw ____________

h. Momentum of ball after the throw ____________

i. change in Momentum ____________

Relative to the observer on the ground;

j. Momentum of ball before the throw ____________

k. Momentum of ball after the throw ____________

l. change in Momentum ____________

How do you account for the two changes in momentum?

Determination and Derivation of Problem of One Mass Moving Hitting (head on) Another Mass at Rest

m_1 = mass of cart 1 u_1 = velocity of cart 1 before collision

m_2 = mass of cart 2 u_2 = velocity of cart 2 before collision

v_1 = velocity of cart 1 after collision

v_2 = velocity of cart 2 after collision

$$\vec{p}_1 + \vec{p}_2 = \vec{p}_1' + \vec{p}_2' \qquad E_{K_1} + E_{K_2} = E_{K_1}' + E_{K_2}'$$

(1) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

(2) $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

(3) $m_1u_1^2 + m_2u_2^2 = m_1v_1^2 + m_2v_2^2$

(7) $m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$

(4) $m_1u_1^2 - m_1v_1^2 = m_2v_2^2 - m_2u_2^2$

(5) $m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$

(8) $m_1(u_1 - v_1) = m_2(v_2 - u_2)$

(6) $m_1(u_1 + v_1)(u_1 - v_1) = m_2(v_2 + u_2)(v_2 - u_2)$

Divide (6) by (8)
$$\frac{m_1 (u_1 + v_1) (u_1 - v_1) = m_2 (v_2 + u_2) (v_2 - u_2)}{m_1 (u_1 - v_1) = m_2 (v_2 - u_2)}$$

(9) $u_1 + v_1 = v_2 + u_2$ or (10) $u_1 - u_2 = v_2 - v_1$

If cart 2 is at rest initially, the $u_2 = 0$ thus (11) $u_1 = v_2 - v_1$

Remove u_2 from equation (10) and then mutiplying (11) by m_1 gives:

(11) $m_1u_1 = m_1v_2 - m_1v_1$

Simplify (1) as $u_2 = 0$ and add to (11)

(11) $m_1u_1 = m_1v_2 - m_1v_1$

(1) $m_1u_1 = m_1v_1 + m_2v_2$

(12) $2m_1u_1 = m_1v_2 + m_2v_2$

Solve for v_2 =

(13) $v_2 = \frac{2m_1}{m_1 + m_2} u_1$

Solve (11) for v_2

(14) $v_2 = u_1 + v_1$

Substitute (14) into (13)

(15) $u_1 + v_1 = \frac{2m_1}{m_1 + m_2} u_1$

(16) $v_1 = \frac{m_1 - m_2}{m_1 + m_2} u_1$

Fill in the following table:

	$m_2 = 4m_1$	$m_1 = 4 m_2$	$m_2 = 3 m_1$	$m_1 = 3 m_2$
v_1	2/5 u_1			
v_2	- 3/5 u_1			

Chapter 7 Quiz

1. How much work is required to carry a 15-kg suitcase a horizontal distance of 50 meters?

____

2. A man pulls a 20 kg mass up a frictionless inclined plane which makes an angle of 30° with the ground. He moves the mass to a point 5.0 meters in height above the floor.

   a. How much work has he done?

   b. How far was the mass moved along the plane?

   c. How large a force was required to pull the mass up the inclined plane?

   a. ______________

   b. ______________

   c. ______________

3. A 10-kg mass is moving with a constant speed of 10 m/sec.

   a. How much work must be done to double the speed to 20 m/sec?

   b. How much work must be done to halve its speed to 5 m/sec?

   a. ______________

   b. ______________

4. A 10 kg body has a kinetic energy of 500 Joules. Its momentum is ______________?

5. A 10 kg body at rest on a frictionless table receives an impulse of 30 newton-sec. What is its final kinetic energy?

____

6. A 200 gram ball, moving at 6.0 m/sec approaches a second ball head on. The second ball has a mass of 100 grams and is initially at rest. While the balls are within 5.0 cm of each other, they repel each other with a constant force of 40 Newtons. The second ball leaves the collision with a speed of 8 m/sec.

   a. How much kinetic energy does the second ball gain in the collision?

   b. What is the kinetic energy of the first ball after the collision?

   c. How far did each ball move during the collision, i.e., while they remained 5.0 cm of each other?

   a. ______________

   b. ______________

   c. ______________

Chapter 7 Test

1. A 40 kg mass moving at a speed of 12 m/sec collides head on with a stationary 20 kg mass. The two masses stick together and move off at the same speed.

   a. What is the final speed of the two masses?

   b. How much kinetic energy is lost in the collision?

   a. ________________

   b. ________________

2. A steel ball has a mass of 4.0 kg and rolls along a smooth, level surface at 60 m/sec.

   a. Find the kinetic energy of the ball.

   b. At first, the ball was at rest on the surface. A force acted on it through a distance of 20 meters to give it the speed of 60 m/sec. What was the magnitude of the force?

   a. ________________

   b. ________________

3. A 10 kg mass moving with a speed of 10 m/sec collides head-on with a stationary 10 kg mass. The collision is elastic.

   a. What is the final velocity of mass one?

   b. What is the final velocity of mass two?

   a. ________________

   b. ________________

4. A 10 kg mass moving with a speed of 10 m/sec collides elastically with a 5.0 kg mass which is initially at rest. What is the final kinetic energy of the system.

