PHYS 11 - CH 9 text pgs 176 - 179

A) <u>MOMENTUM</u> - Heavy or fast moving objects have more <u>momentum</u> (p).

Momentum is a vector quantity and is always in the same direction as velocity.

$$\vec{p} = m\vec{v} \text{ (units are kg m/s)}$$

momentum = mass x velocity

Question: What is the momentum of a 1000.kg car travelling along a highway at 15 m/s?

$p = mv = (1000.)(15) = 1.5 \times 10^4$ kg m/s

B) <u>CHANGES IN MOMENTUM</u>

If we change the mass or velocity, the momentum changes

$$\Delta p = p_2 - p_1 = (mv)_2 - (mv)_1$$

change in mom'm = mom'm after - mom'm before

Question: A ball of mass 2.5 kg speeds up from 6.0 m/s to 8.0 m/s. Determine Δp

$\Delta p = (mv)_2 - (mv)_1$

$= mv_2 - mv_1$ as m remains constant

$= (2.5)(8.0) - (2.5)(6.0)$

$= 5$ kg m/s

Question: A wagon of mass 10kg is rolling along at a speed of 3.0 m/s when a small girl of mass 30kg jumps onto it. The wagon continues to move a the same speed. Determine the change in momentum of the wagon.

$\Delta p = (mv)_2 - (mv)_1$

$= m_2v - m_1v$, as v remains constant

$= (30 + 10)(3.0) - (10)(3.0) = 90$ kg m/s

C) IMPULSE AND MOMENTUM

the rate of change of momentum is directly proportional to the force applied.

Since $F = \Delta p/\Delta t$, then change in momentum Δp

$$\Delta p = F\Delta t$$

Δp is determined by how much force is applied for how long (called "Impulse")

Impulse = $F\Delta t$ (N s)

Impulse = change in momentum, and F is the average force acting during the time interval.

<u>Question</u>: what is the impulse exerted on a golf ball by a club if they are in contact for 0.005 s and the club exerts a force of 550N on the ball?

Impulse = $F\Delta t$ = (550N)(0.005s) = 3 Ns

<u>Question</u>: A cue strikes a pool ball, exerting an average force of 55N over a time of 10 ms (0.01s). If the ball has a mass of 0.2 kg, what speed does it have after impact?

F = 55N, t = 0.01s, m = 0.2 kg

$F\Delta t = (mv)_2 - (mv)_1$, ball was at rest so $v_1 = 0$

$F\Delta t = mv_2 - 0$, $F\Delta t = mv_2$

so $v_2 = F\Delta t/m$ = (55N)(0.01s)/(0.2kg) = 3 m/s

Funsheet Impulse - Change in Momentum

1. Jenny has a mass of 35.6 kg and her skateboard has a mass of 1.3 kg. What is the momentum of Jenny and her skateboard if they are going 9.50 m/s? **3.51 x 10^2 kg m/s**

2. A hockey player makes a slap shot, exerting a 30.0 N on the hockey puck for 0.16 s. What impulse is given to the puck? 4.8 Ns

3. The hockey puck shot in question 2 has a mass of 0.115 kg and was at rest before the shot. With what speed does it head toward the goal? 42 m/s

4. A force of 6.00N acts on a 3.00kg object for 10.0s.
a. What is the object's change in momentum? **60.0 Ns**
b.What is its change in velocity? **20.0 m/s**

5. The velocity of a 600-kg auto is changed from +10.0 m/s to +44.0 m/s in 68.0s by an applied, constant force.
a. What change in momentum does the force produce? **2.04 x 10^4 kg m/s**
b. What is the magnitude of the force? **300. N**

6. A 845-kg drag race car accelerates from rest to 100 km/h in 0.90 s.
a. What is the change in momentum of the car? **2.35 x 10^4 kg m/s**
b. What average force is exerted on the car? **2.6x10^4 N**

7. A sprinter with a mass of 76 kg accelerates from 0 to 9.4 m/s in 2.8 s. Find the average force acting on the runner. **2.6 x 10^2 N**

8. A 0.25-kg soccer ball is rolling at 6.0 m/s toward a player. The player kicks the ball back in the opposite direction and gives it a velocity of 14 m/s. What is the average force during the interaction between the player's foot and the ball if the interaction lasts 2.0 x 10^{-2}s? 2.5 x 10^2 N

9. A force of 1.21 x 10^3 N is needed to bring a car moving at +22.0 m/s to a halt in 20.0s. What is the mass of the car? **1.10 x 10^3 kg**

10. Small rockets are used to make small adjustments in the speed of satellites. One such rocket has a thrust of 35 N. If it is fired to change the velocity of a 72 000-kg spacecraft by 63 cm/s, how long should it be fired? **1.3 x 10^3s**

11. A 10 000-kg freight car is rolling along at 3.00 m/s. Calculate the time needed for a force of 1000 N to stop the car. **30.0 s**

12. A car moving at 10. m/s crashes into a barrier and stops in 0.25 m.
a. Find the time required to stop the car. 5.0 x 10^{-2} s
b. If a 20-kg child were to be stopped in the same time as the car, what average force must be exerted? **4.0 x 10^3 N**
c. Approximately what is the mass of an object whose weight equals the force from part b? Could you lift such a mass with your arm? **4.0x10^2 kg**
d. What does your answer to part c say about holding an infant on your lap instead of using a separate infant restraint?

13. An animal rescue plane flying due east at 36.0 m/s drops a bale of hay from an altitude of 60.0 m. If the bale of hay weighs 175 N, what is the momentum of the bale the moment it strikes the ground? **893 kgm/s**

14. A 10kg lead brick falls from a height of 2.0m.
a. Find its momentum as it reaches the ground. 63 kgm/s
b. What impulse is needed to bring the brick to rest? **63 Ns**
c. The brick falls onto a carpet, 1.0 cm thick. Assuming the force stopping it is constant, find the average force the carpet exerts on the brick. 2x10^4N

d. If the brick falls onto a 5.0-cm foam rubber pad, what constant force is needed to bring it to rest? 4×10^3N

15. A 60-kg dancer leaps 0.32 m high.
a. With what momentum does the dancer reach the ground? 148 kgm/s
b. What impulse is needed to stop? 148Ns
c. As the dancer lands, the knees bend, lengthening the stopping time to 0.050 s. Find the average force exerted on the body.
2.96×10^3N
d. Compare the stopping force to the performer's weight.

16. A 95-kg fullback, running at 8.2 m/s, collides midair with a 128-kg defensive tackle moving in the opposite direction. Both players end up with zero speed.
a. What was the fullback's momentum before the collision? **7.8×10^2kgm/s**
b. What was the change in the fullback's momentum? 7.8×10^2kgm/s
c. What was the change in the tackle's momentum? 7.8×10^2kgm/s
d. What was the tackle's original momentum?
7.8×10^2kgm/s
e. How fast was the tackle moving originally?
6.1m/s

17. A glass ball, ball A, mass 5.0 g, moves at a velocity of 20.0 cm/s. It collides with a second glass ball, ball B, mass 10.0 g, moving along the same line with a velocity of 10.0 cm/s. After the collision, ball A is still moving, but with a velocity of 8.0 cm/s.
a. What was ball A's original momentum?
1.0×10^2gcm/s
b. What is ball A's change in momentum?
60.gcm/s
c. What is ball B's change in momentum?
60.gcm/s
d. What is the momentum of ball B after the collision? **1.6×10^2gcm/s**
e. What is ball B's speed after the collision?
16 cm/s

18. Before a collision, a 25-kg object is moving at +12 m/s. Find the impulse that acted on this object if after the collision it moves at
a. +8m/s. **1.0×10^2Ns** b. -8m/s. **5.0×10^2Ns**

19. A 2575-kg van runs into the back of a 825-kg compact car at rest. They move off together at 8.5 m/s. Assuming no friction with the ground, find the initial speed of the van. **11 m/s**

20. A 15-g bullet is shot into a 5085-g wooden block standing on a friction less surface. The block, with the bullet in it, acquires a velocity of 1.0 m/s. Calculate the velocity of the the bullet before striking the block. **3.4×10^2m/s**

21. A hockey puck, mass 0.115 kg, moving at 35.0 m/s, strikes a rubber octopus thrown on the ice by a fan. The octopus has a mass of 0.265kg. The puck and octopus slide off together. Find their velocity. **10.6 m/s**

22. A 50-kg woman, riding on a 10-kg cart is moving east at 5.0 m/s. The woman jumps of the cart and hits the ground at 7.0 m/s eastward, relative to the ground. Calculate the velocity of the cart after she jumps off. **5.0 m/s west**

23. Two students on roller skates stand face to face, then push each other away. One student has a mass of 90 kg, the other 60kg. Find the ratio of their velocities just after their hands lose contact. Which student has the greater speed? **the 60kg student**

24. A car with mass 1245 kg, moving at 29 m/s strikes a 2175-kg car at rest. If the two cars stick together, with what speed do they move? **11m/s**

25. A 92-kg fullback, running at 5.0 m/s, attempts to dive across the goal line for a touchdown. Just as he reaches the goal line, he is met head-on in midair by two 75-kg linebackers, one moving at 2.0 m/s and the other at 4.0 m/s. If they all become entangled as one mass, with what velocity do they travel? **4.0×10^{-2}m/s** Does the fullback score? yes

Physics 11

MOMENTUM VIDEO PROJECT

Mission:

To produce a momentum video which explains the concepts of momentum for the class to view.

Regulations:

1. Group Size
   - you are to work in groups of 3 or 4
2. Disclaimer
   - stunts which may result in injury or death are discouraged
   - Mr Powell Hugh McRoberts Secondary, and the Richmond School District may not be held responsible for any injury or damage resulting from the production the momentum video

Evaluation:

1. Physical Models of: (8 marks)
   a. Momentum
   b. Conservation of Momentum
   c. Impulse
   d. Elastic & Inelastic Collisions

2. Explanations of each Physical Model (8 marks)
   - explains the concepts of momentum as listed in part 1.

3. Video Length (1 mark)
   - must be 5-10 minutes

4. Preparedness (1 mark)
   - video is properly cued and on a VHS format tape

5. Degree of Difficulty (2 marks)
   - complexity of examples and effort required to produce / film them

6. Entertainment Value (4 marks)
   - film holds the interest of the viewers

Awards:

(2 bonus marks per award)

1. Best Picture
2. Best Directing / Editing
3. Best Special Effects
4. Best Sound Effects

Physics 11

MOMENTUM VIDEO PROJECT

Evaluation Form

Total Marks:_____ /24

Group Members: block________

____

____

____

Criteria: Total Marks____ /24

1. Physical Models of:
   a. Momentum
      physical model _____/2 marks explanation _____/2 marks

   b. Conservation of Momentum
      physical model _____/2 marks explanation _____/2 marks

   c. Impulse
      physical model _____/2 marks explanation _____/2 marks

   d. Elastic & Inelastic Collisions
      physical model _____/2 marks explanation _____/2 marks

3. Video Length _____ /1 mark
   - must be 5-10 minutes

4. Preparedness _____/1 mark
   - video is properly cued and on a VHS format tape

5. Degree of Difficulty _____/2 marks
   - complexity of examples and effort required to produce / film them

6. Entertainment Value _____/4 marks
   - film holds the interest of the viewers

Awards: (3 bonus marks per award) Bonus Marks_____

1. Best Picture _____
2. Best Directing / Editing _____
3. Best Special Effects _____
4. Best Sound Effects _____

CONSERVATION OF MOMENTUM

The law of Conservation of Momentum states:
The Momentum (p) of objects in a closed, isolated system is conserved (doesn't change)

Newton's Third law: $F_A = -F_B$, or $F_A \Delta t = (-)F_B \Delta t$,
since $F\Delta t = \Delta p$, then $\Delta p_A = (-)\Delta p_B$,

$$(mv)_{A2} - (mv)_{A1} = -\{(mv)_{B2} - (mv)_{B1}\},$$

$$(mv)_{A2} + (mv)_{B2} = (mv)_{A1} + (mv)_{B1}$$

where $(mv)_{B2}$ is mom'm of object B after collision

TOTAL P AFTER = TOTAL P BEFORE

Two types of collisions in a straight line:

1. Objects collide and go off separately;

$$\mathbf{(mv)_{A1} + (mv)_{B1} = (mv)_{A2} + (mv)_{B2}}$$

2. Objects collide and stick together;

$$\mathbf{(mv)_{A1} + (mv)_{B1} = (m_A + m_B)v_2}$$

*use neg sign if v_A & v_B are in opposite directions

Question: Glider A of mass 0.355kg moves along a frictionless air track with a velocity of 0.095m/s. It collides with glider B of mass 0.710kg moving in the same direction at a speed of 0.045m/s. After the collision, glider A continues in the same direction with a velocity of 0.035m/s. What is the velocity of glider B after the collision?

$(mv)_{A1} + (mv)_{B1} = (mv)_{A2} + (mv)_{B2}$

$(0.355kg)(0.095m/s) + (0.710kg)(0.045m/s) =$
$(0.355kg)(0.035m/s) + (0.710kg)v_{B2}$

solve for $v_{B2} = 0.075m/s$

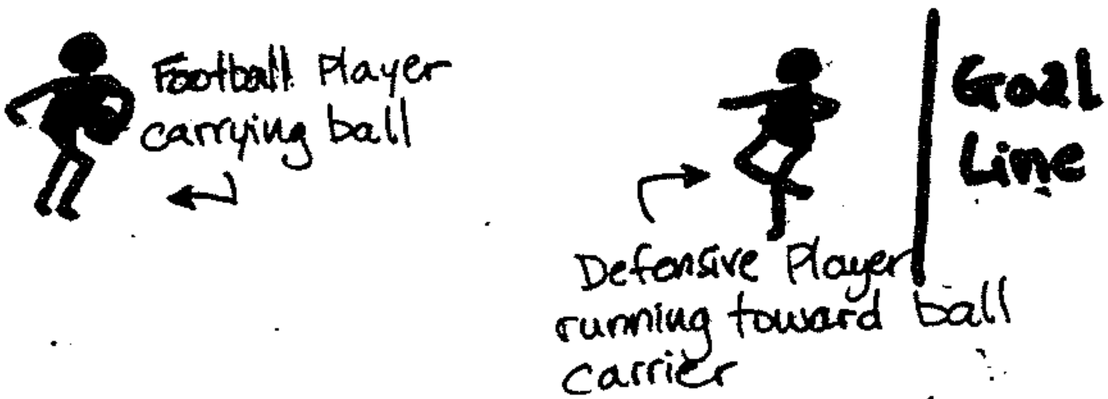
Question: Suppose car A with mass of 6000.kg and a velocity of +2.0m/s runs head-on into car B with a mass of 3000.kg and velocity of -3.0m/s. What is the final velocity of the two cars if they stick together?

$(mv)_{A1} + (mv)_{B1} = (m_A + m_B)v_2$

$(6000.kg)(+2.0m/s) + (3000.kg)(-3.0m/s) =$
$(6000.kg + 3000.kg)v_2$

solve for $v_2 = 0.33m/s$

MOMENTUM AND FOOTBALL



	Ball carrier	Velocity →	← Velocity	Defensive player
A	92 kg	5.1 m/s	2.1 m/s	135 kg
B	84 kg	8.7 m/s	6.8 m/s	104 kg
C	88 kg	6.4 m/s	5.6 m/s	112 kg
D	107 kg	5.8 m/s	8.2 m/s	94 kg

Which ball carriers are most likely to score touchdowns?

W.S. #7-2

Problems

Momentum and Impulse

1. A 280-lb football player runs with a velocity of 12.0 ft/s. What is his linear momentum?
2. A 0.357 magnum bullet has a mass of 0.010 kg and a muzzle velocity of 450 m/s. (a) What is the momentum of the bullet on leaving the muzzle of the gun? (b) Estimating your mass (a 1-kg mass has an equivalent weight of 2.2 lb), how fast would you have to move to have the same linear momentum as the bullet?
3. How fast must a 1600-lb car be traveling to have the same linear momentum as a 2-ton truck traveling with a velocity of 30 mi/h?
4. During a snowball fight, a 0.20-kg snowball traveling with a velocity of 15 m/s hits a student in the back of the head. (a) What is the collision impulse? (Is this an elastic collision?) (b) If the collision is 0.01 s, what is the average impulse force on the student's head?
5. A 0.010-kg bullet leaves a rifle with a muzzle velocity of 500 m/s. The rifle has a mass of 4.0 kg and a barrel length of 1.0 m (a) What is the average force on the bullet while in the barrel? (b) What is the total impulse of the system?
6. A 1600-kg automobile traveling at 25 m/s along a straight, level road has its speed reduced to 15 m/s in 4.0 s. What is the magnitude of the average braking force? [Work the problem two ways: (1) using linear momentum and (2) by finding the average acceleration.]
7. A 0.40-kg basketball is thrown horizontally against a wall with a velocity of 20 m/s. If the ball rebounds with a velocity of 15 m/s, what is the impulse of the collision? (Was the collision elastic?)
8. A 0.20-kg billiard ball traveling with a speed of 15 m/s strikes the rail at an angle of 60° (see Fig. 8.P8). (a) If the ball rebounds with the same speed at the same angle, what is the impulse (magnitude and direction) of the collision? (b) If the ball is in contact with the railing 0.01 s, what is the magnitude of the average force exerted on the ball by the rail?

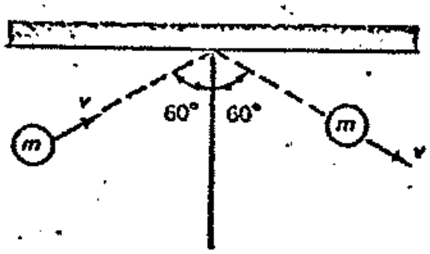


Figure 8.P8

Conservation of Linear Momentum

9. Assuming the rifle in Problem 5 to be held loosely, with what speed does it recoil as the bullet leaves the barrel?
10. A hunter weighing 750 N jumps from a stationary 40-kg canoe to shore with a horizontal speed (relative to the shore) of 1.5 m/s. With what speed does the canoe initially move away from the shore?
11. A 165-lb man and his 99-lb daughter stand together on skates. If they push apart and the father receives a velocity of 1.5 m/s, what is the daughter's velocity? (Neglect friction.)
12. A 2.0-kg block of wood at rest on a horizontal frictionless surface is hit by a 0.010-kg bullet traveling at a speed of 300 m/s parallel to the surface. If the bullet passes through the block and emerges with a speed of 250 m/s, what velocity is imparted to the block?
13. A 66-kg astronaut is stranded at rest 12 m from his spaceship in free space. In order to get back to the ship, he throws a 0.50-kg piece of equipment with a speed of 4.0 m/s directly away from the spaceship. How long will it take the astronaut to reach the ship?
14. Two blocks weighing 2.0 N and 3.0 N are on a horizontal frictionless surface and connected by a spring with a spring constant of 50 N/m. (a) If the blocks are pulled apart and released, what is the speed of the 2.0-N block when the 3.0-N block has a speed of 6.0 m/s at some time after release? (Neglect the mass of the spring.) (b) In general, how are the kinetic energies of the blocks related?

21. Two balls with masses of 2.0 kg and 6.0 kg travel toward each other with speeds of 12 m/s and 4.0 m/s, respectively. If the balls have a head-on *inelastic* collision and the 2.0-kg ball recoils with a speed of 8.0 m/s, what is the velocity of the other ball?

26. A 3200-lb automobile travels with a speed of 30 mi/h northward along a city street, and a 1600-lb sports car travels with a speed of 60 mi/h eastward along an intersecting street. (a) If the cars collide at the intersection and stick together, what is the velocity (magnitude and direction) of the combination immediately after the collision? (b) Was the collision elastic? (*Hint:* Use vector addition of momentum.)

PL11 Momentum Worksheet 7-3
Show all steps in your solution.

