Applications of Newton's Laws of Motion

Advanced Placement Physics B
Mr. DiBucci

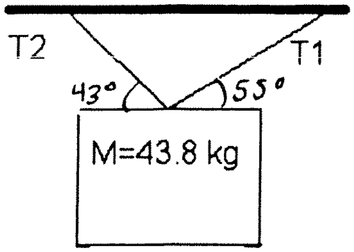
*Name*____ *per.* ___ *date* ______
Equilibrium applications of Newton's Laws *DiBucci*

Equations:

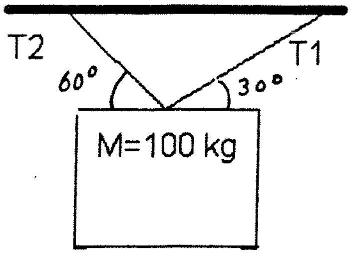
$$\sum \vec{F} = 0$$

***Objective:** Apply Newton's Laws of Motion to analyze objects in equilibrium*

1. The box hanging in the diagram below is in a state of static equilibrium. Calculate the tension in each rope: T1 and T2. angle 1 = 55 degrees Angle 2= 43 degrees, each angle is measured from the horizontal and corresponds to T1 and T2 in each rope.



2. Repeat the same procedure for the box in this problem. Assume angle 1 = 30 degrees and angle 2 = 60 degrees



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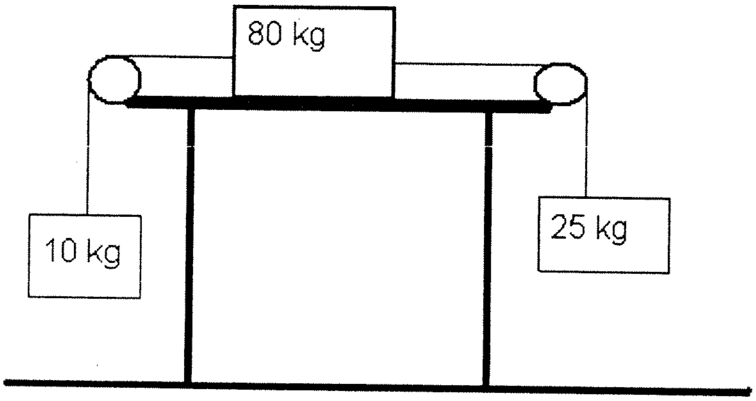
Non equilibrium applications of Newton's Laws DiBucci

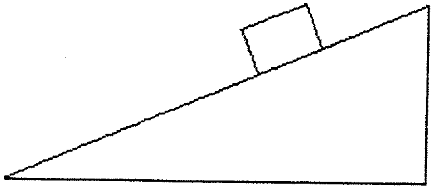
1. Make a free body diagram for each mass in the diagram below, and calculate *the acceleration* *of the system and* *the tension* *in each rope. The coefficient of friction between the 80 kg mass and the table is 0.100. Place your work on a separate sheet of paper if needed.*



2. In the diagram below the box has a mass of 100 kg. The angle of the incline is 50 degrees. The coefficient of friction is 0.15.

a. Make a free body diagram for the mass on the inclined plane below.

b. Calculate the acceleration of the block down the incline.



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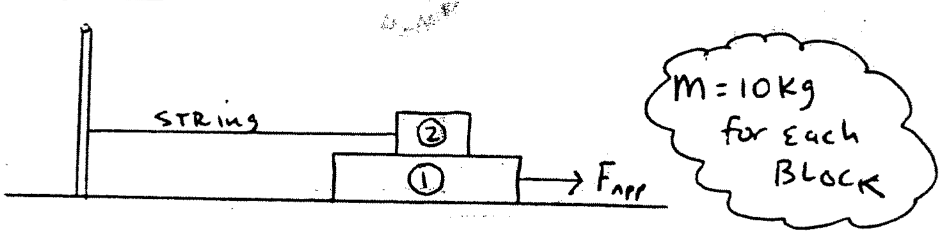
AP Physics **DiBucci**

Applications of Newton's Laws

Consider the following system:

μ_s=0.32 for all surfaces



1. Make a FBD for the upper block.

2. Make a FBD for the lower block.

3. What is the magnitude of the normal force on block 2 that comes from block 1?

4. What is the magnitude of the friction force that the surface applies to block 1?

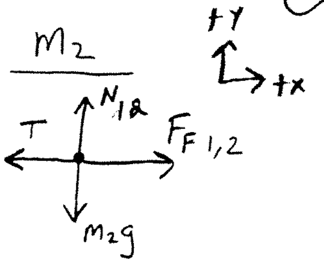
5. What is the maximum applied force that will allow the system to remain at rest?

[illegible]

Solution

DiBucci

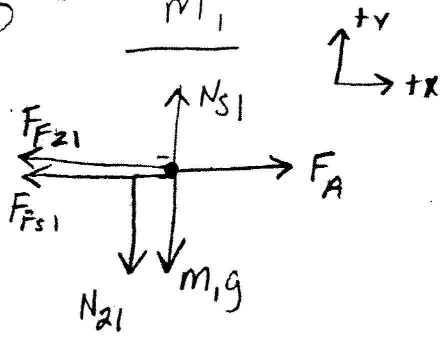
①



Y: $N_{12} - m_2 g = 0$

X: $-T + F_{F12} = \cancel{m_2 a}^{0} = 0$

②



Y: $N_{S1} - N_{21} - m_1 g = 0$

X: $F_A - F_{F21} - F_{FS1} = m_1 a$

③ $N_{12} = m_2 g$

$= (10\,kg)9.8\,m/s^2 = \boxed{98N}$

④ $F_{FS1} = \mu N_{S1}$

$= (.32)(N_{S1})$

$= (.32)(N_{21} + m_1 g)$

$= (.32)(98N + (10)9.8\,m/s^2)$

$= \boxed{62.7N}$

⑤ $\Sigma F_{X_{m_1}} = 0$

$F_A - F_{F21} - F_{FS1} = m_1(0)$

$F_A - \mu N_{21} - 62.7N = 0$

$F_A - (.32)(98N) - 62.7N = 0$

$F_A = \boxed{94.1N}$

6) Let T = 0

$M_2: \Sigma F_{X\,m_2} = m_2 a \quad a = \frac{F_{F12}}{M_2}$

$F_{F12} = m_2 a$

check

$M_1: F_A - F_{F21} - F_{FS1} = m_1 a$

let $F_A - \cancel{F_{F21}} - F_{FS1} = m_1 \frac{F_{F12}}{M_2}$

$F_A = F_{F12}\left(1 + \frac{m_1}{m_2}\right) + F_{FS1}$

$F_A = .32(98N)\left(1 + \frac{10}{10}\right) + 62.7N$

$F_A = \cancel{66.15N}\ \cancel{97.2N}$ 125.4

$F_A - F_{F21} - F_{FS1} = m_1 a$

$\frac{\cancel{66.15N} - (.32)(98) - 62.7}{10} = \frac{10}{10} a$

125.4   10

125.4

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Applications of Newton's Laws

1/ In Figure P5.86, the coefficient of kinetic friction between the 2.00-kg and 3.00-kg blocks is 0.300. The horizontal surface and the pulleys are frictionless, and the masses are released from rest. (a) Draw a free-body diagram for each block. (b) Determine the acceleration of each block. (c) Find the tension in the strings.

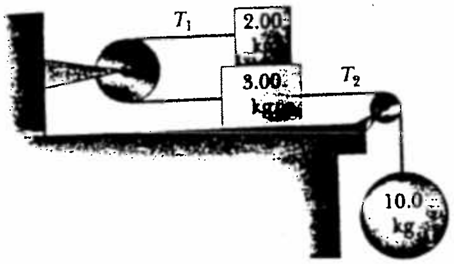


FIGURE P5.86

2) The three blocks in Figure P5.85 are connected by massless strings that pass over frictionless pulleys. The acceleration of the system is 2.35 m/s² to the left and the surfaces are rough. Find (a) the tensions in the strings and (b) the coefficient of kinetic friction between blocks and surfaces. (Assume the same μ for both blocks.)