____

OVER

5. A 2.0 kg mass moving at a speed of 40 m/sec has the same momentum as a 10 kg mass.

   a. What is the speed of the 10 kg mass?

   b. What is the kinetic energy of mass one?

   c. What is the kinetic energy of mass two?

   a. ______________

   b. ______________

   c. ______________

6. A force which increases from 0 to 100 Newtons at a rate of 10 Newtons per second acts on a body for 10 seconds. 12,500 Joules of work are done by this force in accelerating the body from rest to a final speed of 50 m/sec.

   a. What is the mass of the body?

   b. How large a constant force would have been required to give the body the same final speed if the force acted during one meter of travel?

   a. ______________

   b. ______________

7. A package weighs 35 Newtons. A person carries the package from the ground floor to to the fifth floor of an office building or 15 meters upward.

   a. How much work does the person do on the package?

   b. The person has a mass of 80 kilograms. How much total work is done?

   a. ______________

   b. ______________

8. A 5 kg mass moving at 4 m/sec strikes a glancing blow on a stationary 5 kg mass. The collision is elastic. After the collision one mass leaves at 45° to the incident direction.

   a. What is the final velocity of the mass that was initially moving?

   b. What is the final velocity of the mass that initially was at rest?

   a. ______________

   b. ______________

Chapter 7 Test - In pocket

1. A 40 kg mass moving at a speed of 12 m/sec collides head on with a stationary 20 kg mass. The two masses stick together and move off at the same speed.

   a. What is the final speed of the two masses?

   b. How much kinetic energy is lost in the collision?

   a. 8 M/sec

   b. 960 Joules

2. A steel ball has a mass of 4.0 kg and rolls along a smooth, level surface at 60 m/sec.

   a. Find the kinetic energy of the ball.

   b. At first, the ball was at rest on the surface. A force acted on it through a distance of 20 meters to give it the speed of 60 m/sec. What was the magnitude of the force?

   a. 7200 Joules $E_K = \frac{1}{2} mv^2 = \frac{1}{2} \times 4Kg \times (60\frac{M}{s})^2 = 7200 J$

   b. 360 Newtons

   $m = 4Kg$ $\Delta x = 20M$ $F \Delta x = W = \Delta E_K$

   $v = 60\frac{M}{sec}$ $F = ?$ $F = \frac{\Delta E_K}{\Delta x} = \frac{7200 \text{ Joules}}{20 M} =$

3. A 10 kg mass moving with a speed of 10 m/sec collides head-on with a stationary 10 kg mass. The collision is elastic.

   a. What is the final velocity of mass one?

   b. What is the final velocity of mass two?

   a. 0

   b. 10 M/sec same direction as before

4. A 10 kg mass moving with a speed of 10 m/sec collides elastically with a 5.0 kg mass which is initially at rest. What is the final kinetic energy of the system.

   500 Joules $E_{K\,Before} = \frac{1}{2} \times 10Kg \times (10\frac{M}{s})^2 = 500$ Joules

5. A 2.0 kg mass moving at a speed of 40 m/sec has the same momentum as a 10 kg mass.

   a. What is the speed of the 10 kg mass?

   b. What is the kinetic energy of mass one?

   c. What is the kinetic energy of mass two?

   a. 8 m/s

   b. 1600 J

   c. 320 J

ok

6. A force which increases from 0 to 100 Newtons at a rate of 10 Newtons per second acts on a body for 10 seconds. 12,500 Joules of work are done by this force in accelerating the body from rest to a final speed of 50 m/sec.

   a. What is the mass of the body?

   b. How large a constant force would have been required to give the body the same final speed if the force acted during one meter of travel?

   a. 10 Kg

   b. 12,500 N

ok

7. A package weighs 35 Newtons. A person carries the package from the ground floor to to the fifth floor of an office building or 15 meters upward.

   a. How much work does the person do on the package?

   b. The person has a mass of 80 kilograms. How much total work is done?

ok

   a. 525 Joules $W_1 = F\Delta x = 35N \times 15M = 525$ Joules

   b. 12,285 Joules $W_2 = F\Delta x = mg\Delta x = 80kg \times 9.8\frac{M}{s^2} \times 15M = 11760J$

8. A 5 kg mass moving at 4 m/sec strikes a glancing blow on a stationary 5 kg mass. The collision is elastic. After the collision one mass leaves at 45^0 to the incident direction.

   a. What is the final velocity of the mass that was initially moving?