Ans:

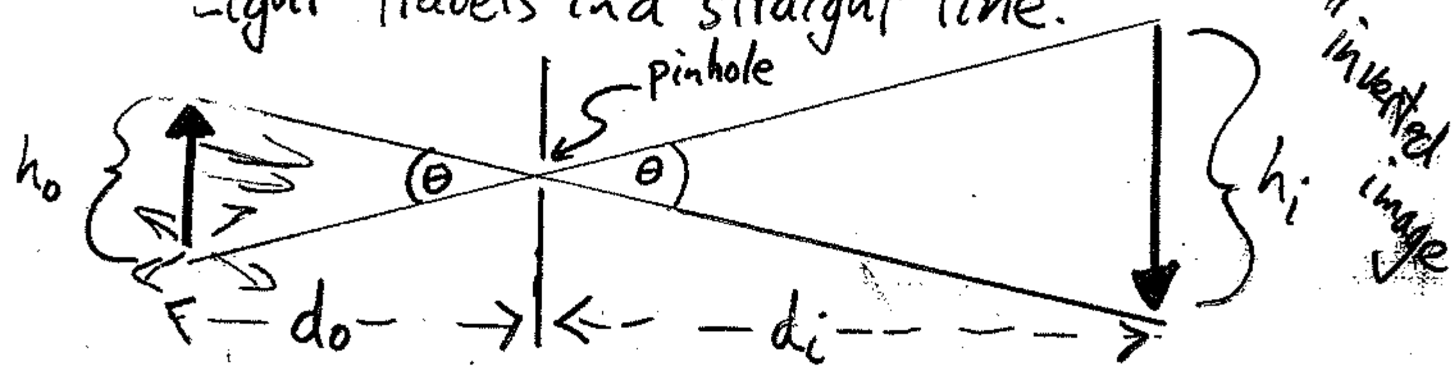
1. a) 60 N·s
   b) 20 m/s
2. 1.21×10^3 N
3. 1.00×10^2 s
4. a) 5.50×10^3 N·s
   b) 91.7 N
5. a) 1.60×10^3 kg
   b) 3.20×10^4 N·s
   c) 3.20×10^4 N·s
   d) 50.0 s
6. a) 2.04×10^4 N·s
   b) 3.00×10^2 N
7. 1.1×10^2 m/s
8. 6.67 m/s in its orig. dir
9. 1.0×10^3 m/s
10. −2.0 m/s
11. 0.22 m/s in its orig. dir
12. 16.0 m/s in the opp dir
13. 7.5 m/s up
14. 2.9 m/s in opp dir.
15. 9.1 cm/s to the right
16. 1.3 m/s

1. A force of 6.00 N acts on a 3.00-kg object for 10.0 s.
   a. What is the object's change in momentum?
   b. What is its change in velocity?
2. What force is needed to bring a 1.10×10^3-kg car moving at 22.0 m/s to a halt in 20.0 s?
3. A net force of 2.00×10^3 N acts on a rocket of mass 1.00×10^3 kg. How long does it take this force to increase the rocket's velocity from 0.0 m/s to 2.00×10^2 m/s?
4. A snowmobile has a mass of 2.50×10^2 kg. A constant force acts upon it for 60.0 s. The snowmobile's initial velocity is 6.00 m/s and its final velocity is 28.0 m/s.
   a. What is its change in momentum?
   b. What is the magnitude of the force that acts upon it?
5. A car weighing 15 680 N and moving at 20.0 m/s is acted upon by a 6.40×10^2 N force until it is brought to a halt.
   a. What is the car's mass?
   b. What is its initial momentum?
   c. What is the change in the car's momentum?
   d. How long does the braking force act on the car to bring it to a halt?
6. The velocity of a 6.00×10^2-kg mass is changed from 10.0 m/s to 44.0 m/s in 68.0 s by an applied, constant force.
   a. What change in momentum does the force produce?
   b. What is the magnitude of the force?
7. What is the final velocity of a rocket of mass 2.0×10^4 kg, starting from rest, if a net force of 1.5×10^4 N acts upon it for 15.0 s?
8. Moving at 20.0 m/s, a car of mass 7.00×10^2 kg collides with a stationary truck of mass 1.40×10^3 kg. If the two vehicles interlock as a result of the collision, what is the velocity of the car-truck system?
9. A bullet of mass 50.0 g strikes a wooden block of mass 5.0 kg and becomes embedded in the block. The block and bullet then flies off at 10.0 m/s. What was the original velocity of the bullet?
10. A 0.50-kg ball traveling at 6.0 m/s collides head-on with a 1.00-kg ball moving in the opposite direction at a velocity of −12.0 m/s. The 0.50-kg ball moves away at −14 m/s after the collision. Find the velocity of the 1.00-kg ball after the collision.
11. A plastic ball of mass 0.200 kg moves with a velocity of 0.30 m/s. This plastic ball collides with a second plastic ball of mass 0.100 kg that is moving along the same line at a velocity of 0.10 m/s. After the collision, the velocity of the 0.100-kg ball is 0.26 m/s. What is the velocity of the second ball?
12. A 40.0-kg projectile leaves a 2.00×10^3-kg launcher with a velocity of $+8.00 \times 10^2$ m/s. What is the recoil velocity of the launcher?
13. Upon launching, a 4.0-kg model rocket expels 50.0 g of oxidized fuel from its exhaust at an average velocity of 6.00×10^2 m/s. What is the vertical velocity of the model rocket after the launch? (Disregard gravitational effects.)
14. Two campers dock a canoe. One camper steps onto the dock. This camper has a mass of 80.0 kg and moves forward at 4.0 m/s. With what speed and direction will the canoe and the other camper move if their combined mass is 110 kg?
15. A thread holds two carts together on a frictionless surface as in Figure 9-7. A compressed spring acts upon the carts. After the thread is burned, the 1.5-kg cart moves with a velocity of 27 cm/s to the left. What is the velocity of the 4.5-kg cart?

16. A 5.00-g projectile is launched with a horizontal velocity of 647 ... launcher moving at 2.00 m/s. What is the

Light - Ch 16-18

Light travels in a straight line.



h_o = object height h_i = image height
d_o = object distance d_i = image distance

(2B)

"similar triangle" $\frac{\text{image height}}{\text{object height}} = \frac{\text{image dist.}}{\text{object dist.}}$

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

Example: A pinhole camera captures a 273 m tall building as a 8.0 cm tall image. The length of the camera is 15.0 cm. How far away must the camera be placed from the building?

$$\frac{0.080\,m}{273\,m} = \frac{0.150\,m}{d_o} \qquad d_o = \frac{(273)(0.150)}{0.080} = 512\,m = 5.1 \times 10^2\,m$$

Object height H_o "Filament"	Image height H_i	Object dist. d_o	Image dist. d_i	Mag. H_i/H_o	= d_i/d_o
3 cm	9 cm	38 cm	130	3.0	3.
	6 cm	65 cm	130	2	2
	12	24 cm	130	4.5	5.
	8	32	100	2.7	3.

data sheet: pinhole cam

Magnification:

$$\frac{h_i}{h_o} = \frac{d_i}{d_o} = \text{"}m\text{" magnification}$$

Example: What is magnification of building in previous example?

$$m = \frac{h_i}{h_o} = \frac{0.080\,m}{273\,m} = 2.9 \times 10^{-4} \text{ times "X"}$$

$$= \frac{d_i}{d_o} = \frac{0.15\,m}{512\,m} = 2.9 \times 10^{-4} \text{ times}$$

or $\frac{1}{3400}$

Calculate magnification for data collected from our pinhole camera. see sheet ①

Practice:

1) Calculate the distance from the pinhole to an object that is 3.5 m high and whose image is 10cm high in a pinhole camera 20cm long.

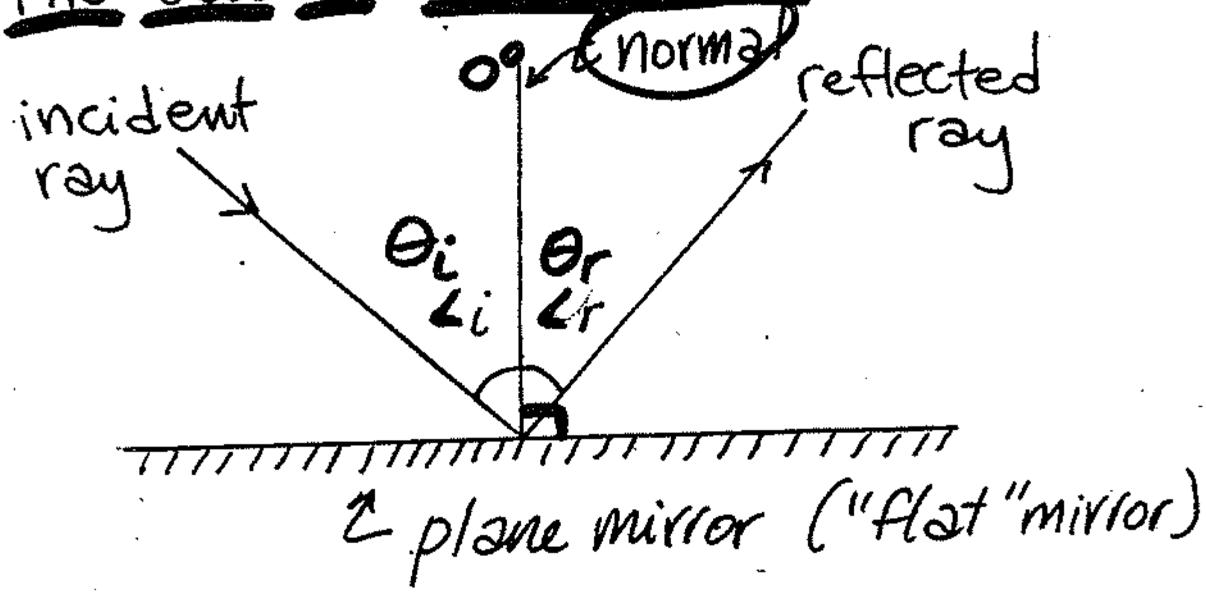
2) Calculate the height of a building 300m away from the pinhole that produces an image 3.0cm high in a pinhole camera 5.0 cm long.

3) A pinhole camera 20.0 cm long is used to photograph a student 175cm high. If the image is 10.0 cm high, how far from the camera is the student?

4) A pinhole camera 25cm long is used to photograph a building 10m high located 30m from the camera. Calculate the image height on the film.

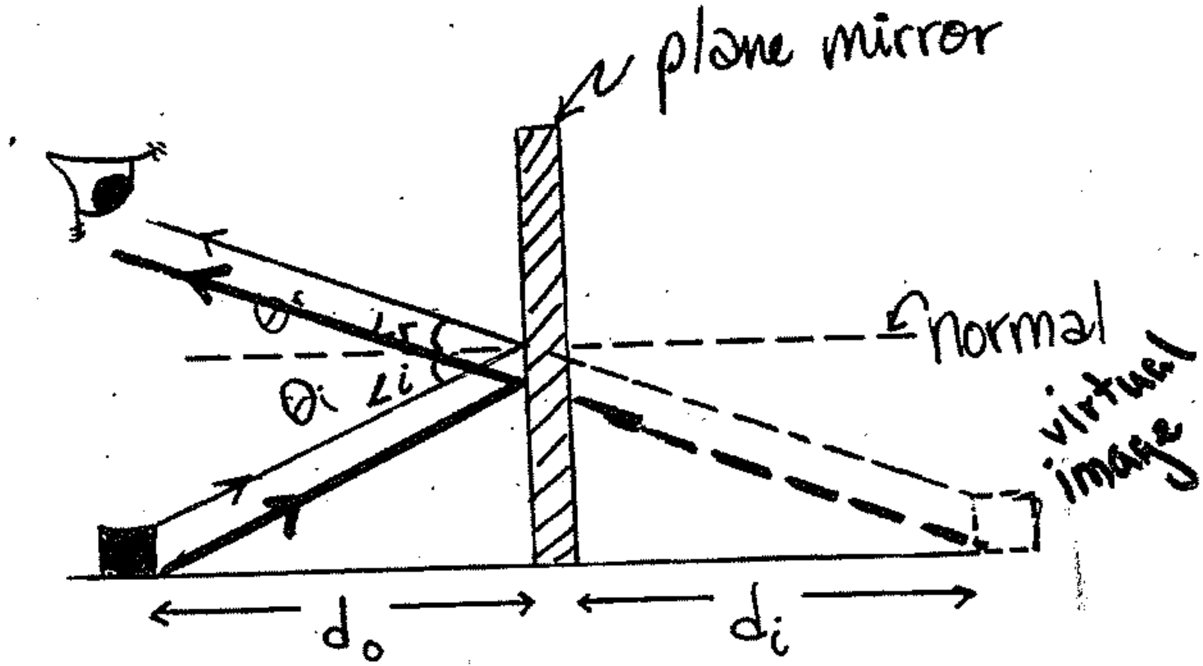
5) Calculate the magnification for questions 1-4 above.

The Law of Reflection



angle of incidence = angle of reflection

The Formation of Images in a Plane Mirror



$$d_o = d_i$$

A ray of light leaving the bottom of the object reflects from the mirror and enters the eye. To the eye, it seems that the ray originates from behind the mirror. However, rays of light do not actually emanate from behind the mirror, and we refer to this as a virtual image (as opposed to a real image). ALL plane mirrors produce virtual images.

DESCRIBING IMAGES

① Attitude - Erect ("upright") or inverted ?
(Right-side up or Upside down)

② Size - Smaller, Larger or same as object.

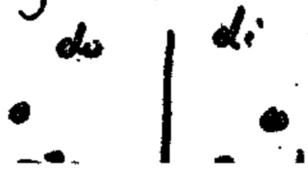
③ Virtual or Real ?

* A real image can be projected onto a screen like the pinhole.

PROBLEMS:

1. A 179 cm tall boy wants to buy a mirror that is tall enough so he can see himself full length in the mirror. His eyes are 12 cm below the top of his head, what is the minimum length of such a mirror?

2. A point object is located a perpindicular distance of 3.0 cm from a plane mirror. Using a full-scale diagram, locate the virtual image.



Phys 11

LOOKING INTO MIRRORS

PURPOSE: To demonstrate the law of reflection and to locate the image in a plane mirror.

MATERIALS:

- ray box
- various slits
- legal paper
- mirror
- clothespins
- protractor
- ruler

PROCEDURE:

Part 1

1. Use a single ray slit on your ray box and direct it at the mirror at an angle. Use the clothespins to prop up your mirror.

2. Mark where the reflected ray leaves the mirror and measure the angles of incidence and reflection using the protractor.

3. Repeat for different angles of incidence.

Data Table 1

	Angle of Incidence	Angle of Reflection
(1)		
(2)		
(3)		

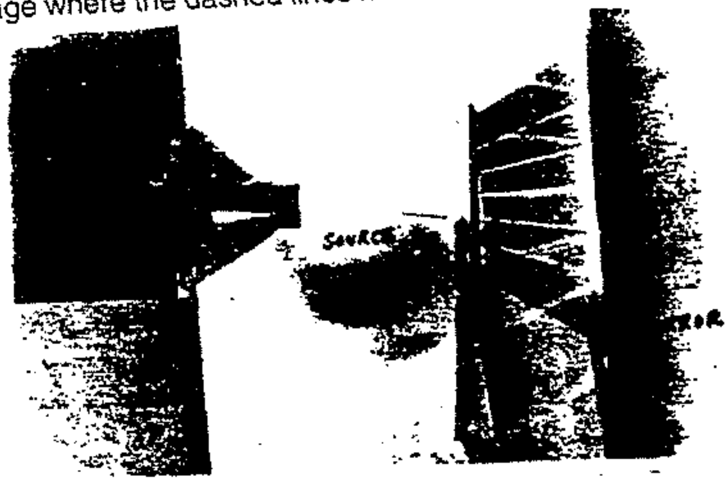
Part 2

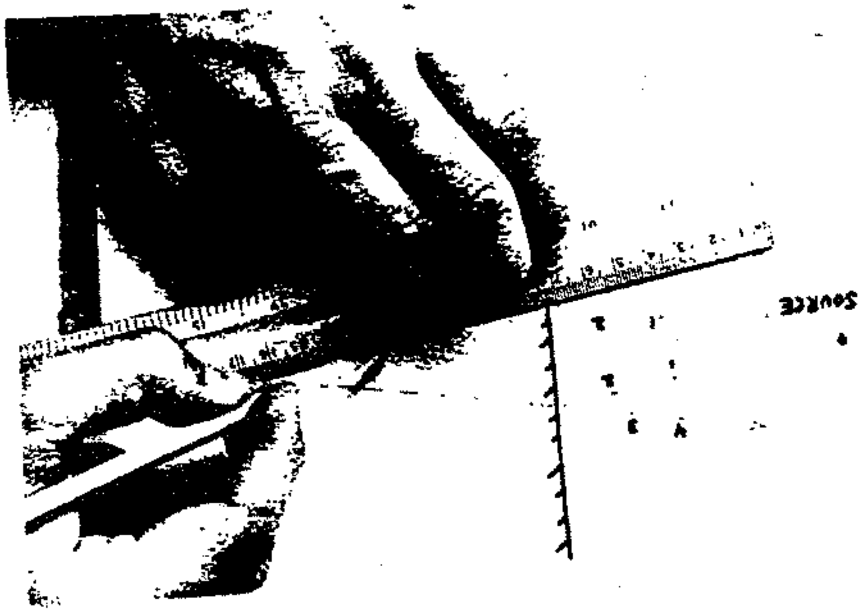
1. Remove the bulb section of your raybox. It will be your "object" for this investigation. Set up the light source to the left margin of your legal paper. It should be approximately 10 cm in front of a plane mirror. A clothespeg can be used to mount the mirror vertically.

2. Use the 5-slit opening of the baffle for your raybox to create five beams of light from the bulb by propping it up clothespegs. Use a sharp pencil to make a few marks to show the path of one of the beams (a) as it travels to the mirror and (b) as it leaves the mirror. Do not move the mirror! Do the same for another beam of light going to and coming from the mirror. Also, mark the position of the filament (object) of the light bulb as accurately as you can.

3. Use your pencil marks to draw in the light rays.

4. With you ruler. draw a dashed line "behind" the mirror for about 12 cm beyond the end of the reflected ray. Repeate with the other reflected ray. Mark the point that they meet at with an "X". Hold your pen where the "X" is as you look into the mirror. Is the image where the dashed lines meet?





DISCUSSION QUESTIONS

1. Where is the image of the mirror? How does the image distance compare with the object distance?

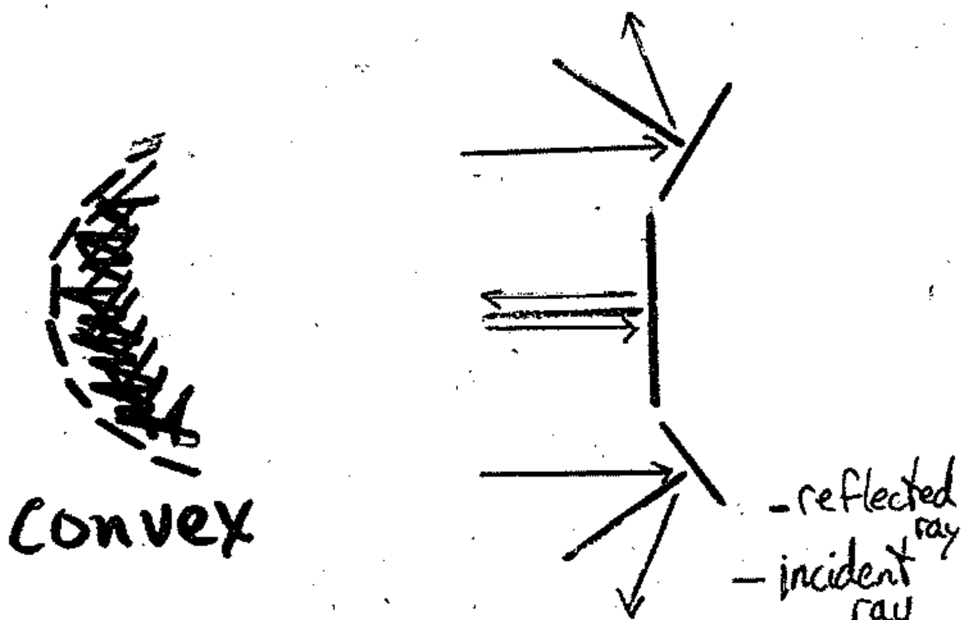
2. How does the reflected ray compare with the incident ray?

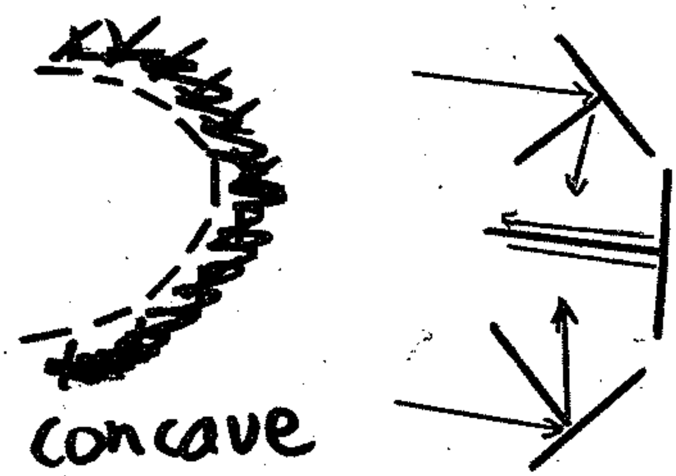
3. According to your observations, where does the reflection of light occur in the "mirror"?

4. Compare the distance from the object to the mirror with the distance from the image to the mirror. Explain any difference you observe.

5. The image in a plane mirror appears to be behind the mirror. Explain why this is so Where does the light you see coming from the image actually originate?

Consider a curved mirror to be a series of plane (flat) mirrors attached together. Remember $\theta_R = \theta_i$ and the "normal" is ⊥ to the mirror





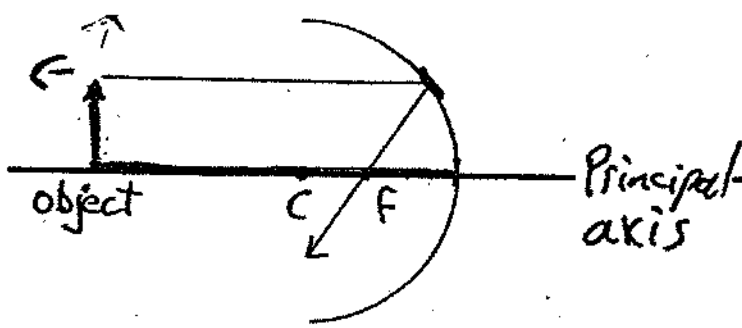
IMAGES FORMED BY SPHERICAL MIRRORS

A spherical mirror is a piece of a mirrored sphere of Radius (R), with its centre at point C.

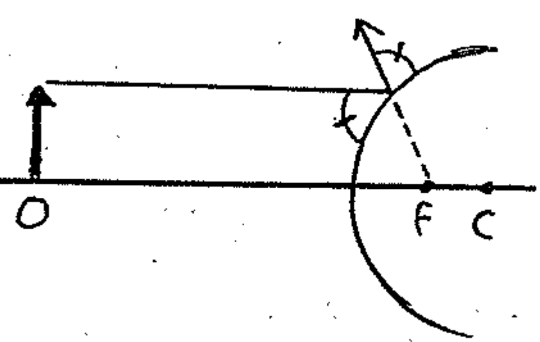
When locating the position and size of an image formed by spherical mirrors, three rays are useful.

RAY 1 A ray initially parallel to the principal axis, which will pass through the focal point (f) upon reflection.