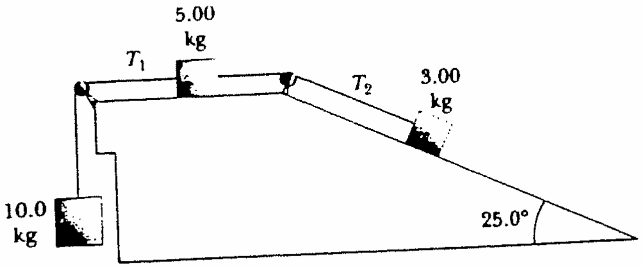


FIGURE P5.85

3) Two blocks of mass 3.50 kg and 8.00 kg are connected by a massless string that passes over a frictionless pulley (Fig. P5.87). The inclines are frictionless. Find (a) the magnitude of the acceleration of each block and (b) the tension in the string.

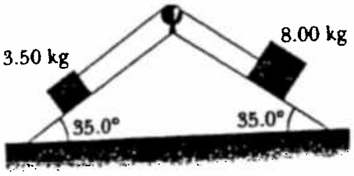
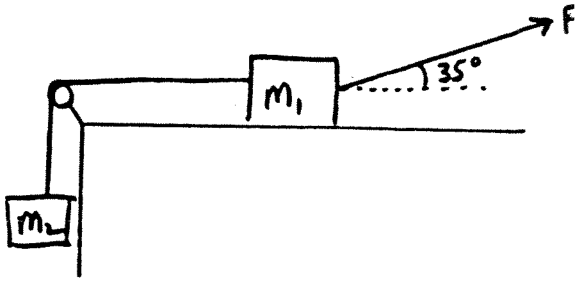


FIGURE P5.87

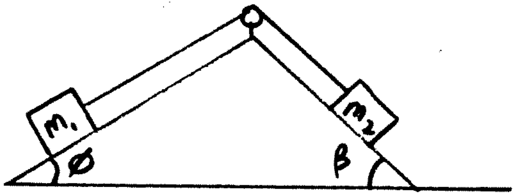
Worksheet **AP PHYSICS**

1. If the coefficient of friction between a tire and the road is 0.4 , what is the shortest distance in which a car can be stopped when it's speed is 30 m/s?
(answer: 115 m)



2. Find a and T for the system shown here:
m_1=40 kg m_2= 10 kg μ_k= 0.25

(answer: a=1.85 m/s/s T=117 N)



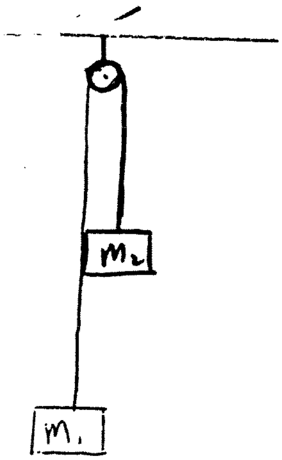
3. Find a and T for the system shown:
Assume that the motion is to the right.
μ_1= coefficient for the left side
μ_2= coefficient for the right side

answers: $$a= \frac{m_2g(\sin\beta - \mu_2\cos\beta) - m_1g(\sin\text{ø} + \mu_1\cos\text{ø})}{(m_1 + m_2)}$$

$$T= \frac{g m_1m_2(\sin\text{ø} + \sin\beta + \mu_1\cos\text{ø} - \mu_2\cos\beta)}{(m_1 + m_2)}$$

NOTE: This is a time consuming problem but it is very important that you can do problems that involve this type of algebraic manipulation. Do yourself a favor and give it a try, even if it is frustrating! Remember, you are an NA tiger!

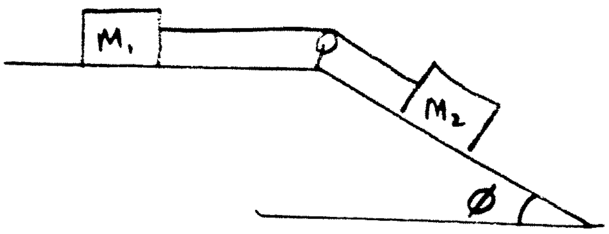
4. Find a and T for Atwood's machine. Don't assume that the mases are equal.
(ASSUME m_2 FALLS)



answers: $$a= \frac{(m_2 - m_1)g}{m_1 + m_2}$$

$$T= \frac{2m_1m_2g}{m_1 + m_2}$$

5. Find a and T for the system shown:
Assume that the motion is to the right.
μ_1= coefficient for the left side
μ_2= coefficient for the right side

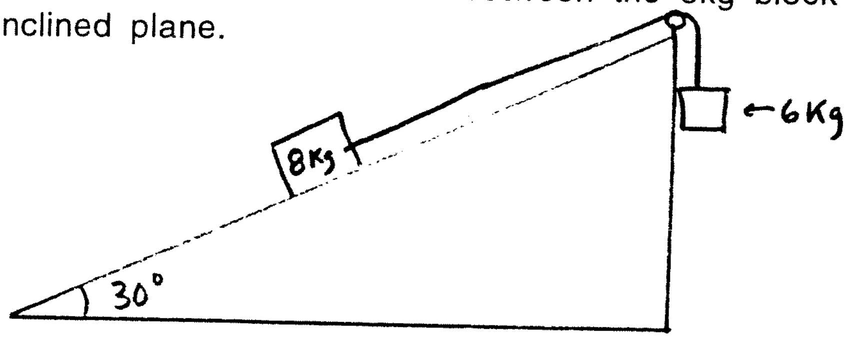


answers: $$a= \frac{m_2 g(\sin\phi - \mu_2 \cos\phi) - m_1 g \mu_1}{m_1 + m_2}$$

$$T= \frac{m_1 m_2 g(\sin\phi + \mu_1 - \mu_2 \cos\phi)}{m_1 + m_2}$$

6. Starting from rest it takes 4.0 seconds for the 6kg block to reach the floor 2.0 m below. Find the coefficient of friction between the 8kg block and the surface of the inclined plane.

(answer: μ_k= 0.237)



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Friction Worksheet

38. (I) If the coefficient of kinetic friction between a 35-kg crate and the floor is 0.30, what horizontal force is required to move the crate at a steady speed across the floor? What horizontal force is required if μ_k is zero? 100 N No Force

39. (I) A force of 40.0 N is required to start a 5.0-kg box moving across a horizontal concrete floor. (*a*) What is the coefficient of static friction between the box and the floor? (*b*) If the 40.0-N force continues, the box accelerates at 0.70 m/s². What is the coefficient of kinetic friction? 0.82, 0.74

40. (I) (*a*) A box sits at rest on a rough 30° inclined plane. Draw the free-body diagram, showing all the forces acting on the box. (*b*) How would the diagram change if the box were sliding down the plane? (*c*) How would it change if the box were sliding up the plane after an initial shove? See my Diagram

41. (I) A 2.0-kg silverware drawer becomes stuck, so the owner gradually pulls with more and more force. When the applied force reaches 8.0 N, the drawer suddenly opens, throwing all the utensils to the floor. Find the coefficient of static friction between the drawer and the cabinet. $\mu = 0.41$

42. (II) Drag race tires in contact with an asphalt surface probably have one of the highest coefficients of static friction in the everyday world. Assuming a constant acceleration and no slipping of tires, estimate the coefficient of static friction for a drag racer that covers the quarter mile in 6.0 s. 2.3

43. (II) For the system of Fig. 4–30 (Example 4–16), how large a mass would body I have to have to prevent any motion from occurring? Assume $\mu_s = 0.30$. 6.7kg

44. (II) A box is given a push so that it slides across the floor. How far will it go, given that the coefficient of kinetic friction is 0.20 and the push imparts an initial speed of 4.0 m/s? 4.1m

45. (II) Two crates, of mass 75 kg and 110 kg, are in contact and at rest on a horizontal surface (Fig. 4–47). A 730-N force is exerted on the 75-kg crate. If the coefficient of kinetic friction is 0.15, calculate (*a*) the acceleration of the system, and (*b*) the force that each crate exerts on the other. 2.5m/s², 4.4x10²N

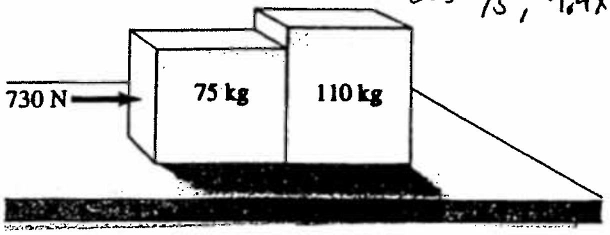


FIGURE 4–47 Problem 45.