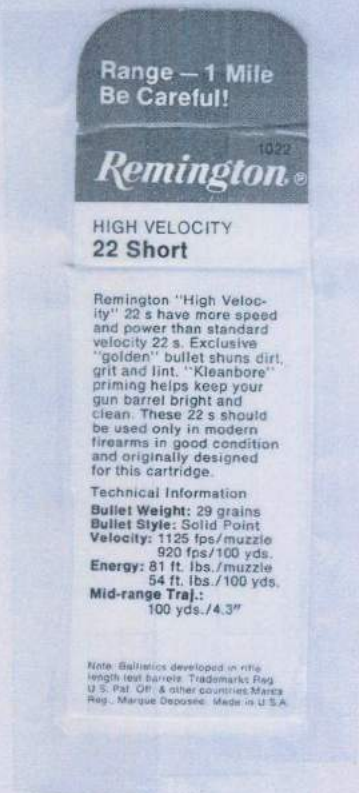
   b. What is the final velocity of the mass that initially was at rest?

W

   a. 2.83 M/sec 45^0

   b. 2.83 M/sec 45^0

18



$920 \frac{ft}{sec}$

1 GRAIN = 0.06479 8918 gm

$$29 \text{ grains} \times \frac{0.064798918 \text{ g}}{1 \text{ grain}} \times \frac{1 \text{ Kg}}{10^3 \text{ g}} = 1.879 \times 10^{-3} \text{ Kg}$$

$$\frac{1}{2} \times 1.879 \times 10^{-3} \text{ Kg} \times \left(3.429 \times 10^2 \frac{M}{sec}\right)^2 = 1.105 \times 10^2 \text{ Joules}$$

$$81 \text{ ft} \cdot \text{lbs} \times \frac{1.35582 \text{ J}}{\text{ft} \cdot \text{lb}} = 1.098 \times 10^2 \text{ Joules}$$

$$\frac{1}{2} \times 1.879 \times 10^{-3} \text{ Kg} \times \left(2.804 \times 10^2 \frac{M}{sec}\right)^2 = 73.898 \text{ J}$$

$$54 \text{ ft} \cdot \text{lb} \times 1.35582 \frac{\text{J}}{\text{ft} \cdot \text{lb}} = 73.214 \text{ J}$$

1 ft·lb = 1.35582 Joules

1 ft/sec = .3048 M/sec

(4.3 inches = 10.922 cm x = .10922 M)

$v_i = 1125 \text{ ft/sec} = 342.90 \text{ M/sec}$

$v_f = 920 \text{ ft/sec} = 280.42 \text{ M/sec}$

$d = 100 \text{ yds} = 91.44 \text{ M}$

$$t = \quad d = \frac{1}{2} t (v_f + v_i) \quad t = \frac{2d}{v_f + v_i} = \frac{2 \times 91.44 M}{342.90 \text{ M/sec} + 280.42 \frac{M}{sec}} = \frac{2 \times 91.44 M}{623.32 \text{ M/sec}}$$

$= .2934$ sec

$$d = \frac{1}{2} a t^2 = \frac{1}{2} \times 9.8 \frac{M}{sec^2} \times (.2934 \text{ sec})^2 = .422 M \quad \text{vs} \quad .10922 M$$

---

v_i = ~~1125 ft/sec~~ 342.90 M/sec

v_f = 280.42 M/sec

d = 100 M

a = ~~?~~ $\quad v_f^2 = v_i^2 + 2ad$

$$\frac{v_f^2 - v_i^2}{2d} = a$$

$$\frac{(280.42)^2 - (342.90)^2 \text{ M}^2/\text{sec}^2}{2 \times 91.44 M} = -214.24 \text{ M/sec}^2$$

$a = -214.24 \text{ M/s}^2 \qquad d = v_i t + \frac{1}{2} a t^2$

d = 45.72 M

v_i = 342.90 M/sec

t = ?

Test Chapter 15

Name KEY B

Date 12-19-79

1. A rocket engine is fired for 100 seconds (and then turned off) accelerating a spacecraft of mass 2000 kg. Before the engine was fired, the spacecraft was observed from earth to be moving at a velocity of 9,000 m/sec. The engine can exert a force of 40,000 N and is fired in the same direction as the spacecraft's initial velocity.

   a. What is the velocity of the spacecraft after the engine is turned off?

   b. What is the kinetic energy of the spacecraft after the engine is turned off?

   c. How much work is done by the engine in accelerating the spacecraft?