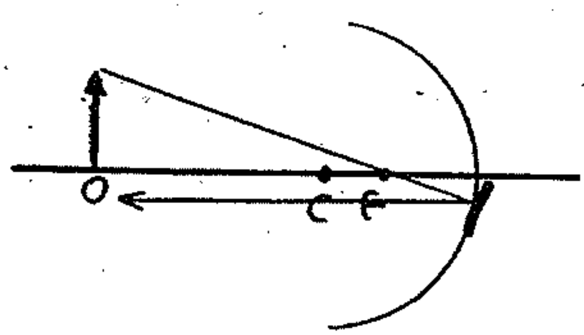
CONCAVE

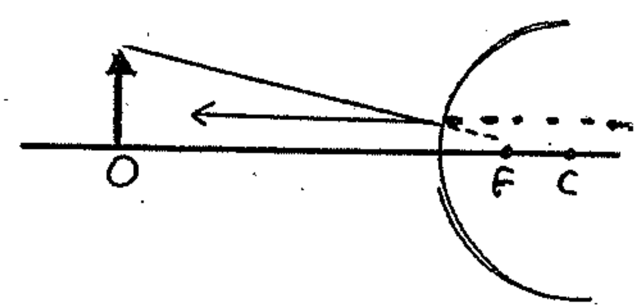


CONVEX

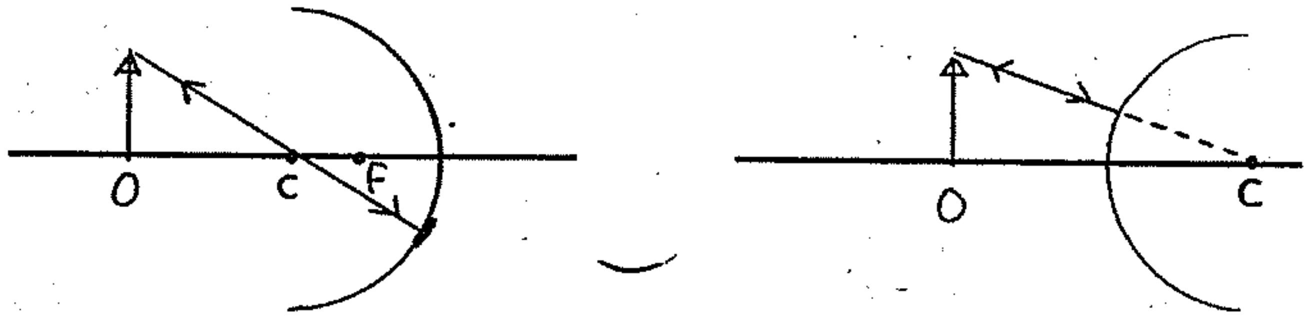


RAY 2 A ray passing through the focal point (f) which will be reflected parallel to the principal axis.





RAY 3 A ray travelling through the centre of curvature (C) of the mirror, which strikes the mirror perpendicularly and is therefore reflected back onto itself.



Where these three light rays converge at a point = position of the top of the image.

Summary

Draw 3 rays from object:

1) one parallel to principal axis, when it hits the mirror it goes through focal point;

2) one through focal point, when it hits the mirror it straightens out and runs parallel to principal axis; and

3) one directly from object to centre of curvature.

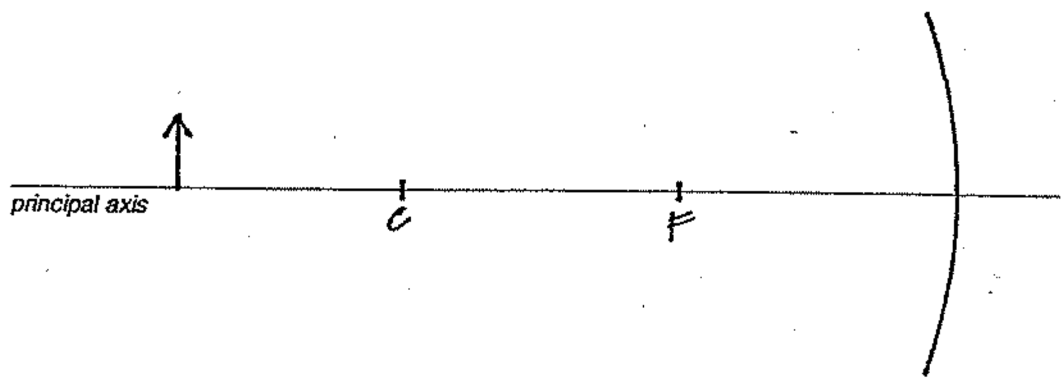
Physics 11

Spherical Mirrors **Name**______________________ **Block**____

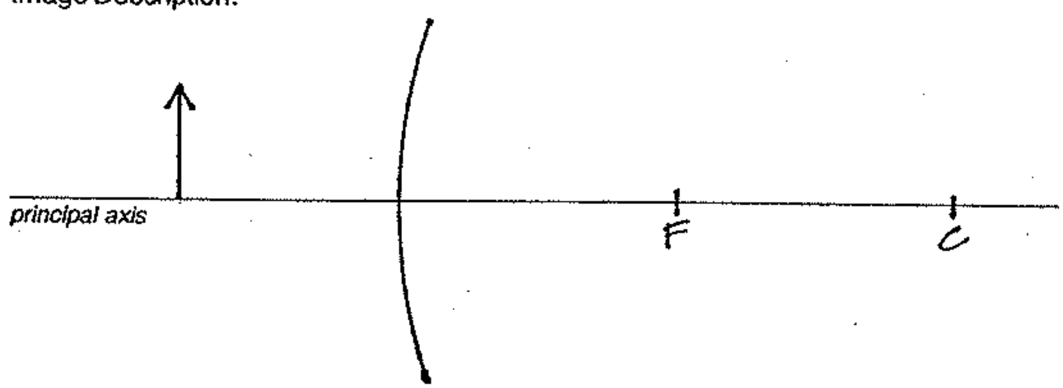
Ray Diagrams - Funsheet

For each of the following, use a ray diagram to show where the image will form. Describe each image: (larger or smaller, upright or inverted, real or virtual)

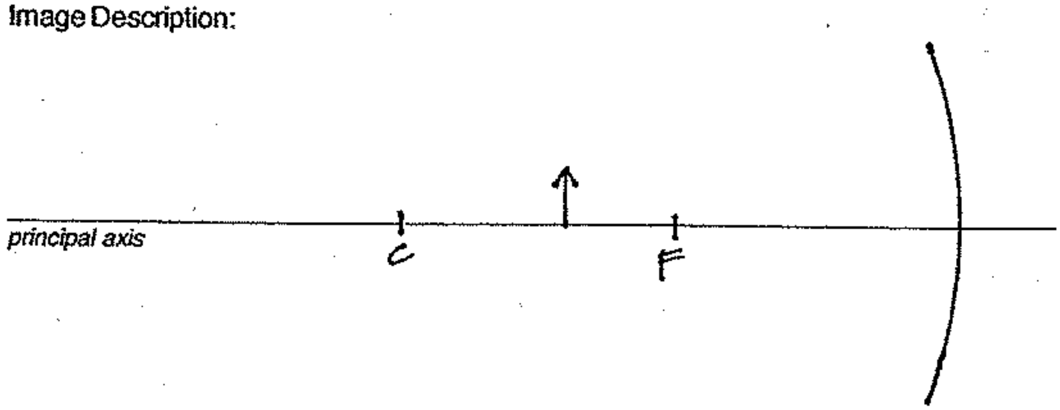
1. Image Description:



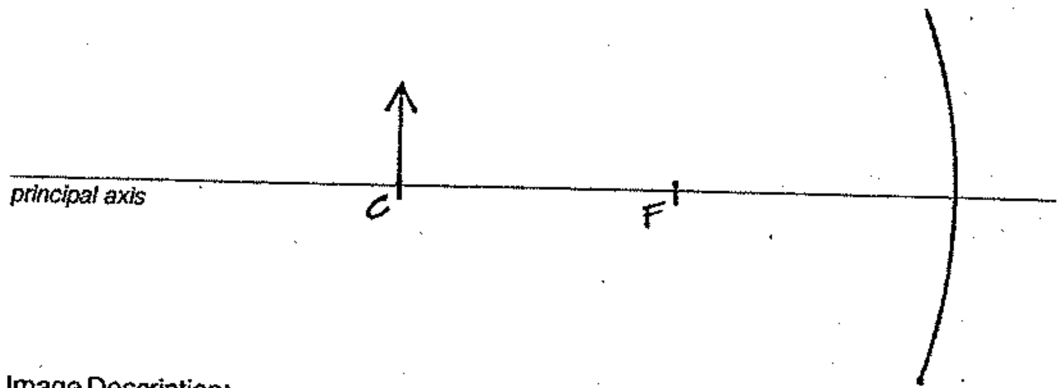
2. Image Description:



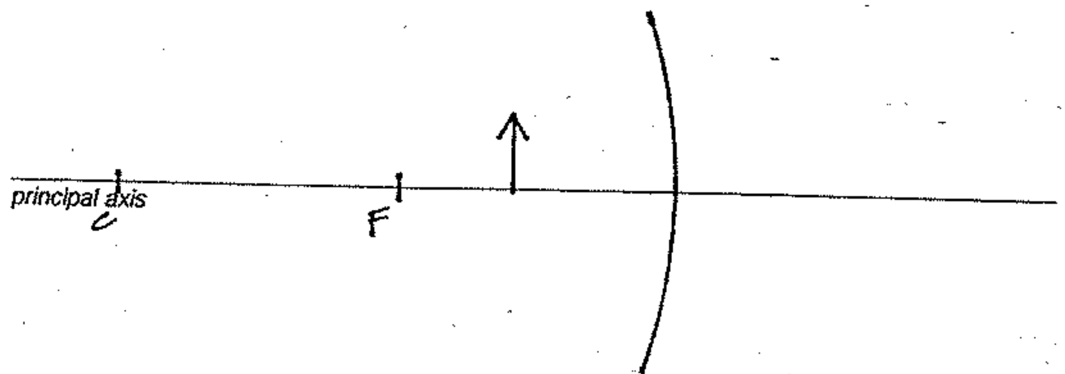
3. Image Description:



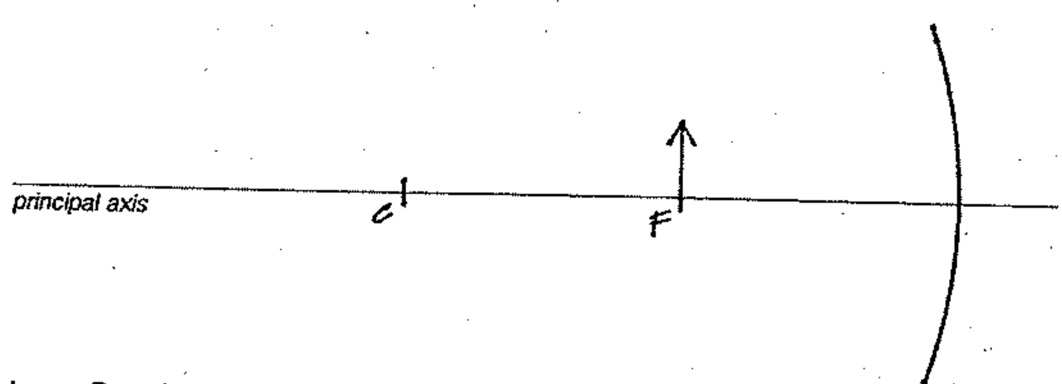
4. Image Description:



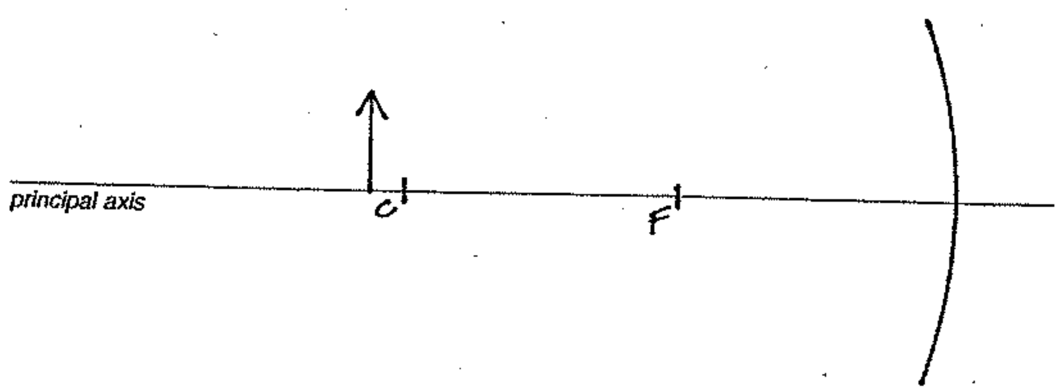
5. Image Description:



6. Image Description:



7. Image Description:



THE MIRROR AND MAGNIFICATION EQUATION

Ray diagrams are useful in determining the properties of the image, but there is a more precise way to describe the image formed.

MAGNIFICATION EQUATION

$$m = h_i/h_o = -d_i/d_o$$

where d_i = distance of image from mirror
d_o = distance of object from mirror

LOCATION OF FOCAL POINT

CONCAVE: $f = 1/2\ R$ CONVEX: $f = -1/2\ R$

where f = focal length and R = radius of curvature

MIRROR EQUATION

Can relate f to d_i and d_o by mirror equation:

$$1/d_o + 1/d_i = 1/f$$

See "Helpful Suggestions" for sign conventions

Example: An object placed 40.0 cm in front of a concave mirror whose radius of curvature is 30.0 cm. Find the position of the image (d_i) and the magnification of the image.

First find the focal length (f) of the concave mirror:

$f = 1/2R = 1/2(30.0cm) = 15.0$ cm.
We know $d_o = 40.0$ cm, find d_i.

We can determine the position of the image using the mirror equation,

$1/d_i = 1/f - 1/d_o = 1/15.0 - 1/40.0 = 0.0417\ cm^{-1}$

$d_i = 1/(0.0417\ cm^{-1}) = 24.0$ cm

since d_i is +ve then image is real

Magnification $m = -d_i/d_o = -(24.0)/(40.0) = -0.600$

So image is only 0.600 (60%) as large as the object. The minus sign indicates that the image is inverted.

MIRROR EQUATION & MAGNIFICATION EQUATION

Helpful Suggestions:

It is important to remember the sign conventions that are used with the mirror equation and the magnification equation. These conventions apply to both convcave and convex mirrors:

Object distance (d_o)

- \+ if the object is in front of the mirror (real object)
- \- if the object is behind the mirror (virtual object)

Image distance (d_i)

- \+ if the image is in front of the mirror (real image)
- \- if the image is behind the mirror (virtual image)

Focal length (f)

- \+ for a concave mirror)
- \- for a convex mirror (

Magnification (m)

- \+ for an image that is upright with respect to the object
- \- image is inverted with respect to the object

Assignment

1. A real image forms 25.0 cm in front of a concave mirror of focal length 20.0 cm. How far is the object from the mirror?

2. What is the focal length of a concave mirror that forms an image on a screen 40.0 cm away of an object that is 20.0 cm in front of the mirror?

3. An object is 10.0 cm in front of a concave mirror of focal length 15.0 cm. Solve for di.

4. Copy the following table into your notebook. Complete the blanks. As an example, the first row of the table shows a completed set of data.

	Type of Mirror	Radius of Curvature	Focal Length	Object Distance	Image			Magnif.
					Distance	Real?	Inverted?	
1)	Concave	20.0 cm	+10.0 cm	+6.67 cm	-20.0 cm	NO	NO	+ 3.0
2)	Plane	——	——	+45 cm				
3)		50.0 cm		+5.0 cm				+ 0.84
4)					+75 cm			- 3.0
5)			+20.0 cm		-40.0 cm			
6)	Convex				-10.0 cm			0.33 (sign?)
7)	Concave	30.0 cm			+150 cm			

LAB : THE REFRACTION OF LIGHT

Purpose

(1) to observe refraction of light travelling from air into (a) water and (b) glass.
(2) to observe what happens to light coming from a medium of higher index of refraction into a medium of lower index of refraction, and to find out the necessary condition for total internal reflection of light.

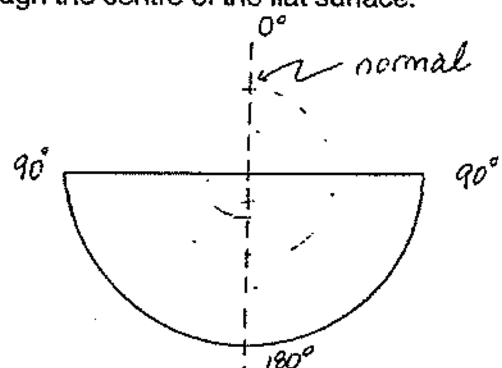
Materials

ray box (single slit)
semi-circular glass block
clear plastic semi-cylindrical dish
polar coordinate paper
water
Fluorescein dye

Procedure

Part I

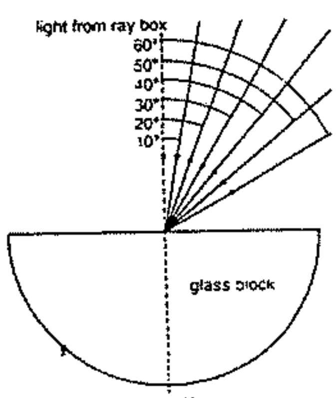
1. Set up the clear plastic semi-cylindrical dish as illustrated. Note that the 0°- 180° line acts as a normal and passes through the centre of the flat surface.



2. Aim a narrow beam of light from a raybox along a line at an angle of 30° to the normal, so it hits the centre of the flat side. The beam should pass through the thin-walled dish without any noticeable deflection.

3. Fill the dish half-way with water and add a grain or two of Fluorescein dye to improve the visibility of the beam in the water.

4. Direct the incident ray at angles of 0°, 10°, 20°, 30°, ..., 90° to the normal and record the angle of refraction (angle between the refracted ray and the normal). Record the information in a data table like the following. Be as precise in your measurements as possible.



Data Table A

Air into water

Angle of incidence (i)	Angle of refraction (r)	Sin i	Sin R
0°			
10°			
20°			
30°			
40°	Sample	Only	
50°			
60°			
70°			
80°			
90°			

Air into glass

Angle of incidence (i)	Angle of refraction (r)	Sin i	Sin R
0			
10			
20			
30			
40			
⋮			

Using a table of sines or a calculator, determine the values of the sines of ∠i and ∠r.

5. Repeat Procedures 1-4 using the glass block.

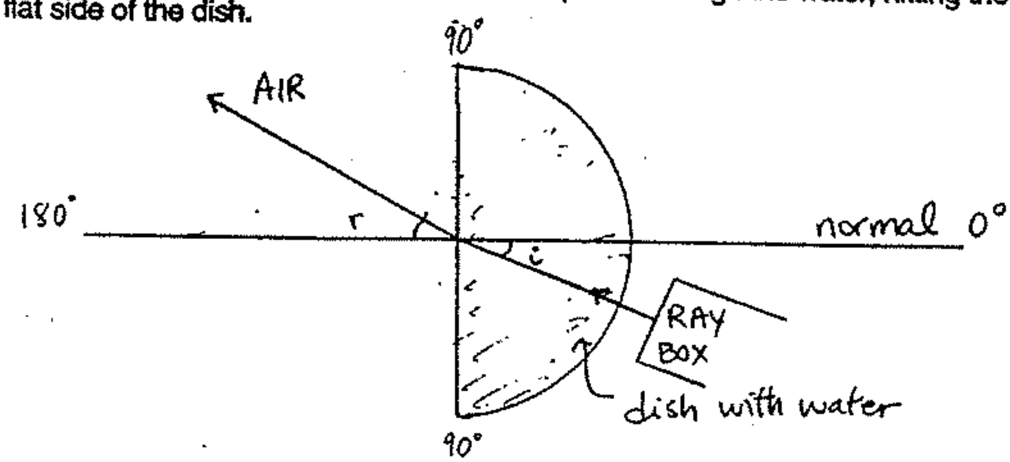
6. Plot a graph of the angle of incidence on the Y-axis and angle of refraction on the X-axis for water and glass. Be sure to label each media.

7. Plot a graph of the sin i on the Y-axis and sin R on the X-axis for water and glass.

8. Find the slopes of the straight part of your graphs.

Part II

1. Shine light through the round side of the dish so that it pases through the water, hitting the centre of the flat side of the dish.



2. Examine your data from Part I. Is the path of light reversible for some of the angles? Is it reversible for all of the angles?

REFRACTION

The speed and direction of water waves are changed when the waves move from one depth to another. The speed and direction of light rays also change when they enter a different medium.

The index of refraction (n) is defined as the ratio of the speeds of light in any two media.

eg.

Substance	n
vacuum	1.0000
air	1.0003
water	1.33
diamond	2.42
glass	1.52

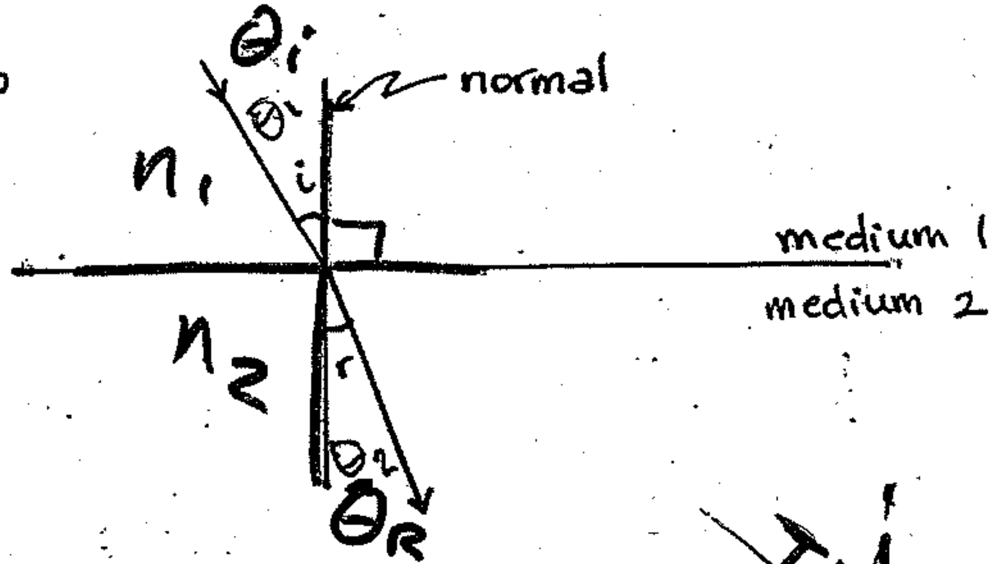
$$n = \frac{v_{vacuum}}{v_{medium}}$$

← speed of light in a vacuum $c = 3.00 \times 10^8$ m/s

Example: If the speed of light in water is 2.25×10^8 m/s, what is the index of refraction of water?