46. (II) (*a*) Show that the minimum stopping distance for an automobile traveling at speed v is equal to $v^2/2\mu_s g$, where μ_s is the coefficient of static friction between the tires and the road, and g is the acceleration of gravity. (*b*) What is this distance for a 1200-kg car traveling 95 km/h if $\mu_s = 0.75$? (*c*) What would it be if the car were on the Moon but all else stayed the same? 47m 280m

47. (II) A flatbed truck is carrying a heavy crate. The co efficient of static friction between the crate and th bed of the truck is 0.75. What is the maximum rate a which the driver can decelerate and still avoid hav ing the crate slide against the cab? -7.4m/s²

48. (II) On an icy day, you worry about parking your car i your driveway, which has an incline of 12°. Your neigh bor Ralph's driveway has an incline of 9.0°, and Bon nie's driveway across the street has one of 6.0°. Th coefficient of static friction between tire rubber and ic is 0.15. Which driveway(s) will be safe to park in? Donnie's

49. (II) A child slides down a slide with a 28° incline, and at the bottom her speed is precisely half what it would have been if the slide had been frictionless. Calculate the coefficient of kinetic friction between the slide and the child. $\mu = 0.40$

50. (II) A coffee cup on the dashboard of a car slides forward on the dash when the driver decelerates from 40 km/h to rest in 3.5 s or less, but not if he decelerates in a longer time. What is the coefficient of static friction between the cup and the dash? 0.32

51. (II) A wet bar of soap (mass = 150 grams) slides without friction down a ramp 2.0 m long inclined at 7.3°. How long does it take to reach the bottom? Neglect friction. How would this change if the soap's mass were 250 grams? 1.85

52. (II) The block shown in Fig. 4–48 lies on a smooth plane tilted at an angle $\theta = 22.0°$ to the horizontal. (*a*) Determine the acceleration of the block as it slides down the plane. (*b*) If the block starts from rest 9.10 m up the plane from its base, what will be the block's speed when it reaches the bottom of the incline? Ignore friction. 3.67 m/s² 8.17 m/s

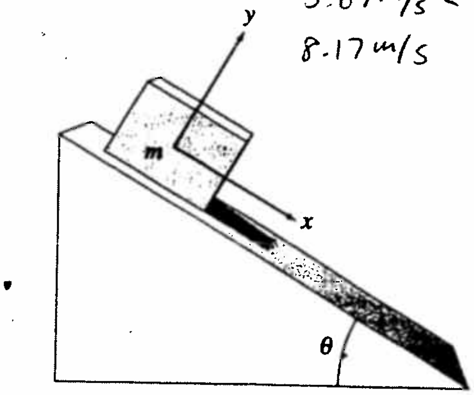


FIGURE 4–48 Block on inclined plane. Problems 52, 53, and 54.

53. (II) A block is given an initial speed of 3.0 m/s up the 22.0° plane shown in Fig. 4–48. (*a*) How far up the plane will it go? (*b*) How much time elapses before it returns to its starting point? Ignore friction. 1.2m UP t = 1.65

54. (II) Repeat (*a*) Problem 52 and (*b*) Problem 53, assuming $\mu_k = 0.20$ between the block and plane.

56. (II) An 18.0-kg box is released on a 37.0° incline and accelerates down the incline at 0.270 m/s². Find the friction force impeding its motion. How large is the coefficient of friction?

Section 4.8 The Normal Force, Section 4.9 Static and Kinetic Frictional Forces

6. A 95.0-kg person stands on a scale in an elevator. What is he apparent weight when the elevator is (a) accelerating upward vith an acceleration of 1.80 m/s^2, (b) moving upward at a contant speed, and (c) accelerating downward with an acceleration of 1.30 m/s^2?

7. **ssm** A rocket blasts off from rest and attains a speed of 5 m/s in 15 s. An astronaut has a mass of 57 kg. What is the stronaut's apparent weight during takeoff?

8. A 55-kg person crouches on a scale and jumps straight up. s the person springs up, the reading on the scale suddenly rises o 622 N. What is the acceleration of the person at this instant?

9. A person exerts a horizontal force of 267 N in attempting to ush a freezer across a room, but the freezer does not move. What s the static frictional force that the floor exerts on the freezer?

0. A block whose weight is 45.0 N rests on a horizontal table. horizontal force of 36.0 N is applied to the block. The coefficients of static and kinetic friction are 0.650 and 0.420, respecively. Will the block move under the influence of the force, and, if o, what will be the block's acceleration? Explain your reasoning.

1. **ssm** A 60.0-kg crate rests on a level floor at a shipping ock. The coefficients of static and kinetic friction are 0.760 and .410, respectively. What horizontal pushing force is required to a) just start the crate moving and (b) slide the crate across the ock at a constant speed?

2. A cup of coffee is sitting on a table in an airplane that is fly- at a constant altitude and a constant velocity. The coefficient tatic friction between the cup and the table is 0.30. Suddenly, lane accelerates, its altitude remaining constant. What is the ximum acceleration that the plane can have without the cup ding backward on the table?

. A 92-kg baseball player slides into second base. The coeffint of kinetic friction between the player and the ground is μ_k = 51. (a) What is the magnitude of the frictional force? (b) If the ayer comes to rest after 1.2 s, what is his initial speed?

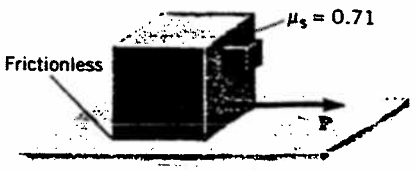
. A 6.00-kg box is sliding across the horizontal floor of an eletor. The coefficient of kinetic friction between the box and the or is 0.360. Determine the kinetic frictional force that acts on e box when the elevator is (a) stationary, (b) accelerating upard with an acceleration whose magnitude is 1.20 m/s^2, and) accelerating downward with an acceleration whose magnitude 1.20 m/s^2.

36) 1.10×10^3N, 931N, 808N
37) 7.3×10^2N
38) 1.5 m/s^2
39) 267N
40) 3.72 m/s^2
41) 447N, 241N
42) 2.9 m/s^2
43) 550N, 7.2 m/s

*45. **ssm** A skater with an initial speed of 7.60 m/s is gliding across the ice. Air resistance is negligible. (a) The coefficient of kinetic friction between the ice and the skate blades is 0.100. Find the deceleration caused by kinetic friction. (b) How far will the skater travel before coming to rest?

*46. During a shuffleboard game (played on a horizontal surface) a disk is given an initial speed of 6.80 m/s. The coefficient of kinetic friction between the disk and surface is 0.290. How much time passes before the disk comes to rest?

*47. The drawing shows a large cube (mass = 25 kg) being accelerated across a horizontal frictionless surface by a horizontal force **P**. A small cube (mass = 4.0 kg) is in contact with the front surface of the large cube and will slide downward unless **P** is sufficiently large. The coefficient of static friction between the cubes is 0.71. What is the smallest magnitude that **P** can have in order to keep the small cube from sliding downward?



**48. While moving in, a new homeowner is pushing a box across the floor at a constant velocity. The coefficient of kinetic friction between the box and the floor is 0.41. The pushing force is directed downward at an angle θ below the horizontal. When θ is greater than a certain value, it is not possible to move the box, no matter how large the pushing force is. Find that value of θ.

44) 21.2N, 23.8N, 18.6N
45) 0.980 m/s^2, opposite
29.5m
46) 2.39s
47) 400N
48) 68°

Section 4.11 Equilibrium Applications of Newton's Laws of Motion

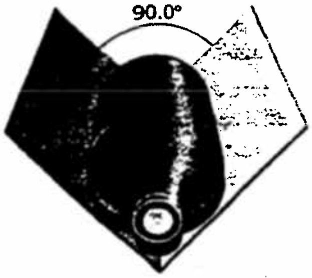
49. **ssm** A 12.0-kg lantern is suspended from the ceiling by two vertical wires. What is the tension in each wire?

50. A supertanker (mass = 1.70×10^8 kg) is moving with a constant velocity. Its engines generate a forward thrust of 7.40×10^5 N. Determine (a) the magnitude of the resistive force exerted on the tanker by the water and (b) the magnitude of the upward buoyant force exerted on the tanker by the water.

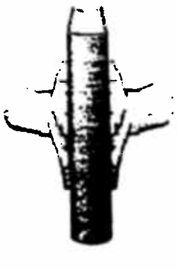
51. As preparation for this problem, review Example 14. Suppose that the pilot suddenly jettisons 2800 N of fuel. If the plane is to continue moving with the same velocity under the influence of the same air resistance **R**, by how much does the pilot have to reduce (a) the thrust and (b) the lift?