2. A 20 kg mass is pulled along a frictionless surface by a force of 8.0 N.

   a. If the mass is accelerated from a speed of 3 m/sec, what is the work done on it after it has moved a distance of 15 m?

   b. What is the kinetic energy of the mass after it has moved that distance of 15 m?

   c. What is the kinetic energy of the mass after it has moved 30 m?

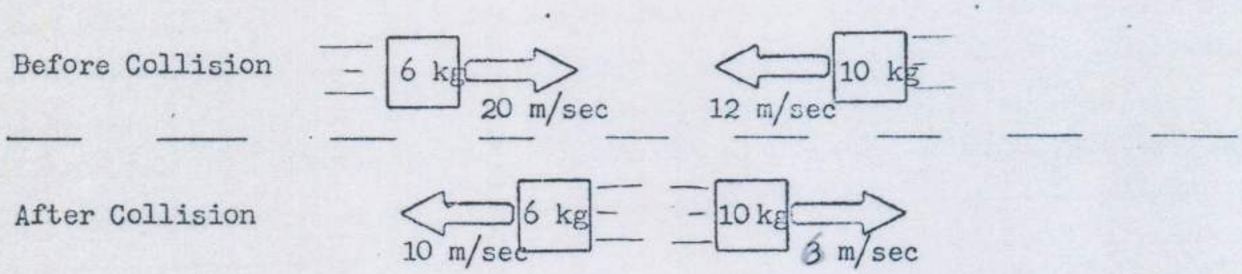
3. A locomotive and a truck both moving in the same direction have equal momentum. The locomotive has a mass of 16,000 kg while the truck has a mass of 4,000 Kg and is moving at 28 m/sec.

   a. What is the speed of the locomotive?

   b. How much work would have to be done on the truck to make its speed the same as that of the locomotive?

   c. Assuming that you apply the same force to stop both the truck and locomotive (both with the same momentum), what factors would you have to take into account to get the job done?

4. Two masses collide as shown below.



   a. Show that momentum is conserved in this collision.

   b. Is this collision:

      i. totally elastic?
      ii. totally inelastic?
      iii. partially elastic?

   Perform necessary calculations which justifies your answer.

Note...!!!! All work is to be done on a separate sheet of paper in as neat and organized manner. If done otherwise, it will not be evaluated.

1. $t = 100$ sec $m = 2000$ kg
$V_i = 9{,}000$ M/sec $F = 40{,}000$ N
$V_f = ?$
$a = F/m$

(a) $a = \frac{V_f - V_i}{t}$ $V_f = V_i + at = 9000\frac{M}{sec} + \frac{40{,}000\ \frac{kg\,M}{sec^2}}{2{,}000\ kg} \times 100\ sec$

$V_f = 9000$ M/sec $+ 2000\frac{M}{sec} = 11{,}000$ M/sec

(b) $E_{K_f} = \frac{1}{2} m v^2$
$= \frac{1}{2} \times 2000\ kg \times (11{,}000\frac{M}{sec})^2 = 1.21 \times 10^{11}$ Joules

(c) $W = F\Delta x = F\,\frac{1}{2}t(V_f + V_i)$
$= \frac{40{,}000\ N}{2} \times 100\ sec \times 20{,}000\frac{M}{sec} = 4 \times 10^{10}$ Joules

OR $W = E_{K_f} - E_{K_i} = E_{K_f} - \frac{1}{2} m v_i^2$
$= 1.21 \times 10^{11}\ J - \frac{1}{2} \times 2000\ kg \times (9000\frac{M}{sec})^2$
$= 1.21 \times 10^{11}\ J - 8.1 \times 10^{10} = 4 \times 10^{10}$ Joules

2. $m = 20$ kg $V_i = 3\frac{M}{sec}$
$F = 8.0$ N $d = 15$ M

(a) $W = F\Delta x = 8.0\ N \cdot 15\ M = 120$ Joules

(b) $E_{K_f} = E_{K_i} + \Delta E_K(W)$
$= \frac{1}{2} \times 20\ kg \times (3\frac{M}{sec})^2 + 120\ J = 90\ J + 120\ J = 210$ Joules

(c) $E_K = E_{K_{15M}} + \Delta E_K$
$= 210$ Joules $+ 120$ Joules $= 330$ Joules

3. $m_L = 16{,}000$ kg $m_T = 4{,}000$ kg $v_T = 28$ M/sec $p_L = p_T = 1.12 \times 10^5$

(a) $v_L = ?$ $m_L v_L = m_T v_T$ $v_L = \frac{M_T}{M_L} \times V_T$
$= \frac{4000\ kg}{16000\ kg} \times 28\frac{M}{sec} = 7\frac{M}{sec}$