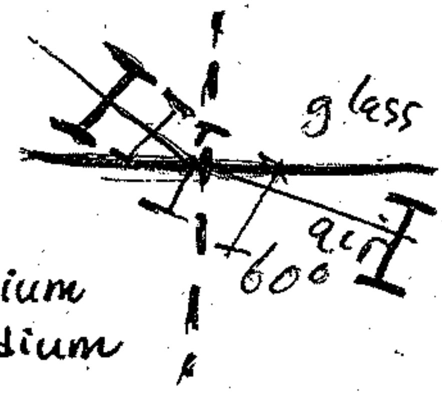
$$n = \frac{v_{vacuum}}{v_{medium}} = \frac{3.00 \times 10^8 \text{ m/s}}{2.25 \times 10^8 \text{ m/s}} = \boxed{1.33}$$

Snell's Law



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where subscript 1 = incident medium
" 2 = refracted medium



Example: Light travels from crown glass into air. The angle of refraction in air is 60°. What is the angle of incidence in glass?

$n_{air} = 1.0003$
$n_{glass} = 1.52$

$$n_g \sin\theta_g = n_a \sin\theta_a$$

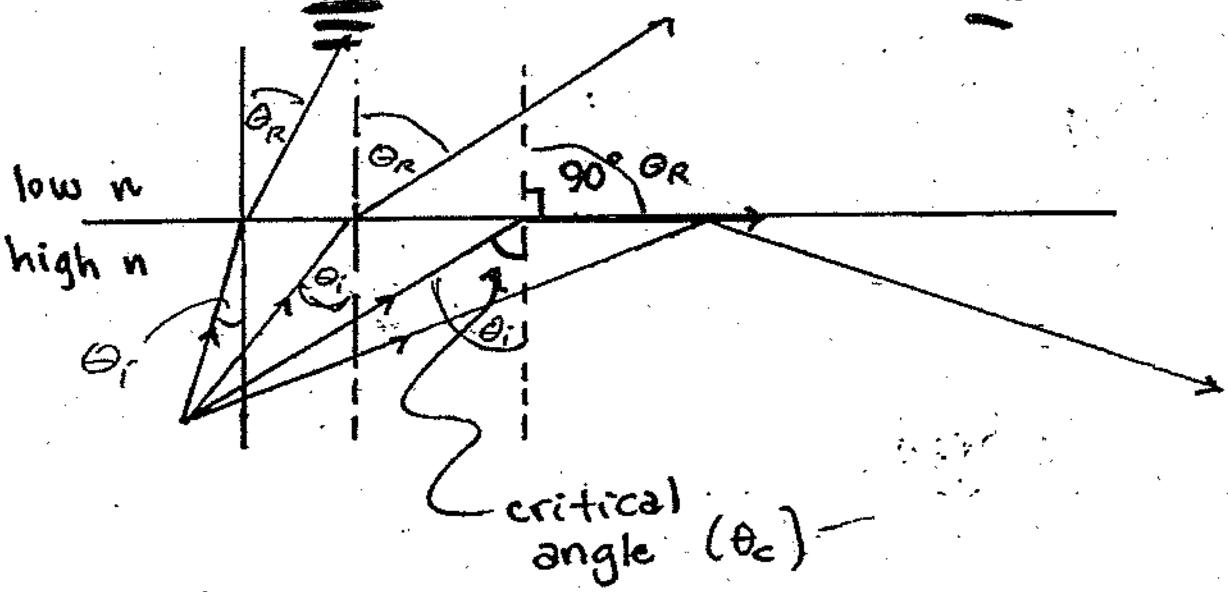
$$\sin\theta_g = \frac{n_a \sin\theta_a}{n_g} = \frac{(1.0003)(\sin 60^\circ)}{(1.52)}$$

$$\sin\theta_g = 0.57 \Rightarrow \sin^{-1}(0.57)$$
$$\theta_g = 34.7^\circ = 35^\circ$$

0.57
INV
SIN

CRITICAL ANGLE & TOTAL INTERNAL REFLECTION

When light travels from a medium of high n to a medium of low n.



when $\theta_i > \theta_c$ no refraction → phenomenon called total internal reflection

Example: What is the critical angle in flint glass when light passes from flint glass into air?

flint glass $n = 1.65$
air $n = 1.0003$

✱ At critical angle, refracted ray is 90°

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\sin\theta_1 = \frac{(1.0003)(\sin 90°)}{(1.65)} \quad \theta_R = 90° \quad \sin 90° = 1$$

$$\theta_1 = 37°$$

$$\theta_c = 37°$$

The critical angle for total internal reflection

When light leaves a medium of higher index $\boldsymbol{n_1}$ to one of lower index $\boldsymbol{n_2}$, (e.g. light escaping glass and going into the vacuum) the outgoing ray will bend down towards the surface. At some point the solution for $\mathbf{sin}\theta_2$ will be greater than unity. When this occurs the solution for the outgoing angle is meaningless and the light is total reflected from the surface. To solve for the angle θ_1 where this occurs we consider Snell's law with $\mathbf{sin}\theta_2$ equal to unity.

$$n_1 \sin \theta_1 = n_2$$

This is referred to as the critical angle θ_c,

$$\sin\theta_C = \frac{n_2}{n_1}$$

The phenomenon of total internal reflection is why optical glass fibers can carry signals with attenuation lengths of hundreds of kilometers.

LIGHT REFRACTION FUNSHEET

1. Calculate the critical angle for
   (a) diamond (n=2.42)
   (b) glass (n=1.500)
   (c) water at 20°C (n= 1.333)
   (d) quartz crystal (n=1.54)

2. Light entering a block of glass at an angle of incidence of 18.5° leaves the boundary between the air and the glass at an angle of 12.0°. What is the index of refraction of this type of glass? (n_{air}= 1.0003)

3. Light is incident on diamond at an angle of 10.0°. At what angle will it refract? (n=2.42)

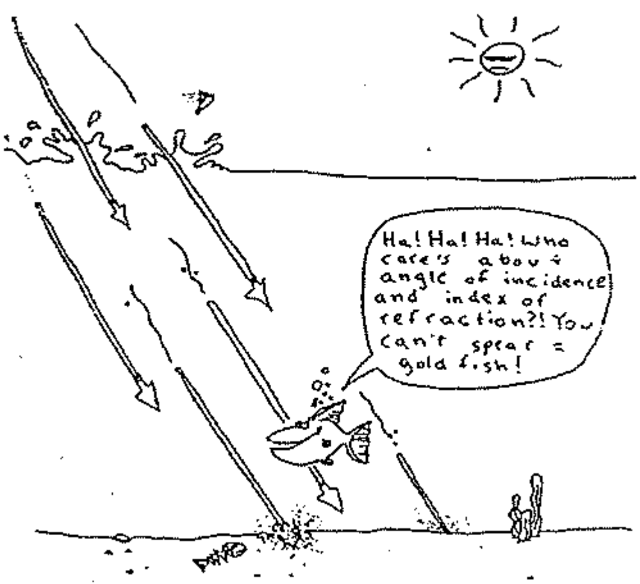
4. A beam of light is incident on a sheet of glass in a window at 30°. Describe exactly what path the light beam will take (a) as it enters the glass and (b) as it leaves the other side of the glass. Assume n=1.500.

5. A certain material has a critical angle of 52.0°. What is its index of refraction?

6. The speed of light in three different media is as follows:
   (a) 2.25×10^8 m/s (b) 1.24×10^8 m/s (c) 1.95×10^8 m/s
   Determine the index of refractino of each medium, and , using the table of indices of refraction, identify the medium in each case.

7. (a) What is the index of refraction of a medium if the angle of incidence in air is 63° and the angle of refraction is 30°?

   (b) What is the angle of incidence in a medium in the case where the angle of refraction in air is 40° and the index of refraction of the medium is 1.58?



Substance	Index of refraction
vacuum	1.0000
air	1.0003
water	1.33
quartz (fused)	1.46
glass (crown)	1.52
quartz (crystal)	1.54
ruby	1.54
glass (flint)	1.65
zircon	1.92
diamond	2.42

LENSES

lens = "lentil" (resemblance to shape of a bean)

→ Eyeglasses, cameras, binoculars, telescopes, microscopes, photocopiers, magnifiers, projectors ...

Diverging lenses = causes incoming parallel rays to spread out.

Converging lenses = causes incoming parallel rays to come together.

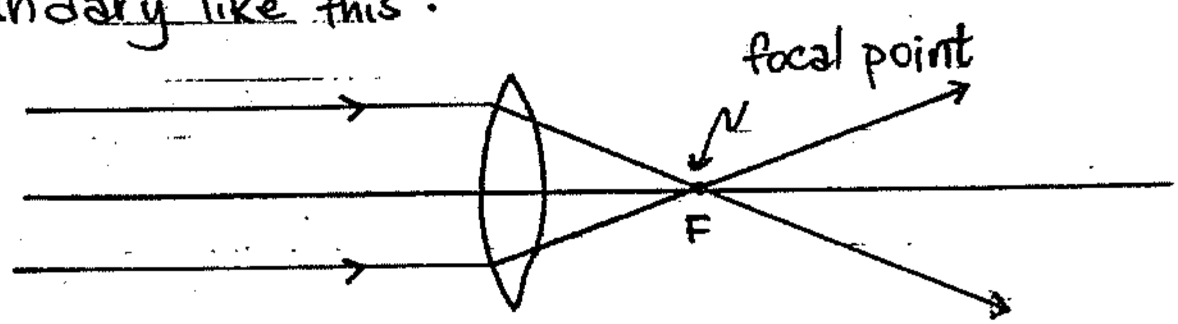
Variety of Shapes:

Diverging | Converging

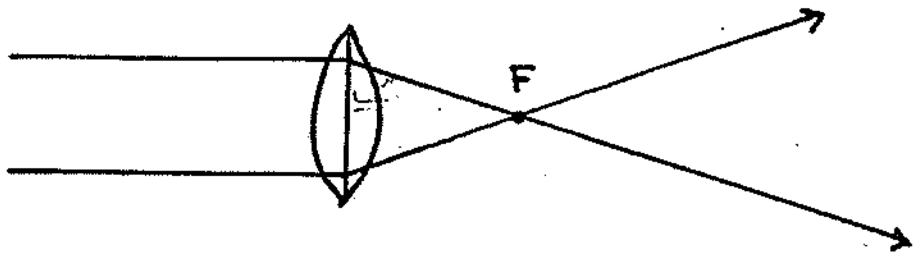
double concave | Plano-Concave | Concave Meniscus | double convex | Plano-Convex | Convex Meniscus

PREDICTING WHERE IMAGES WILL FORM

*Refraction actually occurs at the air-glass boundary like this:

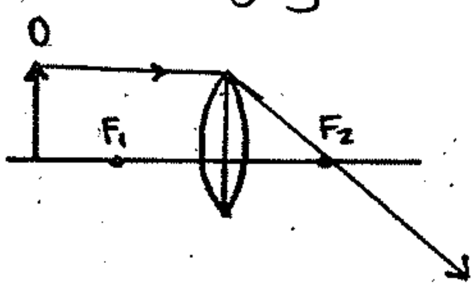
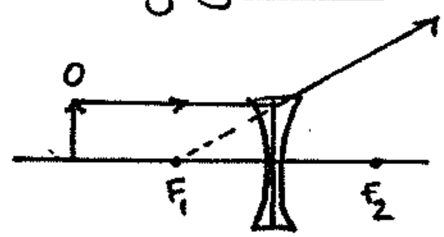
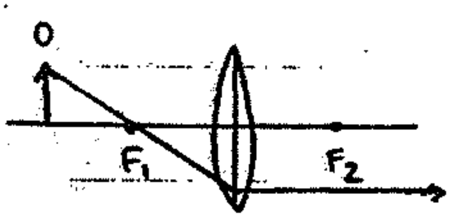
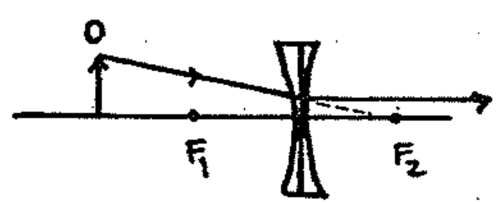
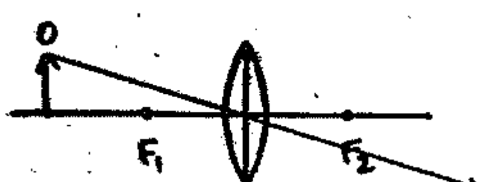
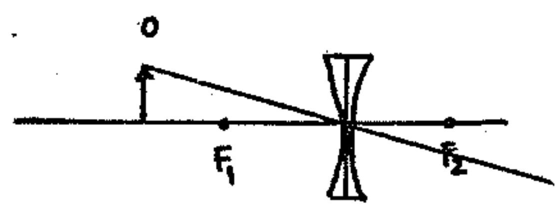


* But for simplicity, the refracted rays are drawn as if the refraction happened at the middle of the lens. For a <u>thin lens</u>, there is little error introduced by doing this.



* Using ray diagrams, you can predict where an image will form <u>if you know the focal length (f)</u>

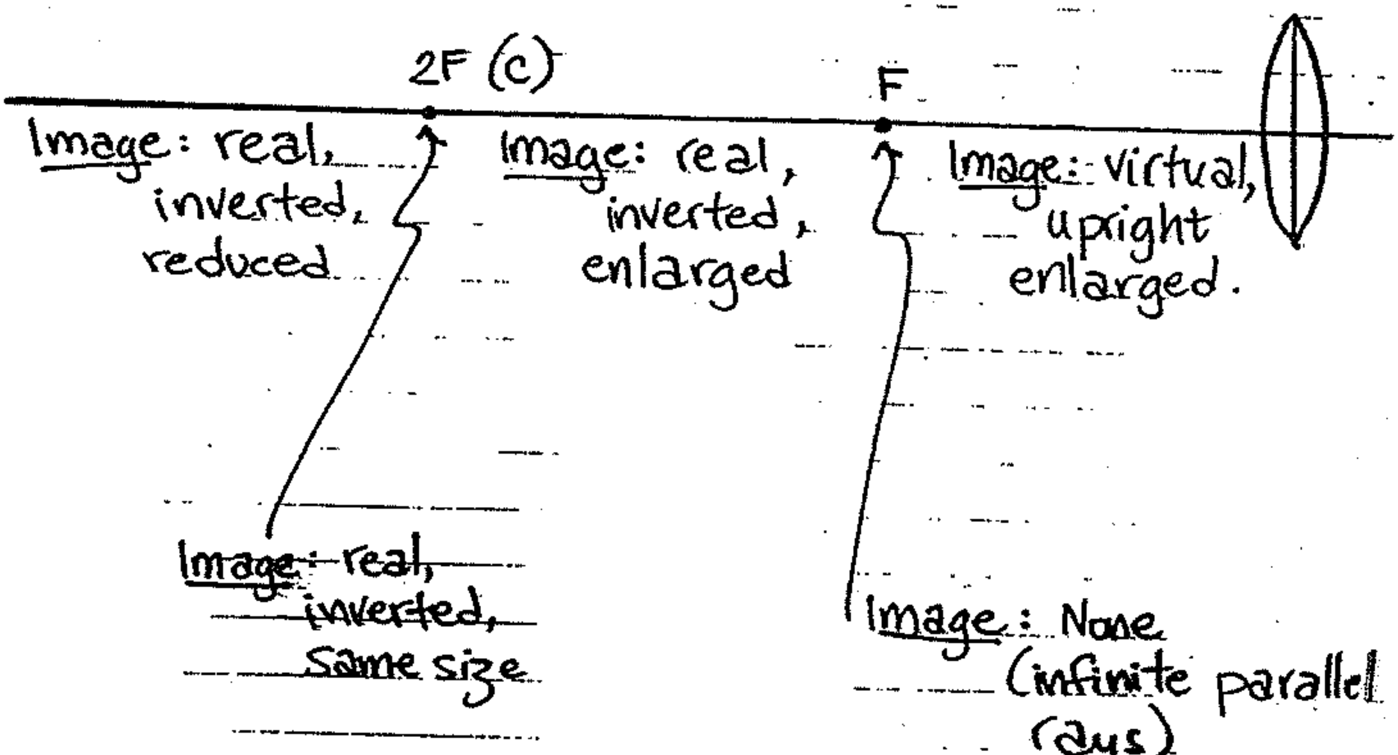
3 rays are useful:

	Converging lens	Diverging lens
(1)		
(2)		
(3)		

* Some conventions:

1. The object is placed to the left of the lens.
2. Real images fall to the right of the lens.
3. Virtual images fall to the left of the lens.

A Image Characteristics for Various Object Distances for a Converging Lens:



B Image Characteristics for Object Distances for a Diverging Lens:

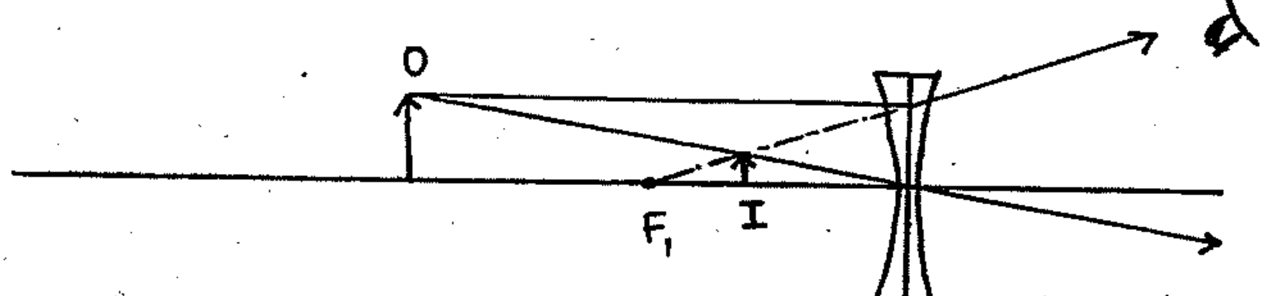
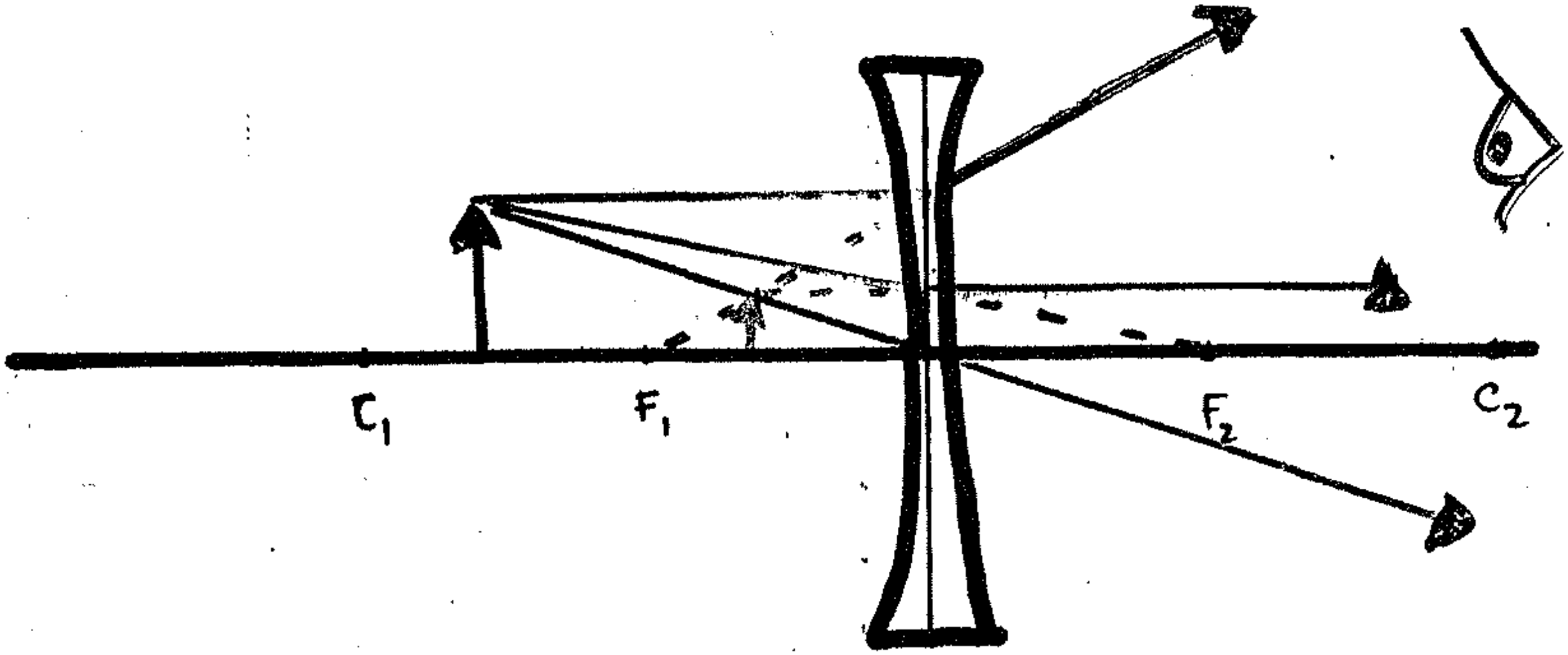
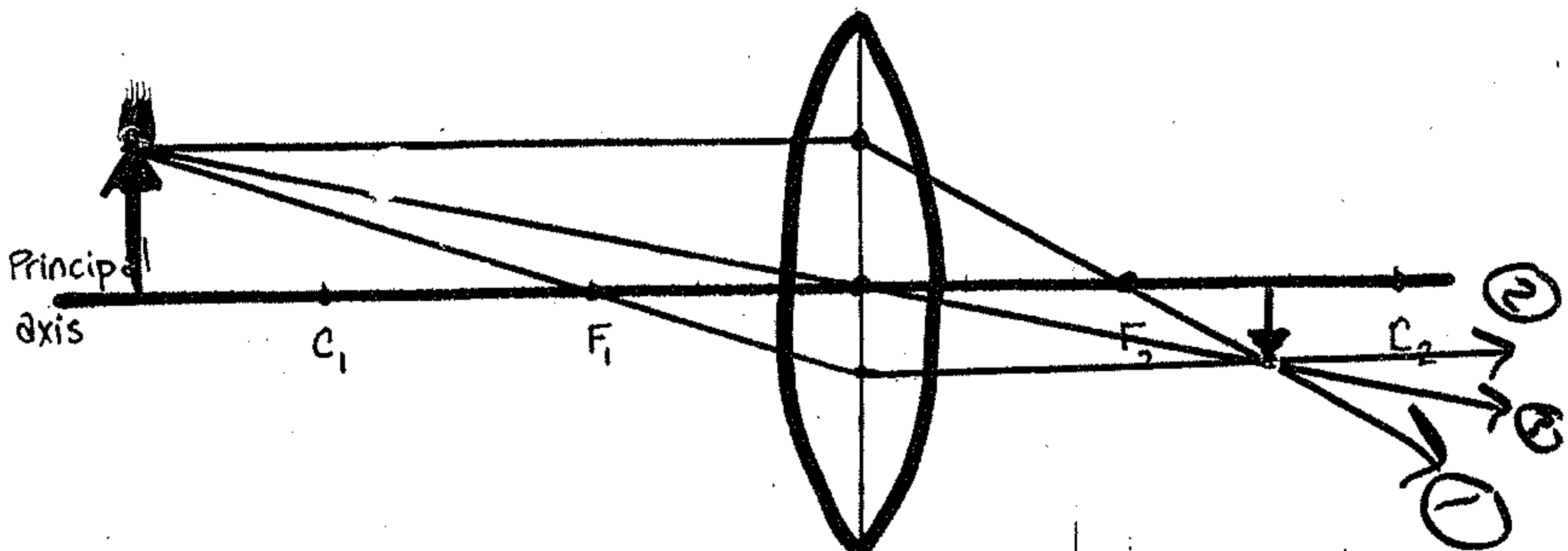