52. A wire is stretched between the tops of two identical buildings. When a tightrope walker is at the middle of the wire, the tension in the wire is 2220 N. Each half of the wire makes an angle of 8.00° with respect to the horizontal. Find the weight of the performer.

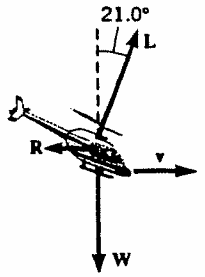
53. **ssm** A 1.40-kg bottle of vintage wine is lying horizontally in the rack shown in the drawing. The two surfaces on which the bottle rests are 90.0° apart, and the right surface makes an angle of 45.0° with respect to the ground. Each surface exerts a force on the bottle that is perpendicular to the surface. What is the magnitude of each of these forces?



54. A student presses a book between his hands, as the drawing indicates. The forces that he exerts on the front and back covers of the book are perpendicular to the book and are horizontal. The book weighs 31 N. The coefficient of static friction between his hands and the book is 0.40. To keep the book from falling, what is the magnitude of the minimum pressing force that each hand must exert?



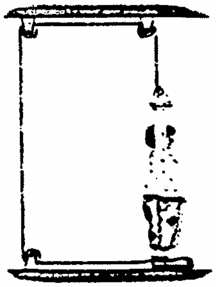
55. The helicopter in the drawing is moving horizontally to the right at a constant velocity. The weight of the helicopter is $W = 53\,800$ N. The lift force **L** generated by the rotating blade makes an angle of 21.0° with respect to the vertical. (a) What is the magnitude of the lift force? (b) Determine the magnitude of the air resistance **R** that opposes the motion.



56. A Mercedes-Benz 300SL ($m = 1700$ kg) is parked on a road that rises 15° above the horizontal. What is the magnitude of the static frictional force exerted on the tires by the road?

57. **ssm** A 20.0-kg sled is being pulled across a horizontal surface at a constant velocity. The pulling force has a magnitude of 80.0 N and is directed at an angle of 30.0° above the horizontal. Determine the coefficient of kinetic friction.

58. The drawing shows a circus clown who weighs 890 N. The coefficient of static friction between the clown's feet and the ground is 0.53. He pulls vertically downward on a rope that passes around three pulleys and is tied around his feet. What is the minimum pulling force that the clown must exert to yank his feet out from under himself?

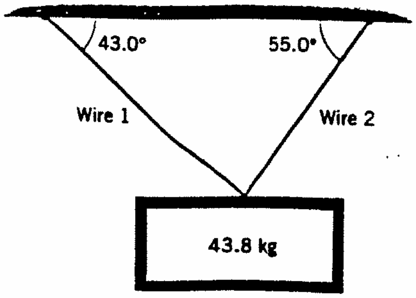


59. A bicyclist coasts at a constant velocity along a road that slopes downward at an angle of 20.0° with respect to the horizontal. The combined mass of the bicycle and rider is 75.0 kg. Find the magnitude of the resistive force that opposes the motion.

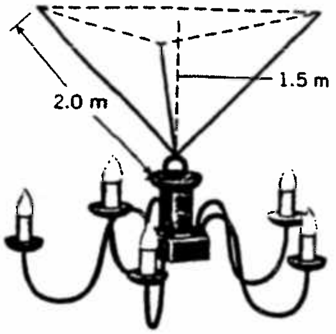
49) 58.8N
50) 7.4×10^5N
1.67×10^9N
51) 1400N, 2400N
52) 618N
53) 9.70N
54) 39N
55) 57,600N
20,600N
56) 4300N

57) 0.444
58) 310N
59) 251N

60. A 43.8-kg sign is suspended by two wires, as the drawing shows. Find the tension in wire 1 and in wire 2.



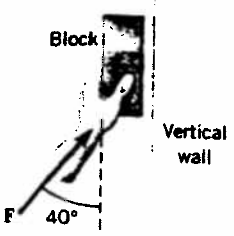
61. **ssm** A 44-kg chandelier is suspended 1.5 m below a ceiling by three wires, each of which has the same tension and the same length of 2.0 m (see the drawing). Find the tension in any wire.



***62.** A skier is pulled up a slope at a constant velocity by a tow bar. The slope is inclined at 25.0° with respect to the horizontal. The force applied to the skier by the tow bar is parallel to the slope. The skier's mass is 55.0 kg, and the coefficient of kinetic friction between the skis and the snow is 0.120. Find the magnitude of the force that the tow bar exerts on the skier.

***63.** A 0.600-kg kite is being flown at the end of a string. The string is straight and makes an angle of 55.0° above the horizontal. The kite is stationary and the tension in the string is 35.0 N. Determine the force (both magnitude and direction) that the wind exerts on the kite. Specify the angle relative to the horizontal.

****64.** The weight of the block in the drawing is 88.9 N. The coefficient of static friction between the block and the vertical wall is 0.560. What minimum force **F** is required to (a) prevent the block from sliding down the wall *(Hint: The static frictional force exerted on the block is directed upward, parallel to the wall.)* and (b) start the block moving up the wall? *(Hint: The static frictional force is now directed down the wall.)*



****65.** **ssm** A bicyclist is coasting straight down a hill at a constant speed. The mass of the rider and bicycle is 80.0 kg, and the hill is inclined at 15.0° with respect to the horizontal. Air resistance opposes the motion of the cyclist. Later, the bicyclist climbs the same hill at the same constant speed. How much force (directed parallel to the hill) must be applied to the bicycle in order for the bicyclist to climb the hill?

****66.** A damp washcloth is hung over the edge of a table to dry. Thus, part (mass = m_{on}) of the washcloth rests on the table and part (mass = m_{off}) does not. The coefficient of static friction between the table and the washcloth is 0.40. Determine the maximum fraction $[m_{off}/(m_{on} + m_{off})]$ that can hang over the edge without causing the whole washcloth to slide off the table.

60) 317N, 249N
61) 1.9×10^2 N
62) 286N
63) 40.0N, 59.8°
64) 78.0N, 219N
65) 406 N
66) 0.29

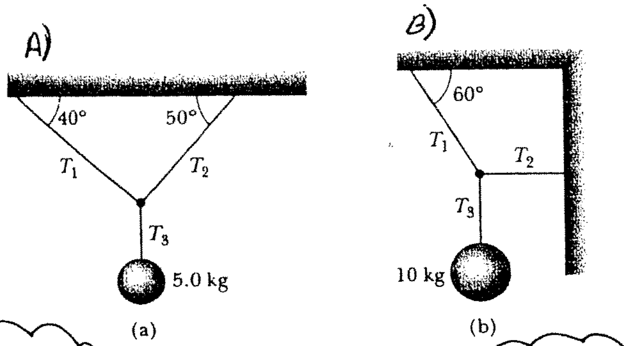
67-79 next page

67) 64°N of E, 220N
68) 100N, 38N
69) 1730N west
70) 612 N
71) 45N, 37N
72) 2.99 m/s², 129N
73) 6.6 m/s
74) 160 N
75) 610N, 2640N
76) 1.30 m/s²
77) 1.3N, 6.5N
78) 29,400N
79) 4.5 m/s², 1200N

Review - Practice

Free response: Show ALL WORK for full credit.

1. Find the tension in each cord for the systems shown in Figure P5.26. (Neglect the mass of the cords.)



(a) (b)

FIGURE P5.26

$T_1 = 31.6N$
$T_2 = 37.6N$

$T_1 = 113N$
$T_2 = 56.6N$

2. A car is traveling at 50.0 mi/h on a horizontal highway. (a) If the coefficient of friction between road and tires on a rainy day is 0.10, what is the minimum distance in which the car will stop? (b) What is the stopping distance when the surface is dry and μ = 0.60?

(MAKE A FREE BODY DIAGRAM FOR FULL CREDIT)

256M, 42.7M

1mi = 1.61km

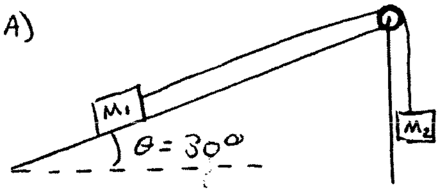
3. A 3.0-kg block starts from rest at the top of a 30.0° incline and slides 2.0 m down the incline in 1.5 s. Find (a) the magnitude of the acceleration of the block, (b) the coefficient of kinetic friction between block and plane, (c) the frictional force acting on the block, and (d) the speed of the block after it has slid 2.0 m.