(b) $W_T = \Delta E_{K_T} = E_{K_f} - E_{K_i}$ $V_i = 28\frac{M}{sec}$ $V_f = 7\frac{M}{sec}$
$= \frac{1}{2} m_T (V_f^2 - V_i^2) = \frac{1}{2} \times 4{,}000\ kg\,(7\frac{M}{sec}^2 - 28\frac{M}{sec}^2)$
$= 2000\,(49 - 784) = 2000 \cdot -735 = -1.47 \times 10^6$ Joules

(c) F_T constant $= F_L$ constant ; $p_T = p_L$ ∴ Δt to stop both is same
$E_{K_L} = \frac{1}{2} \times 16{,}000\ kg \cdot (7\frac{M}{sec})^2 = 3.92 \times 10^5$ Joules
$E_{K_T} = \frac{1}{2} \times 4000\ kg \times (28\frac{M}{sec})^2 = 1.568 \times 10^6$ Joules
$\frac{E_{K_T}}{E_{K_L}} = 4$ ∴ $\frac{\Delta x_T}{\Delta x_L} = 4$

(Let $F_{MAX} = 10^3$ N) $\Rightarrow t = \frac{\Delta p}{F} = \frac{1.12 \times 10^5\ kg\,M}{10^3\ N\ sec} = 1.12 \times 10^2$ sec

$\Delta x_L = \frac{\Delta E_{K_L}}{F} = \frac{3.92 \times 10^5\ J}{10^3\ N} = 3.92 \times 10^2$ M

$\Delta x_T = 1.56 \times 10^3$ M

4. $p_B = 20\frac{M}{sec} \times 6\ kg + -12\frac{M}{sec} \times 10\ kg = 120\frac{kg\,M}{sec} - 120\frac{kg\,M}{sec} = 0 = p_{before}$

$p_A = -10\frac{M}{sec} \times 6\ kg + 6\frac{M}{sec} \times 10\ kg = -60\frac{kg\,M}{sec} + 60\frac{kg\,M}{sec} = 0 = p_{after}$

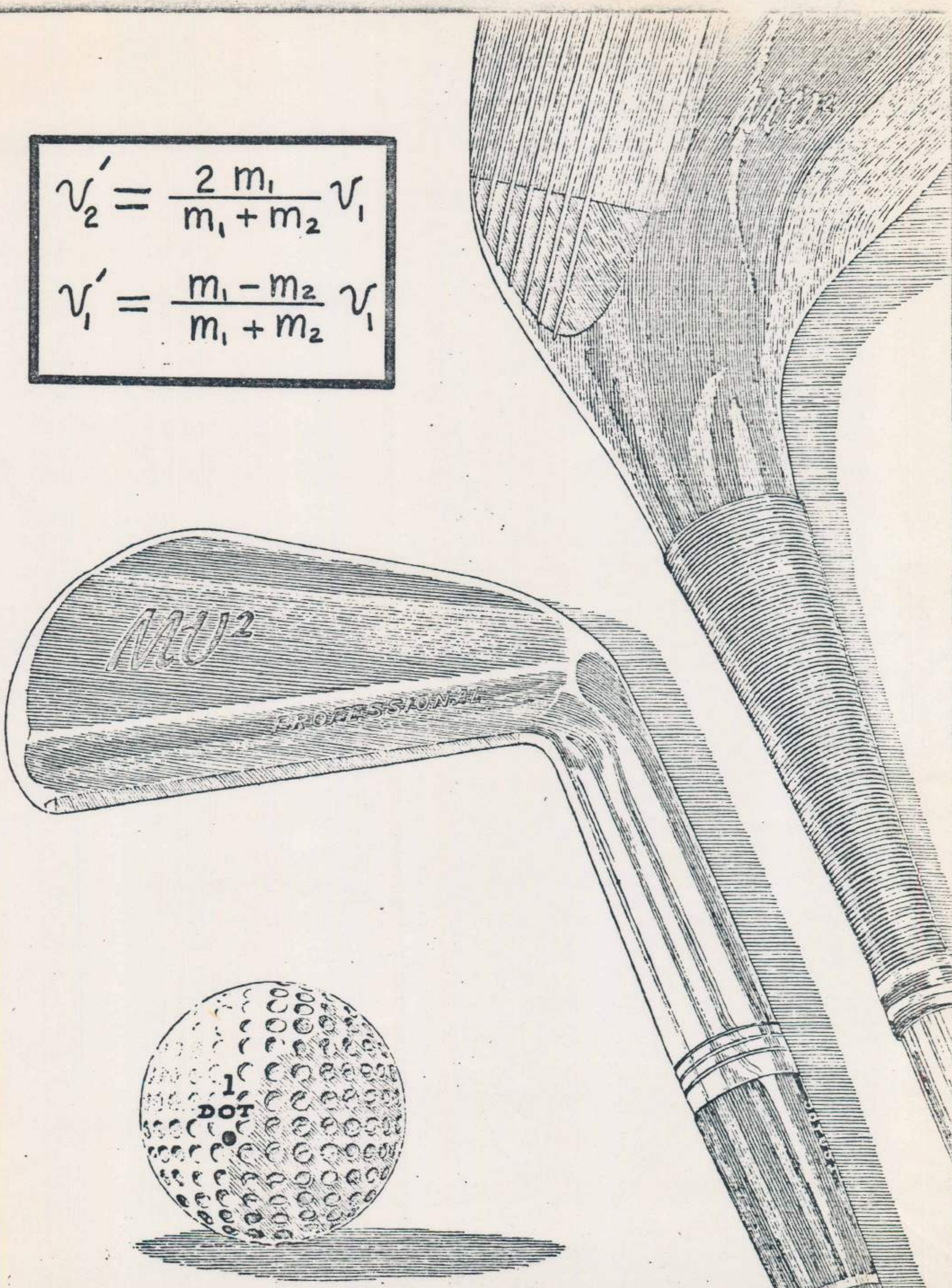
$E_{K_i} = \frac{1}{2} \times 6\ kg \times (20\frac{M}{sec})^2 + \frac{1}{2} \times 10\ kg \times (12\frac{M}{sec})^2 = 1200\ J + 720\ J = 1920\ J = E_i$