Image: virtual, upright and reduced for **ALL** object distances



Images Formed by Diverging Lens (Concave)



Images Formed by Converging Lens (Convex)

Physics 11

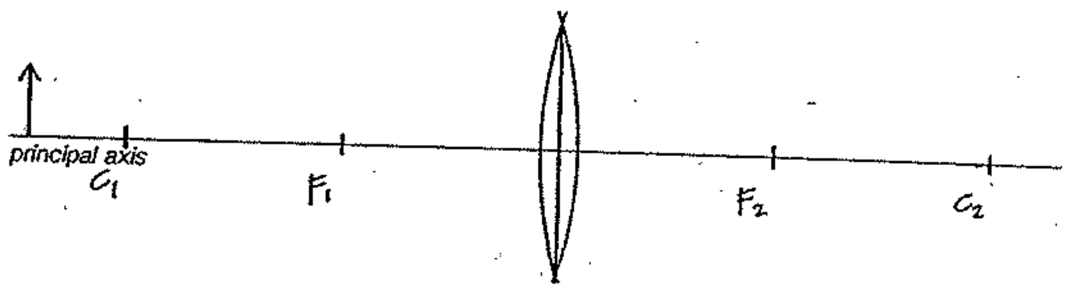
Lenses

Ray Diagrams - Funsheet

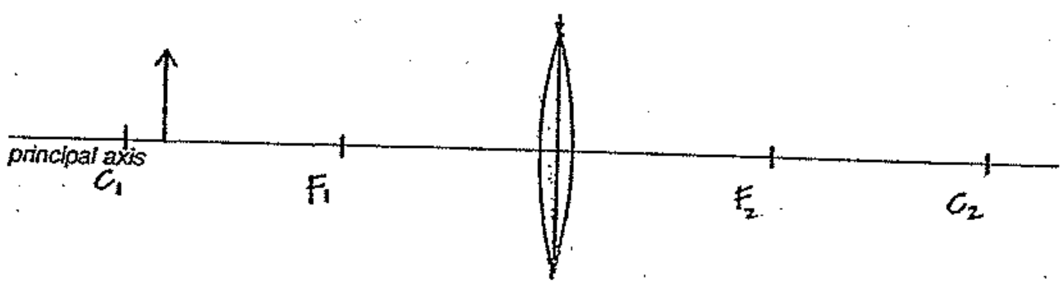
Name________________________ **Block**____

For each of the following, use a ray diagram to show where the image will form. Describe each image: (larger or smaller, upright or inverted, real or virtual)

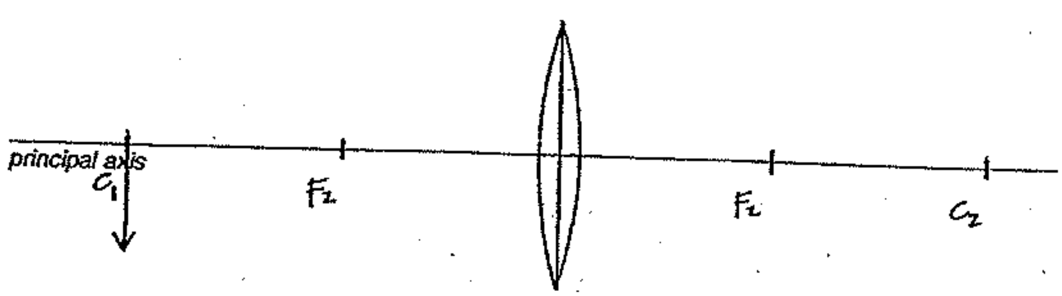
1. Image Description:



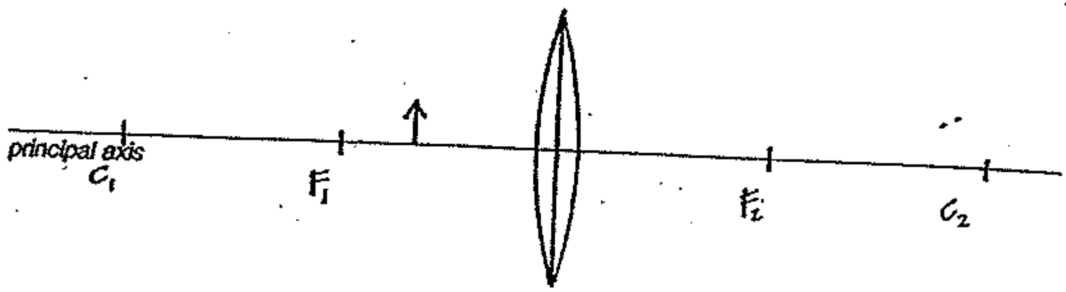
2. Image Description:



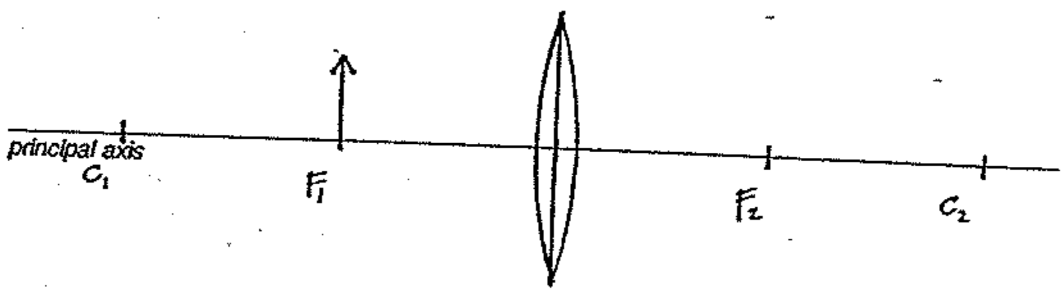
3. Image Description:



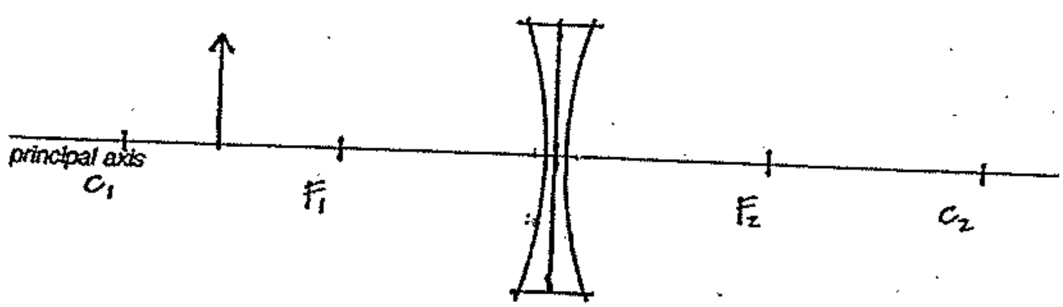
4. Image Description:



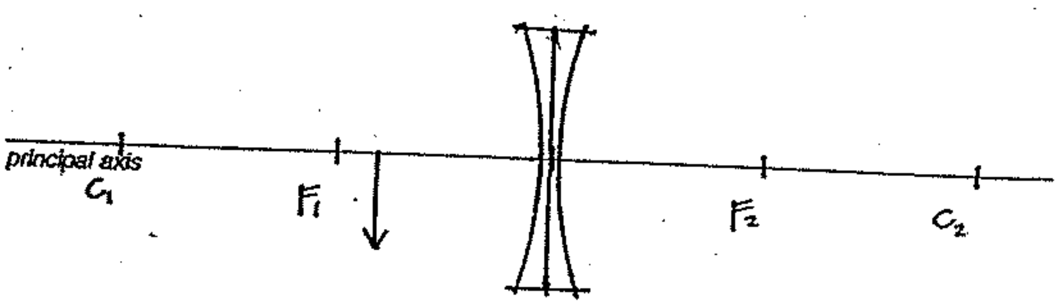
5. Image Description:



6. Image Description:



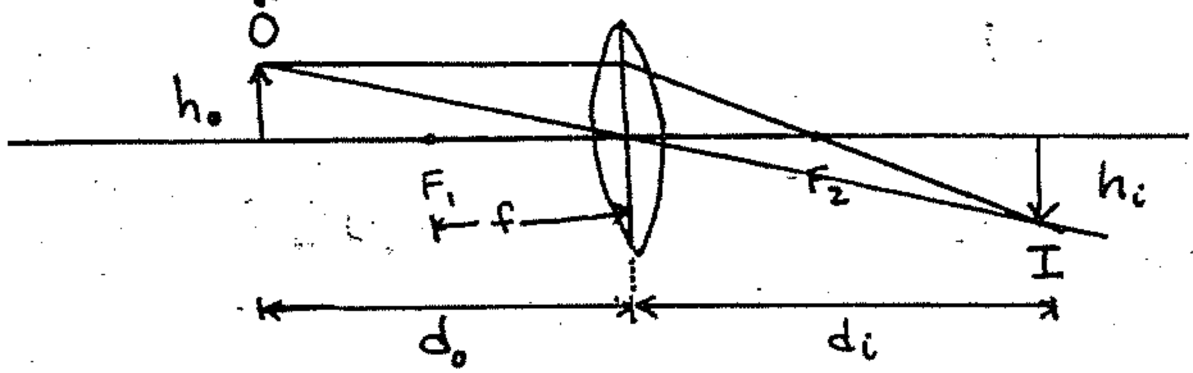
7. Image Description:



THIN-LENS EQUATION

Magnification

$$m = \frac{\text{Image height}}{\text{Object height}} = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$



Thin-Lens Equation (same as mirror equation)

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

Sign Conventions For Lenses

Object Distance (d_o)
- Always positive

Image Distance (d_i)
- \+ image formed to the right of lens (Real)
- \- image formed to the left of lens (Virtual)

Focal Length (f)
- \+ for converging lens
- \- for diverging lens

Magnification (m)

+ image is upright relative to object
- image is inverted

Example: An object is placed 7.10 cm to the left of a diverging lens whose focal length is $f = -5.08$ cm.

(a) Find the image distance and determine whether the image is real or virtual

(b) Find the magnification

Solution:

(a) $\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-5.08} - \frac{1}{7.10\text{ cm}} = -0.338\text{ cm}^{-1}$

$\boxed{d_i = -2.96\text{ cm}}$

d_i is negative ∴ Virtual image

(b) $m = \boxed{-\frac{d_i}{d_o}} = -\frac{(-2.96\text{ cm})}{7.10\text{ cm}} = \boxed{0.417}$

Image is smaller than object and is upright.

"I Love Lenses" Funsheet

1. A convex lens has a focal length of 50.0 mm. How far from the lens will the image form of an object that is 5.00 m away?

2. An object is 100.0 mm away from a lens of focal length 50.0 mm. How far from the lens will the image form?

3. A real image forms 60 mm away from a lens when the object is 30 mm from the lens. What is the focal length of the lens.

4. An object is 25 cm away from a lens of focal length 50 cm. Where will the image form? Will it be a real image or a virtual image?

5. The distance from the lens of someone's eye to the retina is 20.0 mm. If the image of a book held 40.0 cm in front of the eye is in sharp focus, what is the effective focal length of the lens?

6. A candle 5.0 cm high is 80.0 cm in front of a convex lens of focal length 20.0 cm. How high will the image of the candle appear to be on the screen?

7. A candle is placed 30.0 cm from a convex lens of focal length 20.0 cm. What will the magnification of the image be? Will the image be real or virtual?

8. A 2.0 cm tall object is place 7.50 cm to the left of a converging lens whose focal length is 11.8 cm.
    (a) Find the image distance and determine whether the image is real or virtual.
    (b) Determine the magnification
    (c) Determine the image height?

9. Copy this table into your notebook and complete the missing blanks.

	Lens Type	focal length	object distance	image distance	magnification	real/virtual	inverted/upright
a)	converging	25 cm	15 cm				
b)	converging		22 cm	+22 cm			
c)	diverging			−12 cm	0.50		
d)	diverging	−11 cm		−5 cm			
e)		8 cm		18 cm			inv

LIGHT TUTORIAL QUESTIONS

Solution Keys are posted in class for all questions listed. You may do all or a selectior during the tutorial depending on how comfortable you feel with the material.

CHAP. 17 REFLECTION & REFRACTION

Practice Probs. P. 354
(1) 27.7 (3) a) 17.0 b) diamond
(2) 22.1 (4) 1.5

Practice Probs p.355
(5) a) 2.21×10^8 m/s b) 1.95×10^8 m/s c) 1.86×10^8 m/s
(6) 1.50 (7) 2.0×10^8 m/s

Concept Review p. 356
1.2, 1.3

Concept Review p. 361
2.2

Applying Concepts p.363
6,7,8,9

Problems p. 364
(2) 108 (3) 1.46 4) a) 1.34 b) water (5) 34.7 (6) 26.2 (7) 21.0 (17) 1.51 (18) 14 (21) 1.41 (22) no angle

CHAP. 18 MIRRORS & LENSES

Practice Probs. P. 374
(2) b) 15 cm c) -1.5 d) -4.5 mm (3) 15.0 cm (4) 25 cm

Practice Probs. P.376
(5) -12 cm (6) a) -18 cm b) 45 mm (7) a) -27 cm b) 11 cm

Concept Review p. 378
1.3

Practice Probs. P 381
(14) 16 cm; -4.2 mm (15) 50 mm

Practice Probs. P. 383
(17) -8.6 cm (19) 4.7 cm

Reviewing Concepts p.387
1,2,5,9,10

Applying Concepts p.388
3,5,8,9

Problems p. 388
(4) 20.0 cm (6) b) 4.0 cm, c) -8.0 mm (9) 5.0 (10) a) concave mirror b) 32.4 mm (13) a) 66.7 cm b) 1.67ho (14) a) 51 mm b) 1.01×10^3 mm (16) 14 cm

NUCLEAR UNIT GROUP PROJECT – PHYS 11

Goal: By the end of this unit, it is expected that students will be able to demonstrate an understanding of Nuclear Energy concepts.

Task: In your group (4 max), members will work collaboratively to research, learn and teach 2 topics from this unit. Your responsibility to your team and your classmates is to be thorough and effective. Individual responsibility to the team is vital as a peer evaluation will be completed as part your project mark.

Your final mark will be made up of daily work summaries handed in at the end of each work period, a handout on each topic that is prepared for the class, 4 multiple choice questions provided to the teacher, a peer evaluation, and finally, a group presentation. (see reverse of this sheet for the criteria)

Your timeline should be as follows: (topics selected by lottery in advance)

Period #1: Divide up tasks; research/document sources; work summary sheet (computer lab)

Period #2: Organize info; plan presentation and handout; work summary sheet (computer lab)

Period #3: Complete handouts and presentation; work summary sheet (In class)

Period #4: Presentations – 10 minutes each

Period #5: Presentations – 10 minutes each (if needed)

Period #6: Nuclear Unit test (questions taken from those provided by students)

PROJECT CRITERIA

Please use the following criteria to focus your work.

I. WORK SUMMARIES

0 – Unsatisfactory 1 – Satisfactory 2 – Very Good

1. Reports detail activities of all members achieved in class ____________
2. Reports describe areas for further developments ____________
3. All reports completed ____________

II. HANDOUT

0 – Unsatisfactory 1 – Satisfactory 2 – Very Good

1. All learning objectives for each topic are typed at the top of the handout ____________
2. All learning objectives were discussed and clearly explained ____________
3. Handout is typed or neatly written in ink ____________
4. Visuals are included and fully labeled ____________
5. Includes a bibliography citing at least 3 different sources used ____________
6. Teacher is provided with 4 multiple-choice test questions based on the topic. ____________

III. ORAL PRESENTATION

0 – Unsatisfactory 1 – Satisfactory 2 – Very Good

1. Creative and original ____________
2. Information is clear and complete ____________
3. Use of appropriate visual aids ____________
4. Participation of all group members ____________

TOPIC 1: NUCLEAR FUSION

Learning Objectives:

1. Define fusion and provide an example using a nuclear equation.

2. Describe, briefly, why large quantities of energy are released during fusion reactions. Where does the energy come from?

3. Explain how to calculate the amount of energy released or the apparent loss of mass in a fusion reaction if one is known but not the other. Explain any associated formula.

4. Discuss the latest developments in the quest for a working fusion reactor.

TOPIC 2: NUCLEAR FISSION

1. Define Nuclear Fission and provide an example.

2. Describe, briefly, why large quantities of energy are released during fission reactions. Where does the energy come from?

3. Explain how to calculate the amount of energy released or the apparent loss of mass in a fission reaction if one is known but not the other.

4. Describe, using a diagram, what is meant by a chain reaction.

TOPIC 3: RADIOACTIVE ISOTOPES AND TRANSMUTATION

1. Define "radioactive isotope". Give an example.

2. Define "transmutation". Give an example.

3. Using a common nuclear equation, explain how to find the atomic numbers and mass numbers of the product.

4. If the atomic numbers, mass numbers and type of decay are known, explain how to write the equation that describes the transmutation.

TOPIC 4: RADIOACTIVE DECAY AND HALF-LIFE

1. Define radioactive decay. Explain the various types.

2. Explain what is meant by "Half-Life". Explain any associated formulas.

3. If the period of time during which a radioactive sample has been decaying is known along with its half-life, explain how to calculate what proportion of the original sample will remain.

4. If the levels of radioactivity before and after a decay are known along with the half-life, explain how to calculate the approximate age of the remaining sample.

TOPIC 5: NUCLEAR FISSION REACTORS AND BOMBS

1. With the help of diagrams, briefly explain how a nuclear reactor works. Identify the fuel used, function of moderators and control rods, and the safety features for a typical reactor. Explain the workings of the Canadian built "CANDU" reactor.

2. With the help of diagrams, briefly explain how an Atomic bomb works.

3. With the help of diagrams, briefly explain how a Hydrogen bomb works.

4. Discuss issues regarding the handling, storage and disposal of end products from nuclear activities such as bomb construction, reactor operation…

TOPIC 6: NUCLEAR POWER – THE PROs AND CONs

1. Discuss a number of Pros and Cons of nuclear energy as a power source without bias.

2. Discuss whether nuclear power is a practical energy source of the future.

3. Provide specific examples of past, present or future developments/events to support your argument.

4. Provide complete and accurate information including numerical data.

Physics 11

PROPERTIES OF WAVES

Wave motion is one of the major ways in which energy can be transmitted from one place to another. Both particles and waves transmit energy, but there is an important difference. If you throw a ball at a target, the target may gain some kinetic energy, but the ball will have moved from you to the target. If you tie a rope to the target and shake the rope, the target may also gain some kinetic energy. The rope, however, will remain in position between you and the target.

There are many kinds of waves in nature:

- light waves
- sound waves
- radio waves
- earthquake waves
- shock waves
- brain waves
- the "wave" done by fans at a sports event

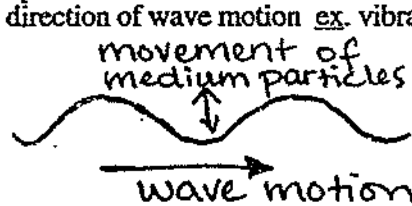
All waves can be grouped into three types:

1. Mechanical Waves
   - include water waves, sound waves, or waves along a spring or rope
   - require a medium to travel in (such as air, water, a rope)
2. Electromagnetic Waves
   - include light waves, radio waves, or x-ray waves
   - no medium required (can travel through a vacuum)
   - all travel at the speed of light (3×10^8 m/s)
3. Matter Waves
   - electrons and other particles show wave-like behavior under certain conditions (Quantum Mechanics)

We will limit our discussion to mechanical waves.

Mechanical waves can be divided into two different types:

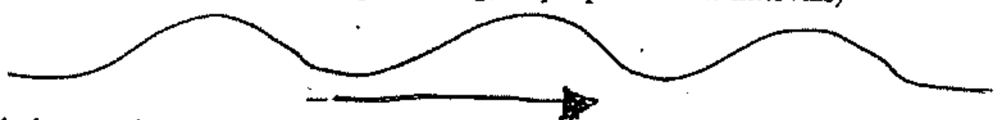
1. Transverse Wave
   - causes particles of the medium to vibrate perpendicularly to the direction of wave motion ex. vibrating guitar strings



2. Longitudinal Wave
   - causes particles of the medium to move in the same direction as the wave motion ex. sound waves
   - also called "Compression Wave"

A single wave that passes through a medium without being repeated is called a **pulse**. (ie. giving your garden hose a quick "yank" to one side, causes a pulse to travel along the hose.)