(MAKE A FREE BODY DIAGRAM FOR FULL CREDIT)

1.78 m/s², 0.368, 9.37N, 2.67m/s

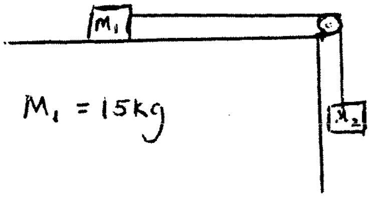
4. For the following Atwood's machines calculate the acceleration and tension in the string. Assume no friction. MAKE A FBD FOR PARTS A+B.

A)



$m_1 = 15kg$

$m_2 = 30kg$



$M_1 = 15kg$

$M_2 = 30kg$

4.9m/s², 147N

6.53 m/s², 98N

Applications of Newton's Laws.

* Equilibrium

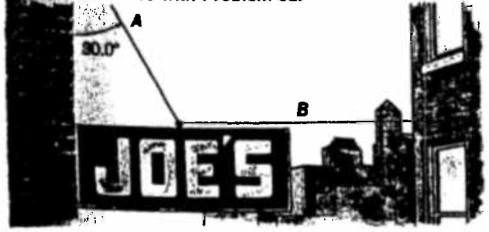
㉙ An object in equilibrium has three forces exerted on it. A 33-N force acts at 90°, and a 44-N force acts at 60°. What is the magnitude and direction of the third force?

㉚ Five forces act on an object: the first, 60 N at 90°; the second, 40 N at 0°; the third, 80 N at 270°; the fourth, 40 N at 180°; and the fifth, 50 N at 60°. What is the magnitude and direction of a sixth force that produces equilibrium of the object?

㉛ A street lamp weighs 150 N. It is supported equally by two wires that form an angle of 120° with each other.
- **a.** What is the tension of each of these wires?
- **b.** If the angle between the wires is reduced to 90.0°, what new force does each wire exert?
- **c.** As the angle between the wires decrease, what happens to the force in the wire?

Joe wishes to hang a sign weighing 750 N so that cable A attached to the store makes a 30.0° angle as shown in Figure 6–28. Cable B is attached to an adjoining building. Calculate the necessary tension in cable B.

URE 6–28. Use with Problem 32.



▶㉝ Rachel pulls her 18-kg suitcase at a constant speed by pulling on a handle that makes an angle θ with the horizontal. The frictional force on the suitcase is 27 N and Rachel exerts a 43-N force on the handle.
- **a.** What angle does the handle make with the horizontal?
- **b.** What is the normal force exerted on the suitcase?

34. You place a box weighing 215 N on an inclined plane that makes a 35.0° angle with the horizontal. Compute the component of the gravitational force acting down the inclined plane.

▶ **35.** You slide a 325-N trunk up a 20.0° inclined plane with a constant velocity by exerting a force of 211 N parallel to the inclined plane.
- **a.** What is the component of the trunk's weight parallel to the plane?
- **b.** What is the sum of your applied force, friction, and the parallel component of the trunk's weight? Why?
- **c.** What is the size and direction of the friction force?
- **d.** What is the coefficient of friction?

▶ **36.** What force would you have to exert on the trunk in Problem 35 so that it would slide down the plane with a constant velocity? What would be the direction of the force?

▶ **37.** A 2.5-kg block slides down a 25° inclined plane with constant acceleration. The block starts from rest at the top. At the bottom, its velocity reaches 0.65 m/s. The length of the incline is 1.6 m.
- **a.** What is the acceleration of the block?
- **b.** What is the coefficient of friction between the plane and block?
- **c.** Does the result of either **a** or **b** depend on the mass of the block?

TRY TO ANSWER Before looking At the Solution!

THINKING PHYSIC-LY

Weight lifting or "pumping iron" has become very popular in the last few years. When lifting a barbell, which grip will exert less force on the lifter's arms: one in which the arms are extended straight upward from the body so they are at right angles to the bars, or one in which the arms are spread so that the bar is gripped closer to the weights? Explain.

29. 74 N, 253°

30. 34 N, 223°

31. **a.** $T_1 = T_2 = 150$ N; **b.** $T_1 = T_2 = 106$ N; **c.** decreases toward 75 N
Refer to Problems and Solutions Manual for diagram.

32. 433 N, right
Refer to Problems and Solutions Manual for diagram.

33. **a.** 51°; **b.** 1.4×10^2 N, up
Refer to Problems and Solutions Manual for diagram.

34. 123 N
Refer to Problems and Solutions Manual for diagram.

35. **a.** 111 N; **b.** zero, constant velocity; **c.** 100 N, down plane; **d.** 0.327

36. 11 N, up plane

37. **a.** 0.13 m/s^2; **b.** 0.452; **c.** no

Answer To
THINKING PHYSIC-LY

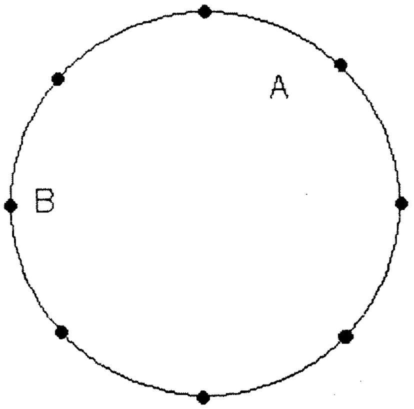
Only the force perpendicular to the barbell contributes to lifting it. A grip in which the arms are extended straight forward from the body, so that all the force exerted is perpendicular to the bar, will exert less force on the weightlifter's arms. Spreading the arms so that the bar is gripped closer to weights reduces the component of force perpendicular to the bar. The lifter must exert more total force for the perpendicular component to equal the force exerted when the arms are perpendicular to the bar.

Circular Motion

Name ____ *Per.* ___ *date* ____

Uniform circular motion *DiBucci*

Consider the diagram below



An object is moving in uniform circular motion in a horizontal circle
The mass of the object is 10 kg.
The angular speed is 70 rev/min (RPM)

A) sketch the velocity and acceleration vector for each point
B) Calculate the angular speed in rad/sec
C) Calculate the linear speed (magnitude of the tangential velocity) in m/s ($r = 20m$)
D) If the centripetal force suddenly went to zero at point A, sketch the path the object would take.
E) Calculate the centripetal acceleration in m/s/s
F) Calculate the Centripetal force in Newtons
G) Sketch the centripetal force vector at points A and B

Show your work here:

Name______________________________ Per __ date ________
DiBucci

Uniform circular motion

Equations: $a_c = \frac{v^2}{r}$ $F_c = \frac{mv^2}{r}$ $v = \frac{2\pi r}{T}$ $F_F = \mu F_N$ $\tan\theta = \frac{v^2}{gr}$

Directions: Complete the following problems in detail. Show all work for full credit.
(make Free BODY DiAgrams)

1. What is the maximum speed with which a 1050-kg car can round a turn of radius 70 m on a flat road if the coefficient of friction between tires and road is 0.80? Is this result independent of the mass of the car? (23.4m/s)

2. A device for training astronauts and jet fighter pilots is designed to rotate the trainee in a horizontal circle of radius 10.0 m. If the force felt by the trainee is 7.75 times her own weight, how fast is she rotating? Express your answer in both m/s and rev/s.
(27m/s, 0.4299 rev/s)

3. A coin is placed 11.0 cm from the axis of a rotating turntable of variable speed. When the speed of the turntable is slowly increased, the coin remains fixed on the turntable until a rate of 36 rpm is reached, at which point the coin slides off. What is the coefficient of static friction between the coin and the turntable? (0.159)

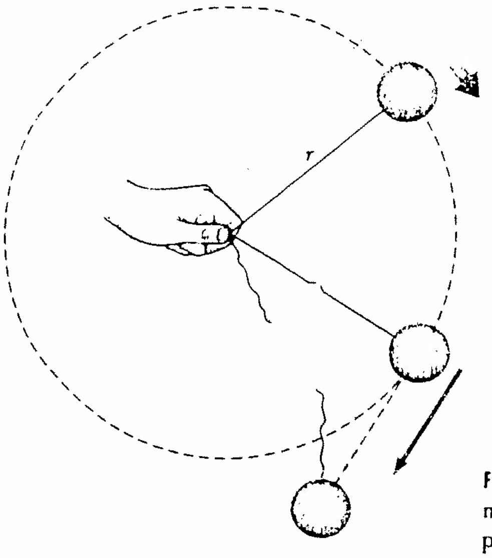


FIGURE 6.2 When the string breaks, the ball moves in the direction tangent to the circular path.