$E_{K_f} = \frac{1}{2} \times 6\ kg \times (10\frac{M}{sec})^2 + \frac{1}{2} \times 10\ kg \times (6\frac{M}{sec})^2 = 300\ J + 180\ J = 480\ J = E_f$

$\Delta E_K = -1440$ Jou[illegible]

$$v_2' = \frac{2\,m_1}{m_1 + m_2}\,v_1$$

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2}\,v_1$$



OBJECTIVES: CH. 23 PSSC Physics
"Work and Kinetic Energy"

You must be able to:

( ) 1. a) Define the general term "energy"
b) Offer 5 examples of this concept (i.e., chemical, etc.)

( ) 2. a) Define "work" correctly--you may use your own words
b) State, in a simple equation, how work may be computed (Sec. 3)
c) Offer a word, or story example, using numbers, to illustrate your correct answer to part b.

( ) 3. Problem of the specific type like # 3 or # 5

( ) 4. a) Define "kinetic energy"--correctly in your own words
b) State the equation that may compute this.
c) Given an object, its mass, traveling at a certain velocity, be able to compute its K.E.
d) As in part C, except that the object is rotating at a certain frequency around a certain radius.

( ) 5. Starting from Newton's law, F = ma, derive (showing all steps) the Kinetic Energy equation.

( ) 6. Problem of the specific type like #11

( ) 7. " " " #21

( ) 8. " " "#28

( ) 9. " " " #30

( ) 10. " " " #31

( ) 11. Essay: What happens to the kinetic energy of a car when you brake it to a stop? (Be complete in your answer)

( ) 12. a) What is an elastic collision?
b) Offer a word or story example explaining this concept.

( ) 13. a) What is an inelastic collision?
b) Offer a word or story example explaining this concept.

______ OBJECTIVES of 13 for _____% Each item counts approx 8%

OBJECTIVE TEST: Ch. 23 PSSC Physics
"Work and Kinetic Energy" Name ____________

1. a) Define the general term "energy":

b) List 5 examples of the above concept:

2. a) Define "work":

b) State, in a simple equation, how "work" may be computed:

c) Offer a word or story example, using <u>numbers</u>, to illustrate your answer to part b:

3. A barbell, symmetrical and weighing 100 pounds, is lying on the floor.

a) How much work would be done in lifting the entire barbell a height of 4 feet 6 inches? Ans: ______

b) How much work would be done in lifting just one end a height 2 feet from the floor? Ans: ______

c) How much work would be done in justim <u>holding</u> (not lifting or lowering) the barbell 4 feet 6 inches from the floor? Ans: ______

d) How much work would be done in moving the barbell sideways fr a position 2 feet above the floor? (It is moved 3 feet sideways) Ans: ______

4. a) Define "kinetic energy":

b) State the equation that may compute this: ____________

c) Compute the kinetic energy of a 7 kilogram bowling ball movin along a floor at a velocity of 1.5 meters/sec. Ans: ______

d) Compute the kinetic energy of a 2.0 kg stone whirling around on the end of a 0.5 m string with a frequency of 2.0 revoluti per second: Ans: ______

5. Starting from Newton's law, F = MA, derive (showing ALL steps) the Kinetic Energy equation:

6. A force of 50 newtons accelerates a 2.0 kg object from rest for a distance of 3.0 meters along a level, frictionless surface; the force then changes to 25 newtons and acts for an additional 2.0 meters.

a) What is the final kinetic energy of the object?

Ans: ________

b) How fast is it moving?