A **periodic wave** or **travelling wave** repeats at regular intervals. (ie. dropping a rock into a pond causes many ripples to reach the edge of the pond at regularly repeated time intervals)



To have a regularly repeating wave, there must be regularly repeating **vibrations.**

When an object has a regularly repeating pattern of motion, one complete motion "away and back" is called one **cycle.**

The time required for one cycle is called its **period (T)**, measured in seconds (s).

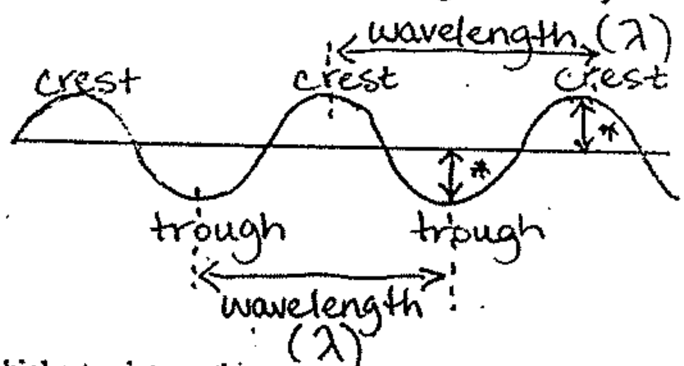
The number of cycles in one second is called its **frequency (f)**, measured in Hertz (Hz).

1 Hz = 1 cycle/second $\quad T = \frac{1}{f} \quad f = \frac{1}{T}$

Radio waves are usually measured in the kilohertz or megahertz range. (1 kHz = 1 000 Hz)
(1 MHz = 1 000 000 Hz)

What is the frequency of your favorite radio station?

This figure illustrates waves emanating from a vibrating source. They could be water waves.



* amplitude

<u>crests</u> = highest points on the waves

<u>troughs</u> = lowest points on the waves

<u>wavelength</u> = distance between successive crests (or between successive troughs) (measured in length units such as metres, centimetres, etc.) ---> symbol is λ (lambda)

<u>amplitude</u> = height of wave crest or trough from rest position (displacement from horizontal line in diagram)
- related to the amount of energy transferred by wave (increased amplitude = increased energy = increased work that wave can do) <u>ie.</u> ripples vs. tidal wave

Physics 11

Chapter 14

WAVES - Frequency and Time Period Funsheet

Please do not write on this sheet.

1. A pendulum swings back and forth 20 times in 15 s. Calculate its period and its frequency.

2. A swimmer notices that 30 waves strike a breakwater in 1.00 min. What is the period of the waves in seconds?

3. Determine the frequency in each of the following:
   (a) a basketball player who scores 36 points in 24 min
   (b) a roadrunner who escapes from a coyote 27 times in a 9 minute cartoon.
   (c) a fan that turns 170 times in 15.0 s.

4. Determine the period of each of the following:
   (a) the pulse from a human heartbeat that is heard 3.0 times in 12 s.
   (b) a tuning fork that vibrates 2048 times in 8.0 s.
   (c) the moon which travels around the earth six times in 162.8 days

5. Calculate the frequency of each of the following periods
   (a) 5.0 s
   (b) 0.01 s
   (c) 2.5×10^{-2} s
   (d) 0.80 s
   (e) 6.0 s
   (f) 0.40 min

6. Calculate the period of each of the following frequencies
   (a) 10 Hz
   (b) 0.25 Hz
   (c) 500 kHz
   (d) 0.10 Hz
   (e) 2.5 Hz
   (f) 3.5 Hz

7. A dog's tail wags 50.0 times in 40.0 s. Calculate
   (a) the frequency
   (b) the period of vibration of the tail

8. A certain tuning fork makes 7680 vibrations in 30.0 s. Calculate
   (a) the frequency
   (b) the period of vibration of the tuning fork

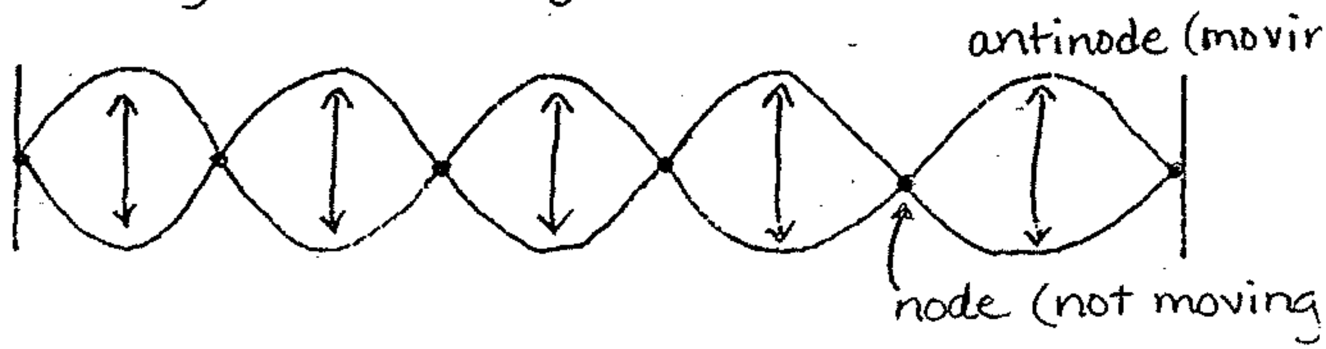
9. Tarzan is swinging back and forth on a vine. If each complete swing takes 4.0 s, what is the frequency of the swings ?

10. A pilot with nothing better to do counts 250 crests of water waves on a lake below, in a distance of 100 m. What is the wavelength of the waves ?

11. If the frequency of a sound is tripled, what will happen to the period of the sound waves ?

Standing Waves

- formed if amplitude and λ of interfering waves are same as each other
- interference pattern remains nearly stationary.



REFRACTION Q's:

(1) The speed of water waves is 30 cm/s in deep water and 15 cm/s in shallow water. If the wavelength in deep water is 1.0 cm, what is the wavelength in shallow water? (0.5 cm)

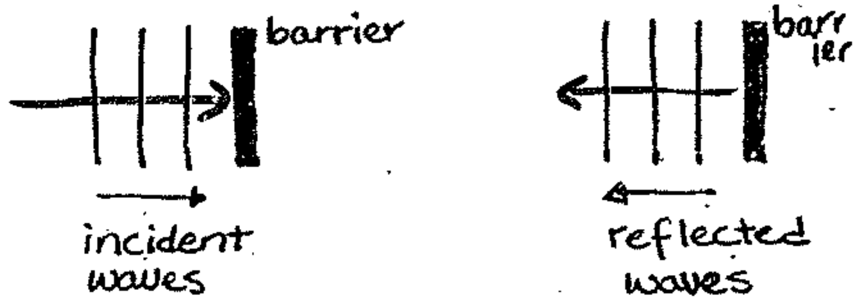
(2) The velocity of sound waves in cold air is 320 m/s and in warm air, it is 384 m/s. If the wavelength of the sound waves was 3.0 m in cold air, what would it be in warm air? (3.6 m

(3) The speed and the wavelength of water waves in deep water are 15.0 cm/s and 2.2 cm, respectively. If the speed in shallow water is 10.0 cm/s, what is the wavelength? (1.5 cm)

(4) Waves travel 0.75 times as fast in shallow water as they do in deep water. What will be the λ of the waves in deep water, if their wavelength is 2.0 cm in shallow water? (2.7 c

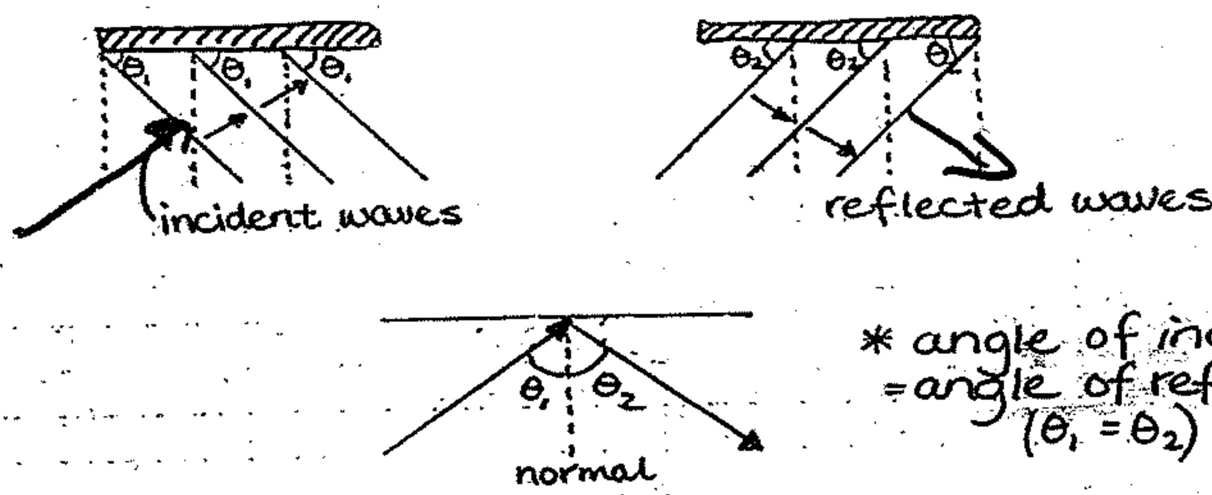
7. REFLECTION OF WATER WAVES

① Incident wave sent so crests are parallel to a barrier:



- reflected waves bounce back in opposite direction along same path.
- speed & λ do not change.

② Incident waves sent towards angled barrier:



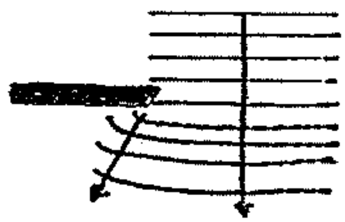
* angle of inciden[ce] = angle of reflecti[on] ($\theta_1 = \theta_2$)

③ Straight incident waves sent towards a parabola:

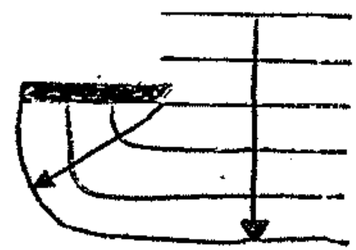
B. DIFFRACTION OF WATER WAVES

diffraction = bending of waves around an obstacle or opening

① short λ diffracted less than long λ.



short λ

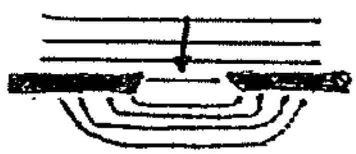


long λ

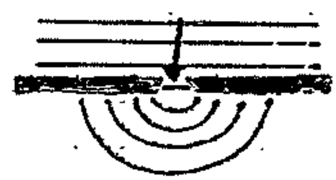
② Straight waves emerge through an opening as circular waves.

A smaller opening increases degree of diffraction.

As opening gets smaller, diffracted waves resemble waves from a point source.



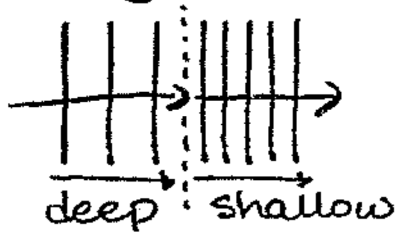
large opening



small opening

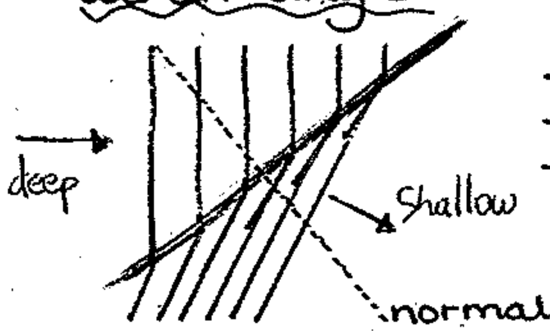
C. REFRACTION OF WATER WAVES.

① Wave moves from deep to shallow water straight on.



- λ decreases
- v decreases
- direction stays same (no refraction)

② Wave moves from deep to shallow water at an angle.



- λ decreases
- v decreases
- direction changes towards normal.

③ To calculate v or λ in shallow or deep water:

$$\boxed{\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}}$$

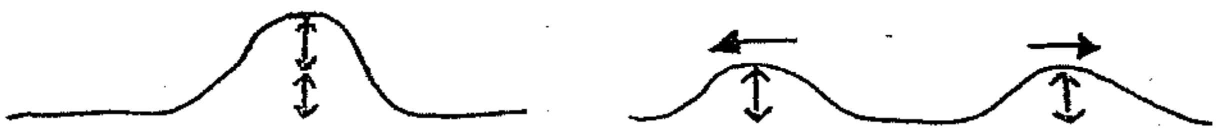
$v_1 / \lambda_1 = f_1 \quad v_2 / \lambda_2 = f_2$

D. INTERFERENCE OF WAVES.

Interference occurs when two or more waves act simultaneously on the same particles in the medium.

Two types:

① constructive interference → builds up (louder sound, brighter light)



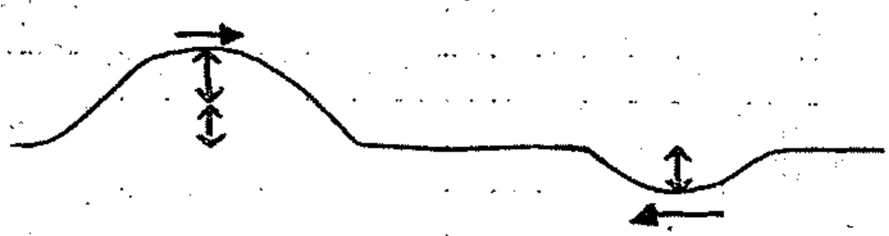
(result)

② destructive interference

(a) cancels out (no sound, no light)

(result)

or (b)



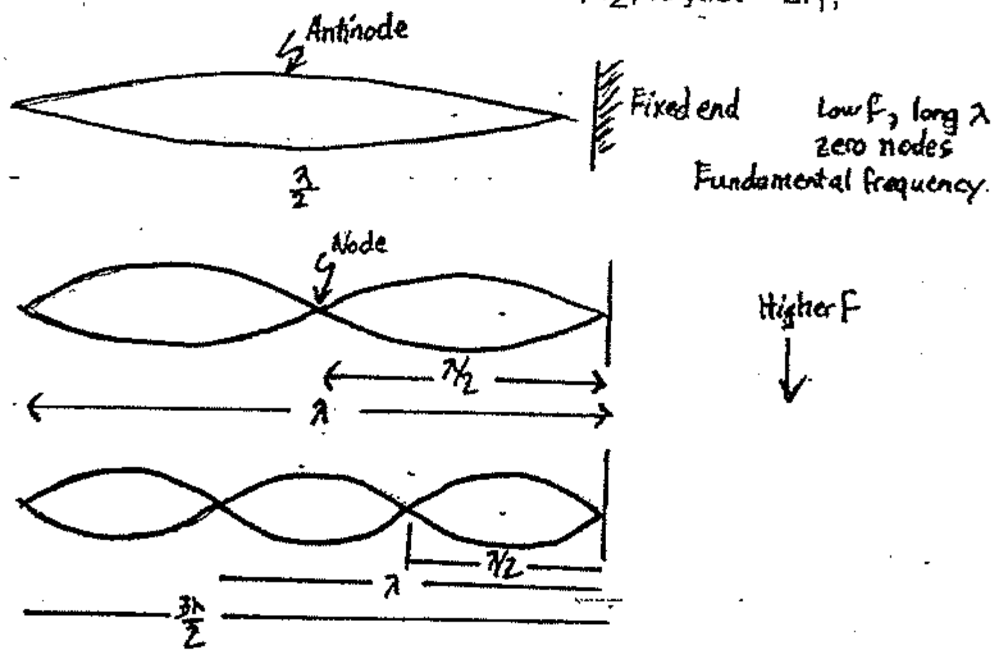
(result)

→ quieter sound, dimmer light

STANDING WAVES (cont"d)

If one end of a rope is kept fixed and the other end is vibrated up and down, the continuous waves will be travel down the rope and be reflected back. They will interfere with the reflected wave and produce a "jumble". But if you vibrate the rope at just the right frequency a "Standing Wave" will be produced. The points of destructive inference, the nodes, are stationary and the points of constructive interference, the antinodes(the loops), are stationary along the rope but move up and down in place.

Standing waves occur at more than one frequency. These are called resonant frequencies, which are whole multiples of the lowest resonant frequency, The lowest resonant frequency is called the fundamental frequency, f_1, which is also called the first harmonic frequency. The second harmonic, f_2, is just = $2f_1$, and $f_3 = 3f_1$, and so on.

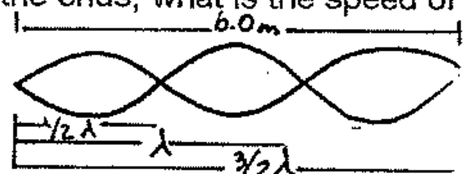


At frequencies at which resonance occurs, very little effort is required to keep the rope vibrating or to achieve a large amplitude. For this reason waves caused by resonant frequencies persist much longer than non resonant frequency waves.

To determine the resonant frequencies, we first note the relationship between the length of the rope "L" and the wavelength "λ". At the fundamental frequency the length of the rope corresponds to one antinode (loop) which is 1/2 of a complete wave or $1/2\lambda$. So at resonance frequency no.1 (the fundamental freq.), the length of the rope $L = 1/2\lambda_1$. At resonance frequency no.2, the length of the rope $L = 2/2\lambda_2$. In general : $L = (n\lambda_n)/2$ or $L = (n/2)\,\lambda_n$ where n is an integer (n = 1, 2, 3...) corresponding to the number of antinodes (loops).

We know that $v = f\lambda$ (universal wave equation), and $\lambda_n = 2L/n$, (from above, just solved for λ) so together $v = f_n(2L/n)$ or $f_n = (nv)/(2L)$ where f_n are the resonance frequencies. The fundamental frequency $f_1 = v/2L$, the second resonant frequency $f_2 = 2v/2L = v/L$, etc.

Example: A standing wave is produced on a 6.0m rope using a 5.0 Hz source. If there are three antinodes between the ends, what is the speed of the waves that produced the pattern?



$f = 5.0\text{Hz}$, $L = 6.0\text{m}$, $n = 3$

$L = (n/2)\lambda$, $6.0\text{m} = 3/2\lambda$, $\lambda = 4.0\text{m}$, $v = f\lambda$, so $v = (5.0\text{Hz})(4.0\text{m}) = 20\text{m/s}$

PHYSICS 11 ASSIGNMENT 17

Physics 11

Interference of Waves

1. A stretched wire is observed to have four equal loops in its standing wave when driven with a frequency of 420. Hz. What driving frequency will set up a wave with two equal segments. 210 Hz

2. What are the wavelengths of the four longest waves that can stand in a string 60. cm long? 120cm, 60cm, 40cm, 30cm

3. What are the four lowest frequencies of a 60. cm string if the speed of the wave is 240. m/s? 200 Hz, 400 Hz, 600 Hz, 800 Hz

4. The G (196 Hz) string of a guitar is 650. mm long. What is the speed of sound in the string? 2.55×10^5 mm/s

5. A stretched wire 1.00 m long has a fundamental frequency of 300. Hz. (a) What is the speed of the waves in the wire? (b) What are the frequencies of the next three harmonics?
a) 600 m/s b) $f_2 = 600$ Hz, $f_3 = 900$ Hz, $f_4 = 1200$ Hz

6. State whether the interference is constructive or destructive in each case.
   (a) A large crest meets a small trough. destructive
   (b) A "supertrough" is formed. constructive
   (c) A small compression meets a large compression. constructive

7. The speed of a wave on a certain 4.0 m rope is 3.2 m/s. What frequency of vibration is needed to produce a standing wave pattern with
   (a) 1 antinode 0.4 Hz (b) 2 antinodes 0.8 Hz (c) 4 antinodes 1.6 Hz

8. The distance between nodes of a standing wave is 40 cm, and the frequency of the source producing the wave by reflection is 880. Hz. Find the speed of the wave in metres per second. 70.4 m/s

Dangerous decibels

Approximate decibel levels of common noises. Continual exposure to more than 85 decibels is considered dangerous:

Hair dryer: 60 to 95

Lawn mower, shop tools: 90

Large orchestra: 98

CD/MP3 player at maximum level: 110

Chainsaw, pneumatic drill, snowmobile: 100

Subway train entering station: 100

Inside subway: 90

Snow blower: 105

Loud rock concert: 115

Jet takeoff: 130

Stock car races: 130

Balloon pop: 157

Shotgun blast: 170

Note: Decibel levels are measured logarithmically. Each increase is 10 times the lower figure. For example, 20 decibels is 10 times the intensity of 10 decibels.