How Fast Can It Spin?

A ball of mass 0.500 kg is attached to the end of a cord whose length is 1.50 m. The ball is whirled in a horizontal circle as in Figure 6.2. If the cord can withstand a maximum tension of 50.0 N, what is the maximum speed the ball can have before the cord breaks? (12.2 m/s)

What Is the Maximum Speed of the Car?

A 1500-kg car moving on a flat, horizontal road negotiates a curve whose radius is 35.0 m as in Figure 6.4. If the coefficient of static friction between the tires and the dry pavement is 0.500, find the maximum speed the car can have in order to make the turn successfully. (13.1 m/s)

The Conical Pendulum

A small body of mass m is suspended from a string of length L. The body revolves in a horizontal circle of radius r with constant speed v, as in Figure 6.3. (Since the string sweeps out the surface of a cone, the system is known as a *conical pendulum.*) Find the speed of the body and the period of revolution, T_p, defined as the time needed to complete one revolution.

$$V = \sqrt{Lg\sin\theta \, TAN\theta}$$

$$T = 2\pi\sqrt{\frac{L\cos\theta}{g}}$$

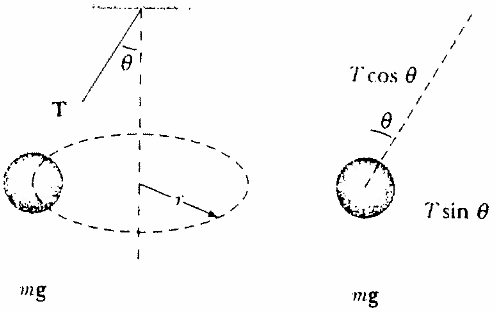
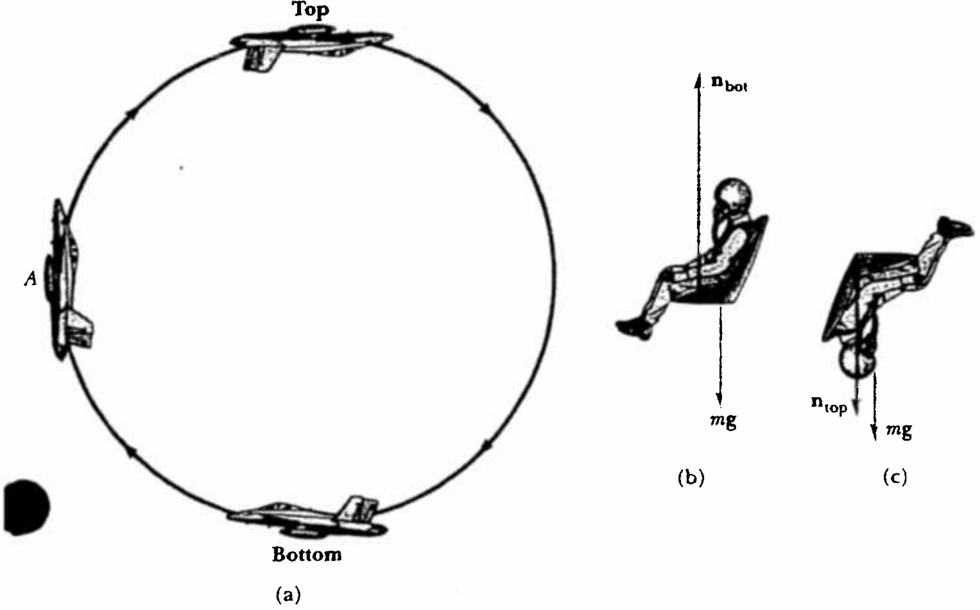


FIGURE 6.3 (Example 6.2) The conical pendulum and its free-body diagram.

Let's Go Loop-the-Loop

A pilot of mass m in a jet aircraft executes a "loop-the-loop" maneuver as illustrated in Figure 6.7a. In this flying pattern, the aircraft moves in a vertical circle of radius 2.70 km at a *constant speed* of 225 m/s. Determine the force exerted by the seat on the pilot at (a) the bottom of the loop and (b) the top of the loop. Express the answers in terms of the weight of the pilot, mg.

2.91 mg, 0.911 mg



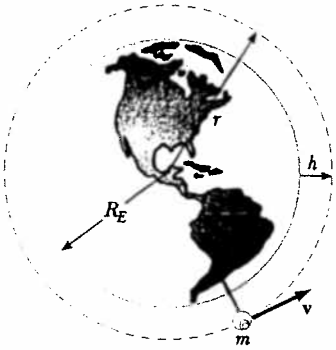
Satellite Motion

This example treats the problem of a satellite moving in a circular orbit around the Earth. In order to understand this problem, we must first note that the gravitational force between two particles having masses m_1 and m_2, separated by a distance r, is attractive and has a magnitude

$$F = G\frac{m_1 m_2}{r^2}$$

where $G = 6.672 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$. This is Newton's law of gravity, which we shall discuss in detail in Chapter 14.

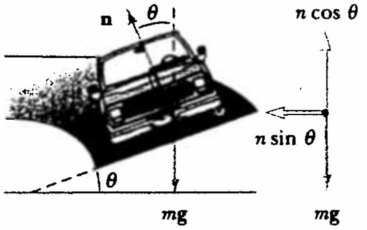
Now consider a satellite of mass m moving in a circular orbit around the Earth at a constant speed v and at an altitude h above the Earth's surface as in Figure 6.6. (a) Determine the speed of the satellite in terms of G, h, R_E (the radius of the Earth), and M_E (the mass of the Earth).



$$V = \sqrt{\frac{GM_E}{R_E + h}}, \quad T_p = \left(\frac{2\pi}{\sqrt{GM_E}}\right) r^{3/2}$$

The Banked Exit Ramp

An engineer wishes to design a curved exit ramp for a toll road in such a way that a car will not have to rely on friction to round the curve without skidding. Suppose that a typical car rounds the curve with a speed of 30.0 mi/h (13.4 m/s) and that the radius of the curve is 50.0 m. At what angle should the curve be banked? 20.1°



PRACTICE PROBLEMS

1. A grinding wheel (radius 7.6 cm) is rotating at 1750 rpm.
   a. What is the speed of a point on the outer edge of the wheel?

   14 m/s

   b. What is the centripetal acceleration of the point?

   2.6×10^3 m/s^2

2. An airplane is flying in a horizontal circle of radius 1.5 km with a speed of 450 km/h. What is the magnitude of the centripetal acceleration of the plane?

   10 m/s^2

3. An airplane is flying in a horizontal circle of radius 1.0 km. What must be the speed of the plane if the pilot is to experience a centripetal acceleration three times that of gravity?

   620 km/hr

4. If the pilot in problem 3 has a mass of 75 kg, what centripetal force acts on him?

   2200N

5. A trick motorcyclist moves in a horizontal circle inside a large vertical drum which has a radius of 10.0 m. If the coefficient of static friction between the tires and the drum is 0.60, what is the smallest possible speed that the motorcycle and rider can have?

13 m/s

6. A car can barely negotiate a 50.0 m unbanked curve when the coefficient of static friction between the tires and road is 0.80. How much bank would the curve require if the car is to safely go around the curve without relying on friction?

39°

7. A satellite is placed in a circular polar orbit. What must be the height above the surface of the earth of its orbit if it is to pass over the same point on the equator twice per day?

3.59×10^7 m = 22,300 mi

8. A spacecraft orbits Mars (mass = 6.40×10^{23} kg) in a circular orbit of radius 8.01×10^5 km. What is the period of the spacecraft?

6.06×10^3 h

9. How many revolutions per minute must a rotating space station (r = 1200 m) turn to provide an artificial gravity of 0.50 g?

0.61 rev/min

10. An airplane pulls out of a dive in a vertical circle of radius 1.0 km traveling with a speed of 550 km/h. How many times greater is the apparent weight of the pilot than his true weight?

3.4

11. The moon of a planet is observed to have a nearly circular orbit, r = 4.00 X 10^5 km, and an orbital period of 21.5 days. What is the mass of the planet?