Ans: ________

7. A "dud" projectile from an antitank gun has a mass of about 2.0×10^1 kg and a speed of 1000 meters/sec. A freight car being move around a switchyard has a mass of about 10,000 kg and a speed of 2 m/s

a) What is the momentum of each?

b) What is the kinetic energy of each?

c) Why does the projectile do much more damage than the freight car when it hits something?

8. A driverless, uncontrolled car of mass 2000 kg coasts along a flat road at a speed of 2.0 m/sec and slams into a parked car of mass ~~10000xkg~~ 1000 kg. After the collision, the cars lock bumpers and both move as a unit.

a) What is the initial momentum of the heavy car? ________

~~b)~~ What is the initial momentum of the light car? ________

b) What is the speed of the 2 combined cars after the collision? Ans: ________

c) What is the total kinetic energy before and after the impact?

Ans: ________

d) Why is this, or is not, an example of an elastic collision?

9. A hockey puck has a mass of 2 kg. It is subjected to a constant force F of 40 newtons at an angle of 45° above the horizontal for 2 seconds.

a) If the puck starts from rest, what is its change in momentum in the first 2 seconds the force is applied?

Ans: ________

b) How much work was done in these 2 seconds?

Ans: ________

c) What would happen to the change in momentum and kinetic energy if the force were doubled? ________ ________

10. A person jumps out of a perfectly good airplane and opens his parachute. After falling a height of 1000 meters, he attains a terminal velocity of 5 m/sec. How much energy has been transferred to the air and into the silk of his parachute?

Ans: ________

11. <u>Essay</u>: What happens to the kinetic energy of a car when you brake it to a stop? (Be <u>complete</u> in your answer)

12. a) What is an "elastic collision"?

b) Offer a word or story example <u>explaining</u> this concept:

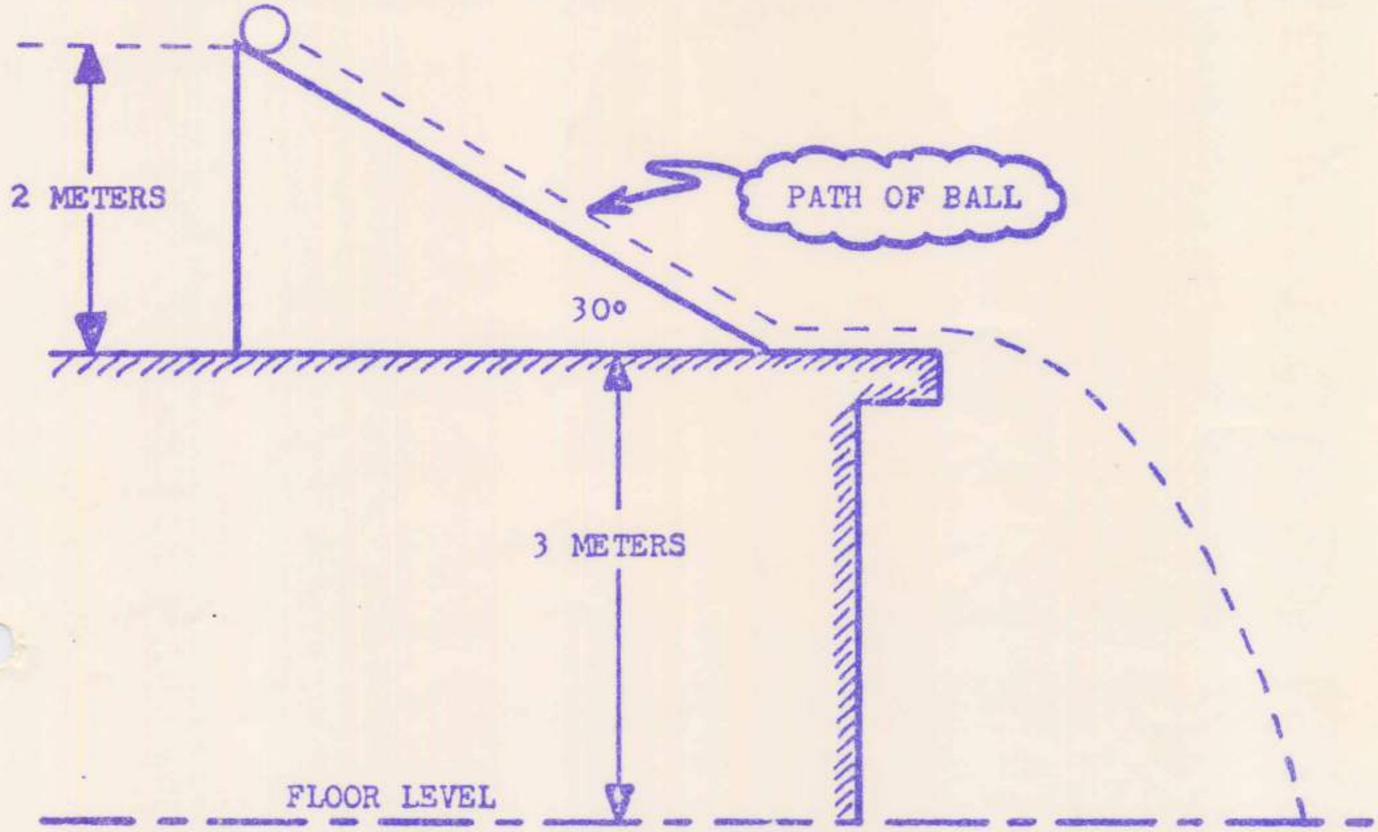
13. a) What is an <u>inelastic</u> collision?