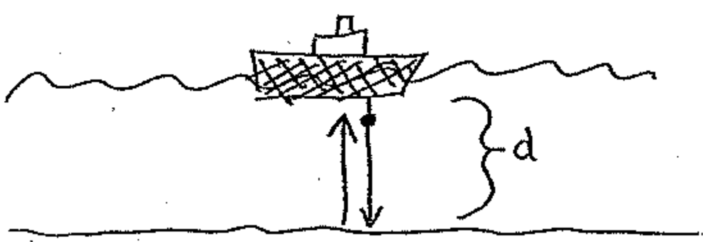
Sources: American Academy of Otolaryngology — Head and Neck Surgery; Canadian Hearing Society; City of Saskatoon; Simon Fraser University; Canadian Medical Association Journal)

A) <u>SOUND WAVES</u>

- originate from a vibrating object
- need a medium to travel through (gas, solid or liquid)
- travel as a longitudinal wave (like compression in a spring)
- molecules in medium collide, transmitting energy away from source
- pitch is the frequency of the sound wave
- loudness is the amplitude of the sound wave
- sound levels (air pressure changes): measured in decibels (dB)
- human hearing: freq. range 20 - 20,000Hz
  (dog: 15 - 50,000Hz)
  < 20 Hz called infrasonic
  > 20,000Hz called ultrasonic
  pain threshold 120dB
  eardrum ruptures 160 dB

B) <u>SONAR</u>

- SOund Navigation And Ranging
- sound reflection is used to measure distances
- ships use depth sounders



$2d = vt$, so $d = vt/2$

- bats also use sonar for navigation

Ex. A student stands 200.m from a canyon wall. If she claps her hands, how long will it take for her to hear the echo? (Speed of sound in air is about 330m/s, depends on temp.)

$$2d = vt, \quad \text{so } t = 2d/v = 2(200.\text{m})/330\text{m/s} = 1.2\text{s}$$

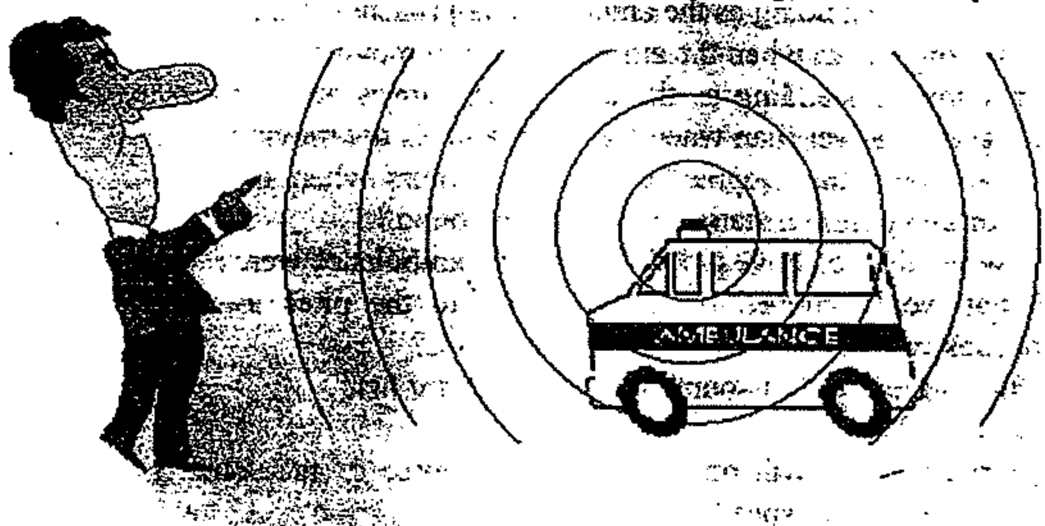
The Doppler Effect

You have probably noticed that the pitch of a siren on a rapidly moving ambulance drops sharply as it passes you. When a speeding race car passes, the sound of its engine changes pitch. The pitch of a moving source of sound is higher than normal when it is approaching a listener and lower when it is moving away. This is know as the *Doppler effect*.

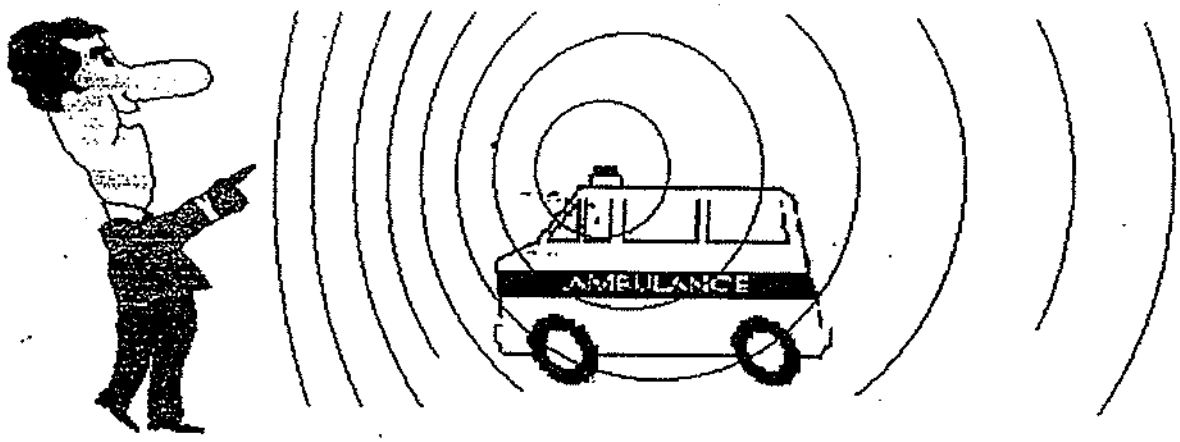
Experiment:
Fit a whistle into a funnel. Tie a string onto the funnel that will allow you to rotate the funnel and whistle in a large horizontal circle over your head.

Observations:
How does the pitch change as the whistle approaches and retreats from you?

What causes the Doppler effect?
The ambulance emits sound waves in all directions at a particular frequency.



1. What can you say about the wavelength of the siren noise? Does it change?
2. Therefore, what can you say about the frequency of the siren noise? Does the pitch change?
3. Is this ambulance moving? How can you tell?
4. How will the siren noise sound in all directions?



5. What happens to the wavelength of the siren noise?

6. So what can you say about the frequency of the siren noise?

As the ambulance moves forward, it is "catching up" with the previously emitted wave crests. Or, since the ambulance is moving forward, the same number of waves must fit into a shorter distance.

7. For someone standing as the ambulance approaches is the pitch of the siren higher or lower than when the ambulance is not moving? Explain why?
8. For someone standing as the ambulance moves away from them is the pitch higher or lower than when the ambulance is not moving? Explain why?
9. Explain how the Doppler effect also occurs when the listener moves toward or away from a stationary source of sound.
10. How would the above picture look if the ambulance were moving faster?
11. What would happen (in question #8) to the pitch as the ambulance approaches you and then moves away from you?
12. What is the speed of sound in (m/s) and (km/ hr)?

The Doppler effect will occur only if the source of the sound is traveling slower than the wave speed.

13. How fast might the ambulance be traveling?

When something travels faster than the speed of sound the wave crests bunch up to produce a shock wave. Supersonic airplanes routinely do this to produce a very loud *sonic boom*.

PHYS 11 TUTORIAL WAVES

P ctice Probs. P. 293.

1. (a) 343 m/s (b) 2.29 m/s (c) 0.787 m
2. (a) 343 m/s (b) 457 Hz (c) 2.19 ms or 2.19×10^{-3} s

Concept Review p. 301 : 2.1, 2.2, 2.3

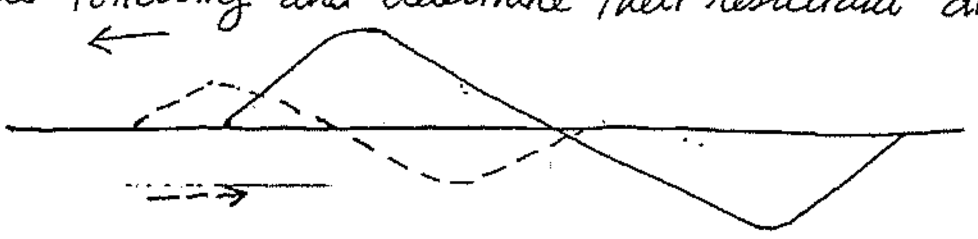
Reviewing Concepts p. 303 : 6, 17

Problems p. 304

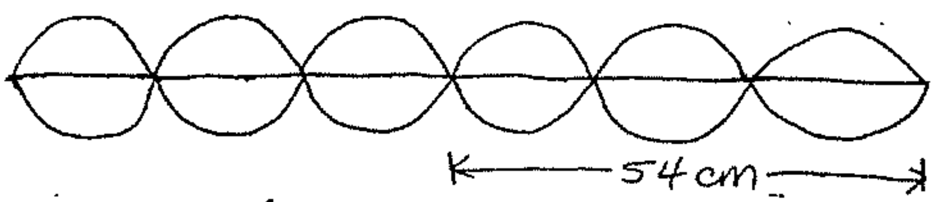
1. 10. s
2. 5.0 m/s
3. (a) 29 cm/s (b) 0.21 s
4. (a) 2.4 m/s (b) 2.9 m
5. 6.0×10^{-7} m
8. (a) 1.50×10^{3} m/s (b) 1.00×10^{-6} s
9. (a) 470 Hz (b) 240 waves 170 m
10. 1350 m
15. (a) amplitude doubled
    (b) amplitudes cancel
    (c) ½ of the second.
16. 0.90 m/s

Extra Practice Problems.

(1) Trace the following and determine their resultant displacement



(2) Standing waves are produced in a string by sources at each end with a frequency of 10.0 Hz.



(a) What is the wavelength of the interfering waves?
(b) What is their speed?

3) A ship is traveling in a fog parallel to a dangerous, cliff-lined shore. T[illegible] boat whistle is sounded and its echo is heard clearly 11.0 s lat[illegible] If the air temperature is 10°C, how far is the ship from the clif[illegible] (Speed of sound = 340 m/s).

(4) A string 1.0 m long vibrates at the rate of 180 Hz. What will its frequency be if it is shortened to (a) 50 cm (b) 60 cm (c) 25 cm

5) When waves slow down on entering a new medium, what happens to (a) their wavelength? (b) their frequency? and (c) their direction? Under what condition will the direction not change?

6) Some microwaves have a frequency of 3.0×10^{10} Hz. What is the wavelength of microwaves of this frequency? Microwaves trav[illegible] the speed of light.

7) Waves of frequency 2.0 Hz are generated at the end of a long steel spring. What is their wavelength if the speed of the waves is 3.0 m/s?

8) When straight waves strike the flat barrier at an angle, how does the ∠i compare with the ∠r?

(9) A fisherman notices that wave crests pass the bow of his anchored boat every 3.0 s. He measures the distance between two crests to be 7.5 m. How fast are the waves traveling?

(10) If a violin string vibrates at 440 Hz. as its fundamental freque[illegible] what are the frequencies of the first four harmonics?

INVESTIGATING THE PROPERTIES OF WAVES

PART 1 - TRANSMISSION AND SPEED

Discussion questions:

1. What is the direction of the wave motion relative to the crest of a wave?
2. How does a decrease in the frequency of the source affect the wavelength of the waves? How is the wavelength affected if the frequency increases?
3. How is the speed of a wave affected by a change in frequency?

PART 2 - REFLECTION

Discussion questions:

1. When a straight wave strikes a barrier so that its wavefront is parallel to the barrier, in what direction is the wave reflected?
2. When an incident wavefront strikes a farrier at an angle(that is obliquely), how do the angles between the barrier and the incident and reflected wavefronts compare?
3. How are straight waves reflected by a parabolic reflector?

PART 3 - DIFFRACTION

Discussion questions:

1. What kind of wavelengths are diffracted more: long or short?
2. What is the relationship between the size of the opening and the amount of diffraction?
3. Describe two conditions for maximum diffraction through an opening in a barrier.

PART 4 - REFRACTION

Discussion questions:

1. What changes occurred in the wavelength of the waves and in their speed when they entered the shallower water?
2. What changes in direction occurred when waves entered shallow water, straight on and obliquely?
3. What changes in the wavelength, speed, and direction do you predict will occur when waves pass obliquely from shallow water to deep water? Draw a sketch illustrating you prediction.

ANSWER KEY TO INVESTIGATING THE PROPERTIES OF WAVES

PART 1 - TRANSMISSION AND SPEED

1. The wave travels at right angles or perpendicular to the crest of a wave.
2. A decrease in frequency increases the wavelength. The wavelength decreases as frequency increases.
3. The speed is not affected by a change in frequency.

PART 2 - REFLECTION

1. It is reflected back in the opposite direction.
2. The angle of incidence and the angle of reflection are equal.
3. A parabolic reflector causes straight waves to come to a point at the center of the parabola.

PART 3 - DIFFRACTION

1. Long wavelengths diffract more.
2. A small opening will diffract waves more.
3. Long wavelengths and small opening will give maximum diffraction.

PART 4 - REFRACTION

1. The wavelengths are shorter and the speed decreases as waves enter shallow water.
2. When entering straight on from deep to shallow water, there is no direction change. When entering obliquely, the direction changes and the refracted wave ray bends towards the normal.
3. As waves pass from shallow to deep water, wavelength and speed will increase and the refracted wave ray will bend away from the normal.

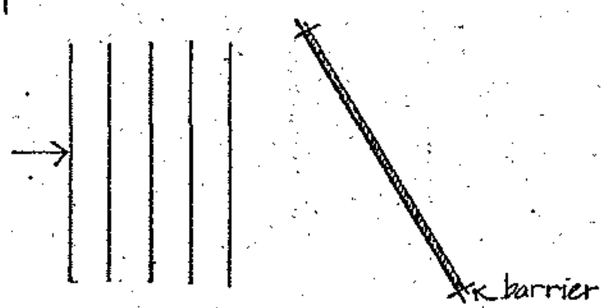
WORKSHEET - WAVES

Physics 11

Instructions - For each of the following diagrams:

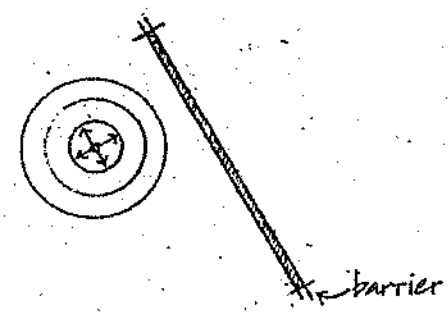
a. Draw the resulting wave pattern on the diagram
b. Identify the phenomenon (reflection, refraction, diffraction, dispersion)
c. Indicate and/or label the following on the diagram where applicable:
    - angle of incidence
    - angle of reflection
    - normal to boundary
    - focal point
    - wave speed (faster or slower)
d. Describe what happens when you increase the frequency

1. phenomenon:



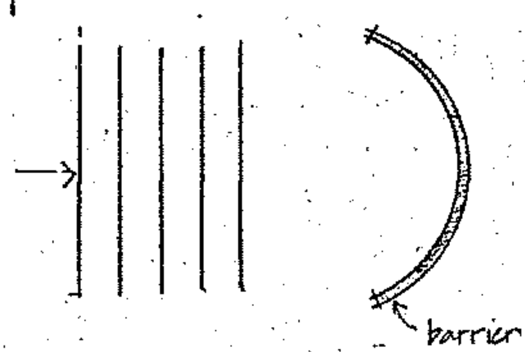
when f↑...

2. phenomenon:



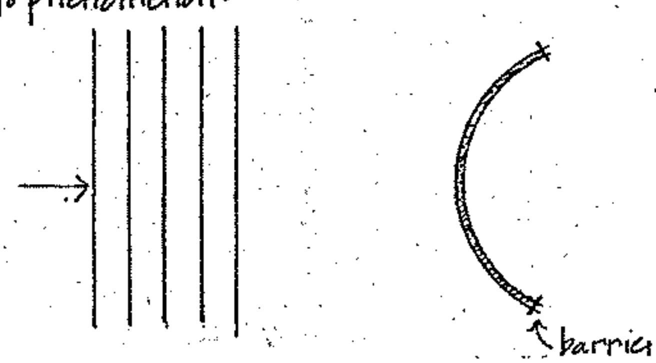
when f↑...

3. phenomenon:



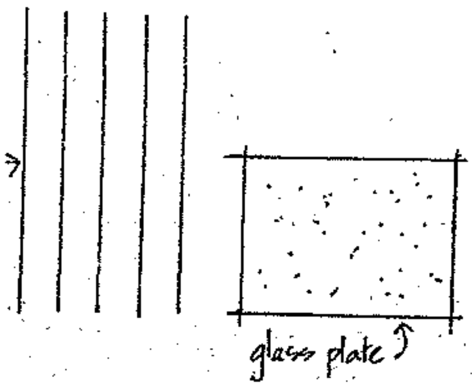
when f↑...

4. phenomenon:



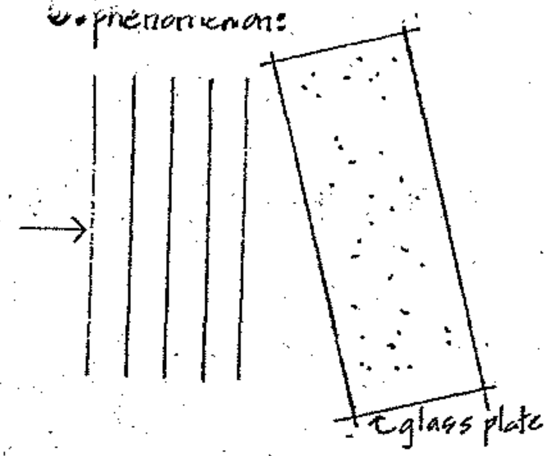
when f↑...

phenomenon:



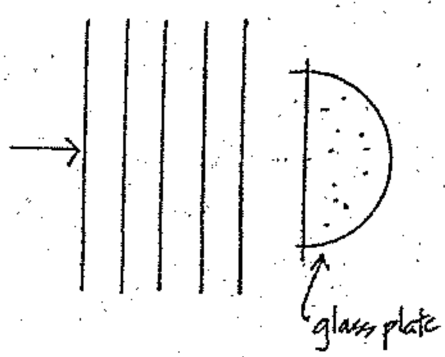
when f↑...

phenomenon:



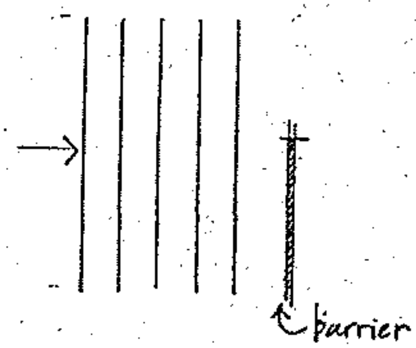
when f↑...

7. phenomenon:



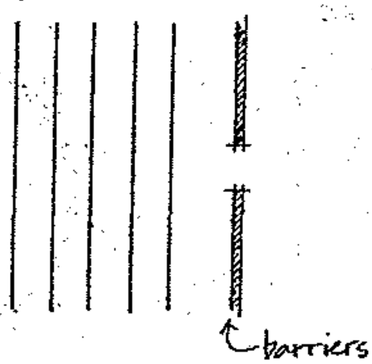
when f↑...

8. phenomenon:



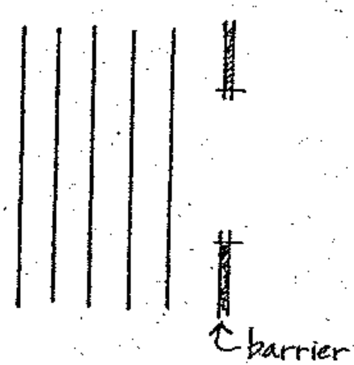
when f↑...

9. phenomenon:



when f↑...

10. phenomenon:



when f↑...

PHYSICS 11 FINAL EXAM BREAKDOWN

1) INTRO TO PHYSICS - 3 QUES

2) KINEMATICS - UNIFORM MOTION - 5 QUES

- NON-UNIFORM MOTION - 4 QUES

3) VECTORS - 5 QUES

4) ENERGY (friction, gravity, inertia, momentum, work, KE, PE, impulse, heat, etc..) - 16 QUES

5) NUCLEAR ENERGY - 6 QUES

6) OPTICS - 3 QUES

7) WAVES - 3 QUES

TOTAL - 45 QUES, all multiple choice, most involve calculations

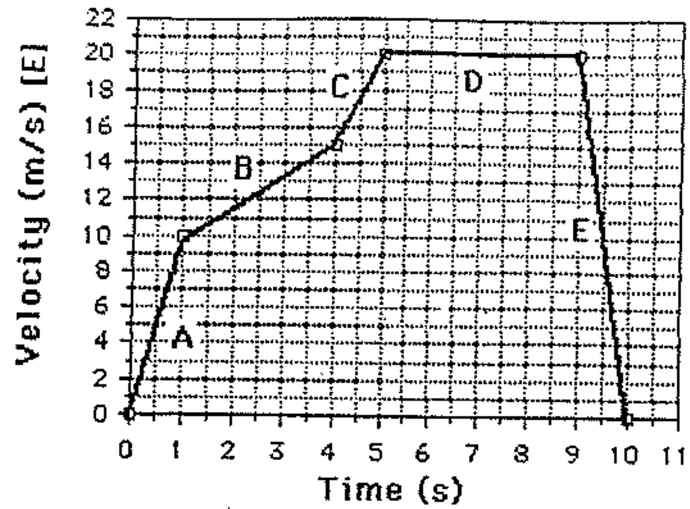
PHYSICS 11 REVIEW PACKAGE

DO NOT WRITE ON THIS PACKAGE! DO ALL YOUR WORK ON SEPARATE PAPER.