1.1 X10^{25} Kg

12. A 1.5 kg toy motorcycle is moving on the inside of a vertical circular track (r = 1.0 m). It arrives at the top of the track with a speed of 5.0 m/s. What force does the track exert on the motorcycle?

23 N

Section 5.1 Uniform Circular Motion, Section 5.2 Centripetal Acceleration

1. **ssm** How long does it take a plane, traveling at a speed of 110 m/s, to fly once around a circle whose radius is 2850 m?

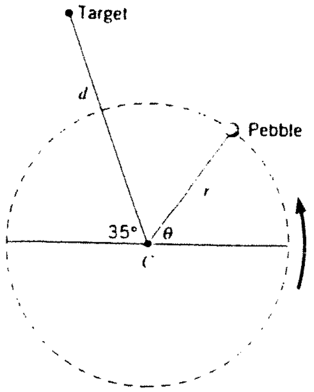
2. The tips of the blades in a food blender are moving with a speed of 21 m/s in a circle that has a radius of 0.053 m. How much time does it take for the blades to make one revolution?

3. A horse races once around a circular track in a time of 118 s, with a speed of 17 m/s. What is the radius of the track?

4. Review Conceptual Example 2 in preparation for this problem. In Figure 5.4, an object, after being released from its circular path, travels the distance *OA* in the same time it would have moved from *O* to *P* on the circle. The speed of the object on and off the circle remains constant at the same value. Suppose that the radius of the circle in Figure 5.4 is 3.6 m and the angle θ is 25°. What is the distance *OA*?

5. **ssm** Computer-controlled display screens provide drivers in the Indianapolis 500 with a variety of information about how their cars are performing. For instance, as a car is going through a turn, a speed of 221 mi/h (98.8 m/s) and a centripetal acceleration of 3.00 *g* (three times the acceleration due to gravity) are displayed. Determine the radius of the turn (in meters).

6. Review Conceptual Example 2 as background for this problem. One kind of slingshot consists of a pocket that holds a pebble and is whirled on a circle of radius *r*. The pebble is released from the circle at the angle θ, so that it will hit the target. The distance to the target from the center of the circle is *d*. (See the drawing, which is not to scale.) The circular path is parallel to the ground, and the target lies in the plane of the circle. The distance *d* is ten times the radius *r*. Ignore the effect of gravity in pulling the stone downward after it is released, and find the angle θ.



7. The blade of a windshield wiper moves through an angle of 90.0° in 0.28 s. The tip of the blade moves on the arc of a circle that has a radius of 0.76 m. What is the magnitude of the centripetal acceleration of the tip of the blade?

*8. The earth rotates once per day about an axis passing through the north and south poles, an axis that is perpendicular to the plane of the equator. Assuming the earth is a sphere with a radius of 6.38 × 10^6 m, determine the speed and centripetal acceleration of a person situated (a) at the equator and (b) at a latitude of 30.0° north of the equator.

*9. **ssm** The large blade of a helicopter is rotating in a horizont circle. The length of the blade is 6.7 m, measured from its tip t the center of the circle. Find the ratio of the centripetal accelera tion at the end of the blade to that which exists at a point locate 3.0 m from the center of the circle.

*10. A centrifuge is a device in which a small container c material is rotated at a high speed on a circular path. Such a de vice is used in medical laboratories, for instance, to cause th more dense red blood cells to settle through the less dense blood serum and collect at the bottom of the container. Suppose the centripetal acceleration of the sample is 6.25 × 10^3 times larger than the acceleration due to gravity. How many revolutions per minute is the sample making, if it is located at a radius of 5.00 cm from the axis of rotation?

1) 160s
2) 0.016s
3) 320m
4) 1.6m
5) 332m
6) 61°
7) $24 m/s^2$
8) 464m/s, $3.37x10^{-2} m/s^2$, 232m/s
$1.69x10^{-2} m/s^2$

9) 2.2
10) 10,600 rev/min

Section 5.3 Centripetal Force

11. A 125-kg crate rests on the flatbed of a truck that moves at a speed of 15.0 m/s around an unbanked curve whose radius is 66.0 m. The crate does not slip relative to the truck. Obtain the magnitude of the static frictional force that the truck bed exerts on the crate.

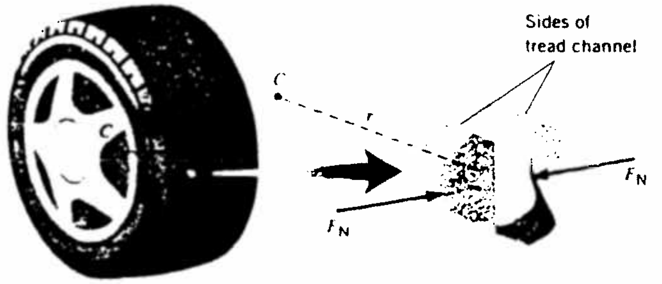
12. A car is safely negotiating an unbanked circular turn at a speed of 21 m/s. The maximum static frictional force acts on the tires. Suddenly a wet patch in the road reduces the maximum static frictional force by a factor of three. If the car is to continue safely around the curve, to what speed must the driver slow the car?

13. **ssm** Review Example 3, which deals with the bobsled in Figure 5.5. Also review Conceptual Example 4. The mass of the sled and its two riders in Figure 5.5 is 350 kg. Find the magnitude of the centripetal force that acts on the sled during the turn with a radius of (a) 33 m and (b) 24 m.

14. A child is twirling a 0.0120-kg ball on a string in a horizontal circle whose radius is 0.100 m. The ball travels once around the circle in 0.500 s. (a) Determine the centripetal force acting on the ball. (b) If the speed is doubled, does the centripetal force double? If not, by what factor does the centripetal force increase?

15. A model airplane is being flown on a guideline that can sustain at most 180 N of tension. The mass of the plane is 0.75 kg, and its speed is 28 m/s. Assuming that the guideline is nearly parallel to the ground, what is the radius of the smallest horizontal circle in which the plane can be flown?

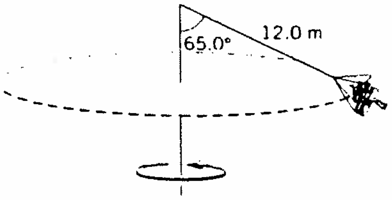
16. A stone has a mass of 6.0×10^{-3} kg and is wedged into the tread of an automobile tire, as the drawing shows. The coefficient of static friction between the stone and each side of the tread channel is 0.90. When the tire surface is rotating at 13 m/s, the stone flies out of the tread. The magnitude F_N of the normal force that each side of the tread channel exerts on the stone is 1.8 N. Assume that only static friction supplies the centripetal force, and determine the radius r of the tire.



***17.** **ssm www** The hammer throw is a track and field event in which a 7.3-kg ball (the "hammer") is whirled around in a circle several times and released. It then moves upward on the familiar curving path of projectile motion and eventually returns to earth, some distance away. The world record for this distance is 86.75 m, achieved in 1986 by Yuriy Sedykh. Ignore air resistance and the fact that the ball is released above the ground rather than at ground level. Furthermore, assume that the ball is whirled on a circle that has a radius of 1.8 m and that its velocity at the instant of release is directed 41° above the horizontal. Find the magnitude of the centripetal force acting on the ball just prior to the moment of release.

***18.** What is the *minimum* coefficient of static friction necessary to allow a penny to rotate along with a $33\frac{1}{3}$-rpm record (diameter = 0.300 m), when the penny is placed at the outer edge of the record?

***19.** A "swing" ride at a carnival consists of chairs that are swung in a circle by 12.0-m cables attached to a vertical rotating pole, as the drawing shows. Suppose the total mass of a chair and its occupant is 220 kg. (a) Determine the tension in the cable attached to the chair. (b) Find the speed of the chair.



****20.** A rigid massless rod is rotated about one end in a horizontal circle. There is a mass m_1 attached to the center of the rod and a mass m_2 attached to the outer end of the rod. The inner section of the rod sustains three times as much tension as the outer section. Find the ratio m_2/m_1.

11) 426 N

12) 12 m/s

13) 1.2×10^4 N, 1.7×10^4 N

14) 0.189 N, , Factor g 4

15) 3.3 m

16) 0.31 m

17) 3500 N

18) 0.186 m

19) 5.1×10^3 N, 15 m/s

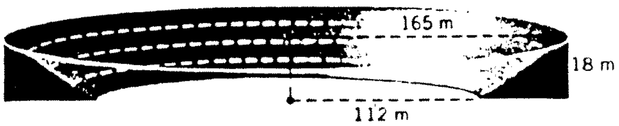
20) 1/4

Section 5.4 Banked Curves

21. **ssm** A curve of radius 120 m is banked at an angle of 18°. At what speed can it be negotiated under icy conditions where friction is negligible?