b) Offer a word or story example <u>explaining</u> this concept:

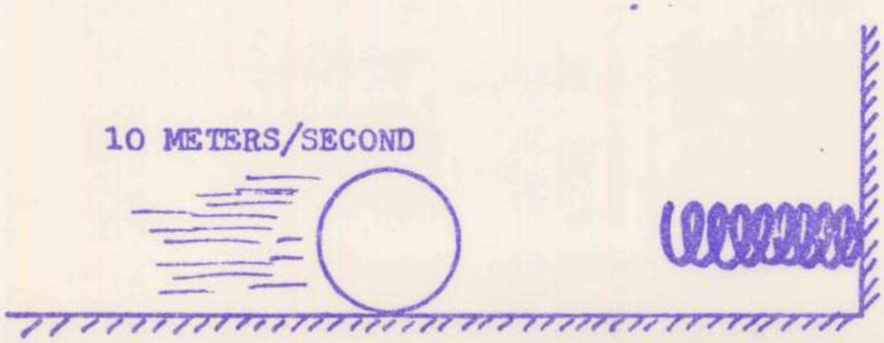
PSSC PHYSICS QUIZ #______ Name ______________________

CONSERVATION OF ENERGY Date ______________________

1. A 2 kilogram ball is released from the top of a frictionless plane as shown in the diagram below. What is the speed of the ball when it hits the floor? (3 pts.)



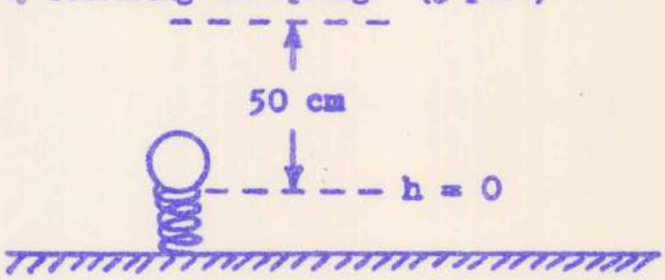
2. A ball with a mass of 1.0 kilogram has a speed of 10 meters per second along a frictionless horizontal floor. The ball runs into a spring bumper with a spring constant of 400 Newton/meter. How far is the spring compressed? (3 pts.)



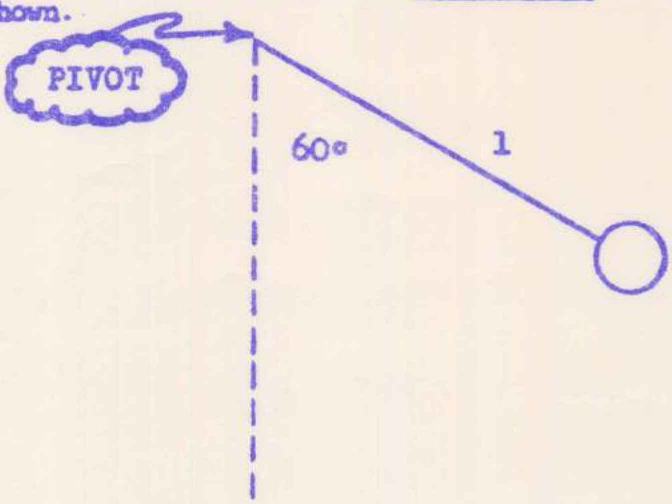
PSSC PHYSICS QUIZ #_____ Name ______________________ _____

CONSERVATION OF ENERGY Date ______________________

3. A spring ($k = 400$ Newton/meter) is compressed 50 centimeters; then a ball is placed on top of the spring (see diagram below). What is the mass of the ball, if it obtains a height of one (1) meter above $h = 0$ when the ball is shot into the air by releasing the spring. (3 pts.)



4. A pendulum ball has a mass of 5 kilograms and is pulled back to an angle of 60° as shown.



If the length of the pendulum is 160 centimeters, what is the speed of the ball as it passes directly below the pivot point? (1 pt.)

E.P.: Make up the next question for this quiz following the pattern in the above problems. The pattern is contained in the underlined words.