KINEMATICS REVIEW

1. If a car accelerates from rest at a constant 5.5 m/s^2, how long will be required to reach 28 m/s? (5.1 s)
2. A biker passes a lamp post at the crest of a hill at 4.5 m/s. She accelerates down the hill at a constant rate of + 0.40 m/s^2 for 12 s. How far does she move down the hill during this time? (83 m)
3. A boat is able to move through still water with a maximum speed of 20 m/s. The boat makes a trip to town 3 km downstream and then back to its starting point. The river flows at a constant speed of 5 m/s. What is the minimum time required for the round trip? (320 s)
4. An object falls freely from rest (constant acceleration). If in the first second it falls a distance h, how far will it fall during the next second? (3h)
5. An object is thrown straight up from ground level with a speed of 50 m/s. What is its distance above the ground 1.0 s after being thrown? (45 m)
6. A speedboat travelling north slows down from a speed of 25 m/s to 10 m/s in a time of 5.0 s. What is its average acceleration? (3.0 m/s^2 south)
7. Suppose you go on a trip that covers 240 km and takes 4 hours. What is the average of the magnitude of the velocity? (60 km/h)
8. A speeding motorist travelling at 28 m/s passes a parked police officer. The officer begins to chase the motorist the moment the motorist passes. The officer accelerates at a constant 1.8 m/s2 and the motorist travels at a constant speed of 28 m/s, how much time will it take the officer to catch up? (31 s)
9. A car travelling on the highway at 15 m/s accelerates at 3.0 m/s2 for 5.0 s. What is its final velocity? (30 m/s)
10. A baseball falling from rest, reaches a speed of 38 m/s after falling 84 m. What is the average acceleration of the baseball? (8.6 m/s^2)
11. A one kilogram object falls to earth from a height of 20 m. ($g=10$ m/s^2). What is its velocity just before it hits the ground? (20 m/s)
12. How far would a car travel in 6.0 s if its initial velocity was 2.0 m/s and it accelerated at 2.0 m/s^2? (48 m)
13. What height will be reached by an arrow shot straight up at an initial velocity of 15 m/s? (Ignore air resistance) (11 m)
14. An elevator travelling at an initial unknown velocity, accelerates uniformly at a rate of 0.50 m/s^2 for a time of 4.0 seconds. During the acceleration period the displacement of the elevator was + 8.0 m. What was the initial velocity of the elevator? (1.0 m/s)
15. A cyclist is riding at a constant speed of 5.00 m/s when she sees a flash of lightning. Wanting to get home quickly, she accelerates at 1.00 m/s^2 for 4.00 s and then rides at a constant speed for 30.0 s. If she then takes a further 12.0 to slow down uniformly to rest, the total distance travelled after seeing the lightning flash is? (352 m)

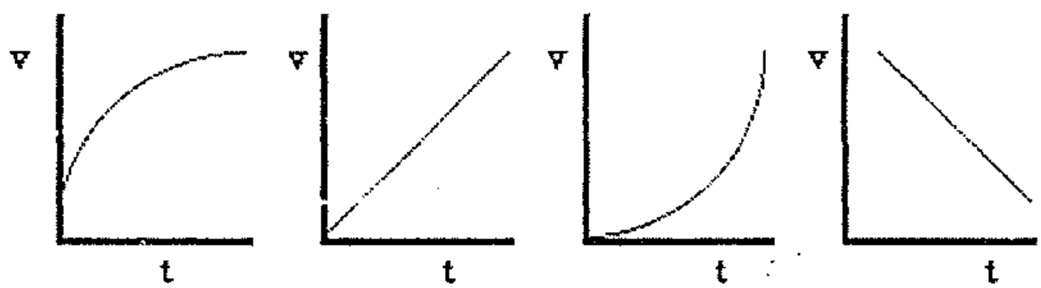
Shown below is the velocity-time graph for an object during a 10 s time interval



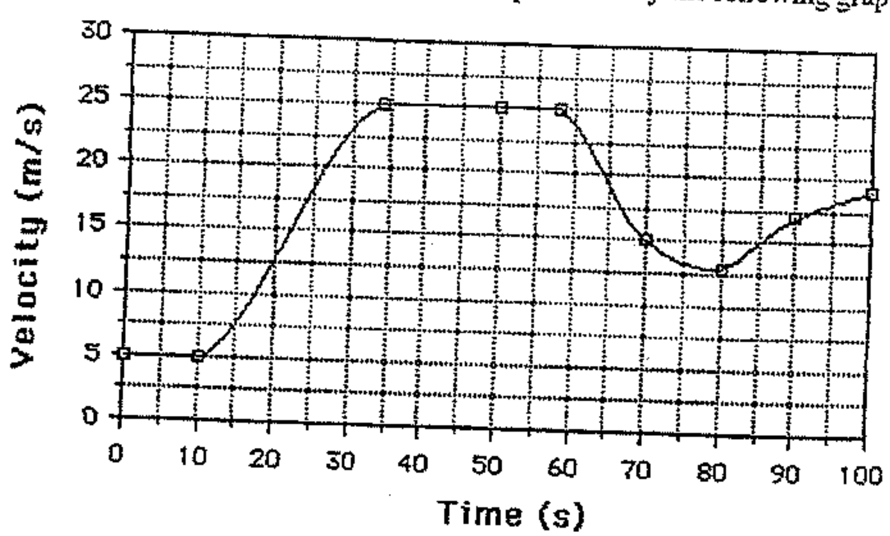
Which segment of the graph shows the smallest magnitude of acceleration? (D)

If frictional forces are considered minimal, which of the following velocity-time graphs best describes the motion of a freely falling object near the surface of the earth?

A) B) C) D)



The motion of an object travelling in a straight line is represented by the following graph:



In the above graph what was the magnitude of the acceleration of the object during the 25 s time interval between 10 s and 35 s ? (0.80 m/s2)

Which of the following equations would be used to calculate the period, T of an electric timer which takes 4.3 seconds to produce the ticker tape shown below.

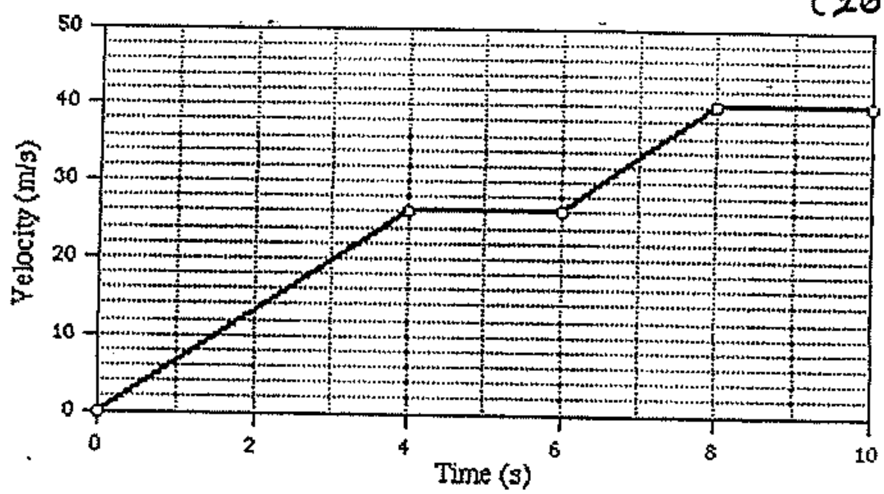
✓A $T = \frac{4.3}{32}$

B $T = \frac{32}{4.3}$

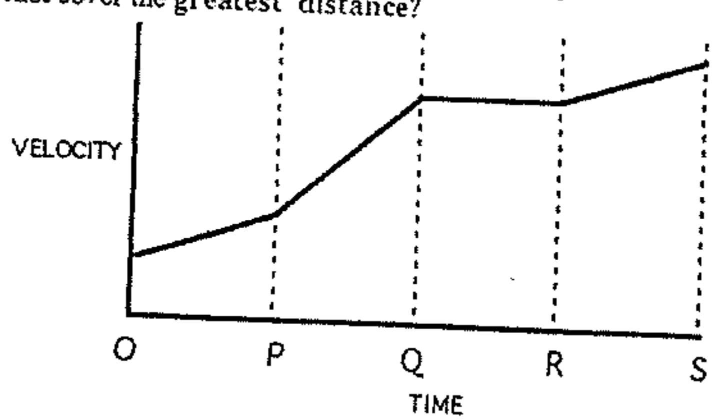
C $T = 4.3 \times 32$

D $T = \frac{1}{4.3 \times 32}$

The graph shown below represents the velocity of an object moving in a straight line. From the graph, find the velocity of the object at time = 5.0 seconds. (26 m/s)



The graph to the right describes the velocity of a cyclist during equal time intervals. In which time interval did the cyclist cover the greatest distance? (R-S)



DYNAMICS REVIEW

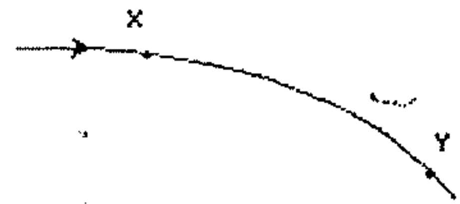
1. Two objects are separated a distance of 4.0 m. One object has a mass of 2.0 kg and the other has a mass of 6.0 kg. What is the gravitational force acting on the 2.0 kg mass? (5.0×10^{-11} N)
2. What is the gravitational field strength 95 km from the surface of the Earth? (9.5 N/kg)
3. The force of gravity acting on a 750 g mass is? (7.4 N)
4. What force would balance the weight of an object with a mass of 6.0 kg? (g=10 N/kg) (60 N up)
5. If the spring constant of a certain spring is 175 N/m, a force of 26.0 N would stretch the spring by how many centimeters? (14.9 cm)
6. A crate is pulled horizontally along the floor with a uniform velocity by a horizontal force of 500 N. If the mass of the crate is 250 kg. What is the coefficient of friction between the crate and the floor? (0.2)
7. A crate that weighs 254 kg, sitting on level ground, is pulled by a fork-lift. If the static coefficient of friction between the crate and the ground is 0.450, how much force must be applied by the fork-lift in order to just start the crate moving? (1120 N)
8. A girl pushes a 35 kg sled against a friction force of 75 N. If she causes the sled to accelerate at 2.1 m/s^2, what force does she apply? (1.5×10^2 N)
9. A box with a mass of 26 kg is resting on a wooden table. The coefficient of friction is 0.27. Find the horizontal force necessary to give the box an acceleration of 1.2 m/s^2? (1.0×10^2 N)
10. When the space shuttle lifts off the pad at Cape Kennedy Space Center, its engines provide a total thrust of 2.4×10^7 N. If the shuttle weighs 2.0×10^6 kg, what is its initial acceleration? (use g = 10 m/s^2) (2.2 m/s^2)
11. An elevator weighing 12 000 N is accelerating upwards. The tension in the cable is 20 000 N and the frictional resistance to motion is 5 000 N. The unbalanced force on the elevator is? (3 000 N up)
12. A car having a mass of 1500 kg and travelling at 5.0 m/s is accelerated for 10 s to a velocity of 24 m/s. The net force is? (2.9×10^3 N)
13. A professional golfer can give a golf ball (mass 0.175 kg) an initial velocity of 140 m/s. If the ball is in contact with the club for 0.02 s, calculate the average force applied to the ball when it is hit. (1200 N)
14. An 8.0 N force is exerted for 4.0 s on a 16 kg block, causing it to move in a straight line. If frictional forces are minimal, the change in speed of the block will be? (2.0 m/s)
15. A car of mass 800 kg is travelling E at 30.0 m/s and collides with a truck travelling W at 40.0 m/s, which has a mass of 1600 kg. The two vehicles are locked together after the collision. What is their combined velocity? (16.7 m/s W)
16. A cue strikes a pool ball, exerting an average force of 55 N over a time of 10 ms. If the ball has mass 0.2 kg, what speed does it have after impact? (.3 m/s)
17. A 4.2 kg rifle shoots a 0.050 kg bullet at a speed of 3.00×10^2 m/s. At what speed does the rifle recoil? (-3.6 m/s)
18. A student throws a 0.10 kg ball at a wall. The ball hits the wall perpendicularly with a speed of 5.0 m/s and then bounces back with a new speed of 4.0 m/s. The change in momentum of the ball is? (-0.90 kgm/s)

19. The time needed for a net force of 10 N to change the velocity of a 5.0 kg mass by 3.0 m/s is? (1.5 s)

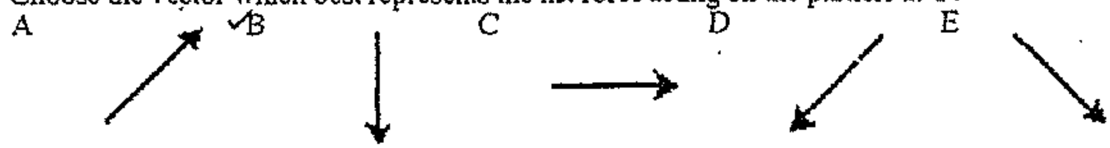
20. A student whose mass is 50.0 kg is on roller skates. The student throws a 5.0 kg medicine ball horizontally away from himself with a speed of .10 m/s. Neglecting friction, find the speed of the student after he throws the ball.

(0.01 m/s)

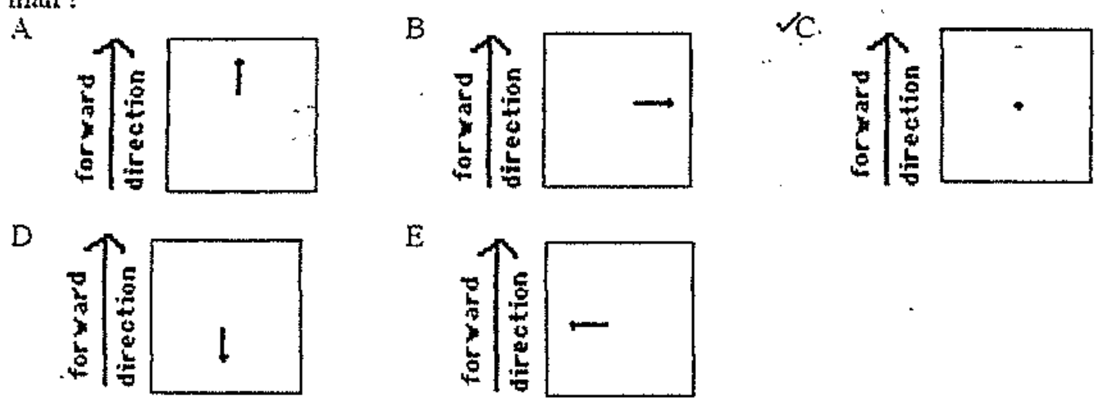
A small projectile is launched horizontally in a vacuum and follows a path from X through Y as shown.



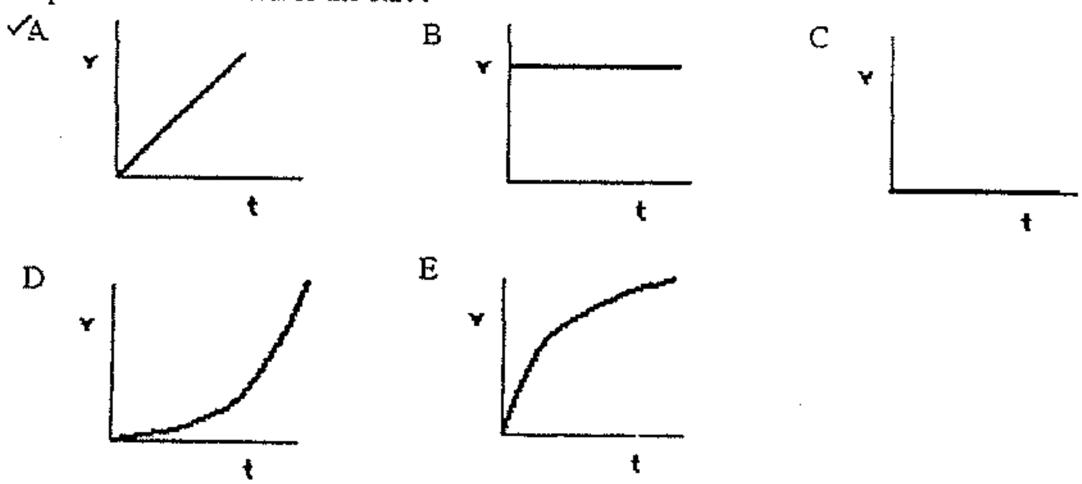
Choose the vector which best represents the net force acting on the particle at Y.



A man on a train is seated facing forward. He holds a thread fastened to a lead ball so that the ball is suspended over the center of an open book. The train maintains a speed of 40 km/h for 10 minutes. Which diagram best represents the position of the lead ball over the book, as seen by the man ?



A cart, initially at rest, is pulled with a constant, unbalanced force. Which speed-time graph best represents the motion of the cart ?



WORK & ENERGY REVIEW

1. A forklift raises a 583 kg box 1.2 m
   (a) How much work was done by the forklift? (6.9×10^3 J)
   (b) How much gravitational potential energy did the box gain? (6.9×10^3 J)
2. An electric motor develops 65 kW of power as it lifts a loaded elevator 17.5 m in 35.0 s. How much force does the motor exert? (1.3×10^5 N)
3. A net force of 90.0 N does 45.0 J of work on a brick. How far has the brick moved? (0.500 m)
4. A student accelerates a block by applying a 3.6 N force. If there is a force of friction of 2.6 N resisting the motion, how much work is done in moving the block 5.0 m horizontally? (18 J)
5. A 30 kg carton of books is carried up a flight of stairs 4.0 m high (g = 10 N/kg). If the time required is 1.0 min, what is the power required? (20 W)
6. A 75 kg science teacher runs up a set of stairs with a vertical height of 2.2 m, in 1.5 s. What power did this teacher develop? (1100 W)
7. What is the potential energy of a 1.6 kg partridge on a branch in a pear tree 13 m above the ground? (200) = 2.0×10^2 J
8. What is the kinetic energy of a 0.01kg bullet fired from a gun with a speed of 1000 cm/s? (0.5 J)
9. How fast would a 1.1 kg ball be travelling if it had a kinetic energy of 480 J? (29.5 m/s)
10. A pole vaulter of mass 60. kg just cleared 4.0 m. How fast was he running the instant before his jump? (Assume that the height he jumped is due entirely to his Ek) (9 m/s)
11. Calculate the final temperature when 2.0 kg of lead at 50.0° C are heated with 2000 J (c=130 J/kgC) (58° C)
12. A 5.0 kg stone is released 20.0 m above the ground. What is its speed when it hits the ground? $\sqrt{(3.9 \times 10^2 \text{ m/s})}$ = 20 m/s
13. Calculate the specific heat capacity of 400 g of gdd if 1.3 kJ of energy is required to raise its temperature from 50° C to 75° C. (1.3×10^2 J/kgC)
14. Nancy's furnace burns 1.8 x 103 J of natural gas in one month. This results in heat being added to her house. The heat energy is measured to be 1.4 x 103 J per month. How efficient is Nancy's furnace? (78%)
15. A baseball is thrown upward with a speed of 20 m/s (g=10 m/s2). The ball will rise to a maximum height of? (20 m)
16. A 7 kg steel ball moving at 5 m/s hits a 8 kg ball of putty at rest and sticks to it. The two go on at 2.2 m/s
   (a) What is the kinetic energy of the two balls before the collision? (90 J)
   (b) What is the kinetic energy of the two balls after the collision? (40 J)
   (c) Calculate the change in kinetic energy (-50 J)

WAVES REVIEW

1. An A note of 440 Hz is played on a violin submerged in a swimming pool at the wedding of two scuba divers. Given that the speed of waves in pure water is 1498 m/s, what is the wavelength of that tone? (3.4 m)
2. A string stretched between fixed posts is 250 cm long and oscillates in its fundamental mode at 100 Hz. Determine the speed of a transverse wave on the string. (~~3000 Hz~~) 500 m/s
3. A sound wave is directed toward a vertical cliff 680 m from the source. A reflected wave is detected 4.0 s after the wave is produced.
   (a) What is the speed of sound in air? (340 m/s)
   (b) The sound wave has a frequency of 5.00×10^2 Hz. What is the wavelength? (0.68 m)
   (c) What is the period of the wave? (2.00×10^{-3} s)

4. The velocity of sound waves in cold air is 320 m/s,a nd in warm air, it is 384 m/s. if the wavelength of the sound waves was 3.0 m in cold air, what would it be in warm air? (3.6 m)
5. Standing waves are produced in a string by two waves travelling in opposite directions at 6.0 m/s. The distance between the second node and the sixth node is 80 cm. Determine the wavelength and the frequency of the original waves. (40cm;15 Hz)
6. A pendulum bob completes 25 swings in 45 s. What is the pendulum's frequency? (0.55 Hz)
7. A motor turns at 4500 rpm (revolutions per minute). What is the period of this motor? (1.3×10^{-2} s)
8. A fisherman notices that his fishing line float bobs up and down 15 times every minute and that the waves are 2.0 m apart. How fast are the water waves moving? (0.50 m/s)
9. A skipping rope is used to generate some waves. The waves take 1.6 s to cross the 2.7 m length of the rope. The period between each successive wave is 0.50 s. What is the wavelength of these waves? (0.84 m)
10. A standing wave pattern is set up using waves that have a period of 2×10^2 s and a speed of 25 m/s. The waves have an amplitude of 2.1 m. What is the distance between the nodes and the amplitude of the standing wave? (0.25m & 4.2 m)
11. In a standing wave pattern in a slinky-spring the distance between successive nodes is 0.30 m. The frequency of the waves is 15 Hz. What is the speed of the waves? (9.0 m/s)
12. Radio astronomers detect radio waves at a frequency of 660 Hz. Given that radio waves travel at the speed of light, the wavelength of these radio waves would be? (455 km)

GEOMETRICAL OPTICS REVIEW

1. A light wave has the speed of 3.00×10^8 m/s in a vacuum and 1.80×10^8 m/s in some new medium. What is the refractive index of this new medium? (1.67)
2. Diamond has a refractive index of 2.42. How fast does light travel in diamond? (1.24×10^8 m/s)
3. A light ray travelling in air enters glass at an angle of 30.0°. It is bent so that it emerges from the boundary at an angle of 19.2°. What is the index of refraction on this glass? (1.52)
4. A ray of light strikes a block of quartz with an angle of incidence of 68°. The refractive index of quartz is 1.54. What is the angle of refraction? (37°) = 37°
5. A light ray goes from water (n=1.33) at an angle of 56° into ruby (n=1.54). What is the angle of refraction in the ruby? (45°)
6. To some extent, the brilliance of diamonds is attributable to its total internal reflection. To improve the quality of a diamond, the jeweler must cut the stone at the angle that will maximize the internal reflection. Calculate the critical angle for a diamond-air surface that will produce total internal reflection. The refractive index of diamond is 2.42 and of air is 1.0. (24°)
7. Light travelling through air enters a glass plate at an angle of 40° and is refracted at an angle of 25°. The index of refraction of the plate of glass is? (1.52)
8. An object is placed 40.0 cm in front of a convex mirror. The image appears 15 cm behind the mirror. What is the focal length of the mirror? (11 cm)
9. An object is placed in front of a concave mirror of focal length 50.0 cm and a real image is formed 75 cm in front of the mirror. How far is the object from the mirror? (150 cm)
10. An object is placed 60 cm in front of a concave mirror. The real image formed by the mirror is located 30 cm in front of the mirror. What is the object's magnification? (-0.5)
11. A pinhole camera captures a 5.0 cm image of a house. If the length of the camera is 12.0 cm and was placed 25 m away from the house, how tall was the house? (10 m)
12. A concave spherical mirror has a radius of curvature of 100 cm. What is its focal length? (50 cm)
13. A 2.2 cm talll bug stands 6.80 cm to the left of a converging lens whose focal length is 11.8 cm
    (a) Find the image distance (-16.0 cm)
    (b) Determine the magnification (2.35)
    (c) Determine the image height (5.2)

USEFUL CONSTANTS

$g = 9.80\ m/s^2$

radius of Earth = 6.4×10^6 m

$c = 3.00 \times 10^8$ m/s

g (at Earth surface) = 9.80 N/kg

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$