22. At what angle should a curve of radius 150 m be banked, so cars can travel safely at 25 m/s without relying on friction?

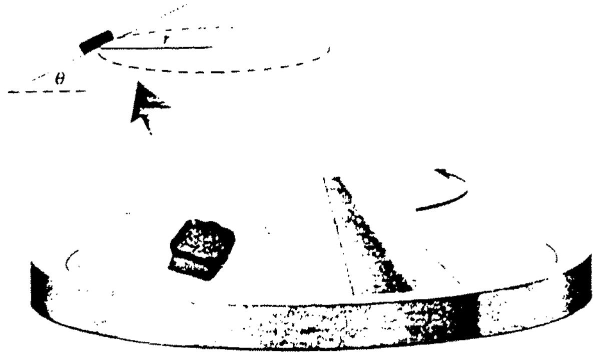
23. On a banked race track, the smallest circular path on which cars can move has a radius of 112 m, while the largest has a radius of 165 m, as the drawing illustrates. The height of the outer wall is 18 m. Find (a) the smallest and (b) the largest speed at which cars can move on this track without relying on friction.



*24. There is a similarity between a plane banking into a turn and a car going around a banked curve. The lifting force **L** in Figure 5.10 plays the same role as the normal force $\mathbf{F}_N$ in Figure 5.11. (a) Derive an expression that relates the banking angle to the speed of the plane, the radius of the turn, and the acceleration due to gravity. (b) At what angle with respect to the horizontal should a plane be banked when traveling at 195 m/s around a turn whose radius is 8250 m?

*25. **ssm www** Refer to problem 24 before attempting to solve this problem. A jet ($m = 2.00 \times 10^5$ kg), flying at 123 m/s, banks to make a horizontal circular turn. The radius of the turn is 3810 m. Calculate the necessary lifting force.

*26. The drawing shows a baggage carousel at an airport. Your suitcase has not slid all the way down the slope and is going around at a constant speed on a circle (r = 11.0 m) as the carousel turns. The coefficient of static friction between the suitcase and the carousel is 0.760, and the angle θ in the drawing is 36.0°. How much time is required for your suitcase to go around once?



21) 20 m/s

22) $\theta = 23°$

23) 19 m/s, 23 m/s

24) $\text{TAN}\theta = v^2/rg$, 25.2°

25) 2.12×10^6 N

26) 45s

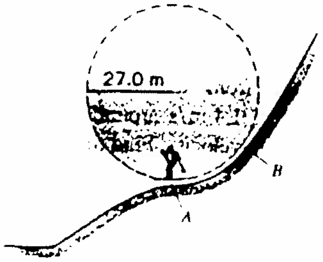
Section 5.7 Vertical Circular Motion

37. **ssm** The condition of apparent weightlessness for the passengers can be created for a brief instant when a plane flies over the top of a vertical circle. At a speed of 215 m/s, what is the radius of the vertical circle that the pilot must use?

38. A fighter pilot dives his plane toward the ground at 230 m/s. He pulls out of the dive on a vertical circle. What is the minimum radius of the circle, so that the normal force exerted on the pilot by his seat never exceeds three times his weight?

39. The maximum tension that a 0.50-m string can tolerate is 14 N. A 0.25-kg ball attached to this string is being whirled in a vertical circle. What is the maximum speed that the ball can have (a) at the top of the circle and (b) at the bottom of the circle? *(Hint: The tension serves the same purpose as the normal force in Figure 5.21.)*

40. A downhill skier, whose mass is 50.0 kg, attains a speed of 21.0 m/s just as she reaches the point where a jump is necessary (point *A* in the drawing). When she leaves the ground, her velocity is horizontal. In other words, point *A* is at the bottom of the circular arc *AB* (radius = 27.0 m). Determine the normal force acting on the skis at point *A*.

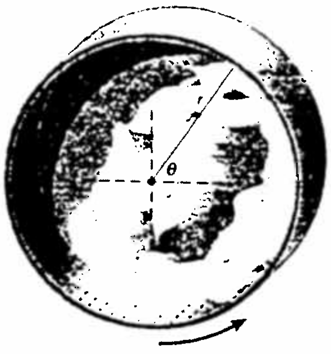


41. **ssm** A 2100-kg demolition ball swings at the end of a 15-m cable on the arc of a vertical circle. At the lowest point of the swing, the ball is moving at a speed of 7.6 m/s. Determine the tension in the cable. *(Hint: The tension serves the same purpose as the normal force at point 1 in Figure 5.21.)*

***42.** A roller-blader is traveling up one side of a hill and down the other side, trying to go fast enough to lose contact with the ground as she goes over the top. The crest is a circular arc with a radius of 20.0 m. Determine the minimum speed that she needs to achieve at the top of the hill.

***43.** A stone is tied to a string (length = 0.950 m) and whirled in a circle at the same constant speed in two different ways. First, the circle is horizontal and the string is nearly parallel to the ground. Next, the circle is vertical. In the vertical case the maximum tension in the string is 10.0% larger than the tension that exists when the circle is horizontal. Determine the speed of the stone.

****44.** In an automatic clothes drier, a hollow cylinder moves the clothes on a vertical circle (radius r = 0.32 m), as the drawing shows. The appliance is designed so that the clothes tumble gently as they dry. This means that when a piece of clothing reaches an angle of θ above the horizontal, it loses contact with the wall of the cylinder and falls onto the clothes below. How many revolutions per second should the cylinder make in order that the clothes lose contact with the wall when θ = 70.0°?



37) 4.72×10^3 m

38) 2.7×10^3 m

39) 5.7 m/s , 4.8 m/s

40) 1.31×10^3 N

41) 2.9×10^4 N

42) 14.0 m/s

43) 9.65 m/s

44) 0.85 $\frac{rev}{s}$

Section 5.5 Satellites in Circular Orbits, Section 5.6 Apparent Weightlessness and Artificial Gravity

27. A satellite is placed in orbit 6.00×10^5 m above the surface of Jupiter. Jupiter has a mass of 1.90×10^{27} kg and a radius of 7.14×10^7 m. Find the orbital speed of the satellite.

28. Suppose the surface (radius = r) of the space station in Figure 5.19 is rotating at 35.8 m/s. What must be the value of r for the astronauts to weigh one-half of their earth weight?

29. **ssm www** A satellite is in a circular orbit around an unknown planet. The satellite has a speed of 1.70×10^4 m/s, and the radius of the orbit is 5.25×10^6 m. A second satellite also has a circular orbit around this same planet. The orbit of this second satellite has a radius of 8.60×10^6 m. What is the orbital speed of the second satellite?

30. Venus rotates slowly about its axis, the period being 243 days. The mass of Venus is 4.87×10^{24} kg. Determine the radius for a synchronous satellite in orbit about Venus.

31. The moon orbits the earth at a distance of 3.85×10^8 m. Assume that this distance is between the centers of the earth and the moon and that the mass of the earth is 5.98×10^{24} kg. Find the period for the moon's motion around the earth. Express the answer in days and compare it to the length of a month.

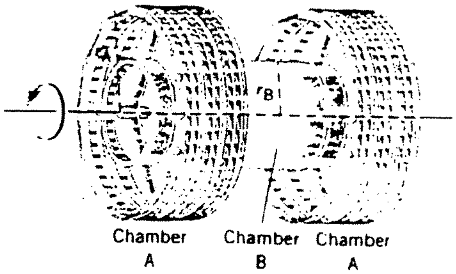
32. The earth travels around the sun once a year in an approximately circular orbit whose radius is 1.50×10^{11} m. From these data determine (a) the orbital speed of the earth and (b) the mass of the sun.

33. **ssm** A satellite has a mass of 5850 kg and is in a circular orbit 4.1×10^5 m above the surface of a planet. The period of the orbit is two hours. The radius of the planet is 4.15×10^6 m. What is the true weight of the satellite when it is at rest on the planet's surface?

•34. The earth orbits the sun once a year at a distance of 1.50×10^{11} m. Venus orbits the sun at a distance of 1.08×10^{11} m. These distances are between the centers of the planets and the sun. How long (in earth days) does it take for Venus to make one orbit around the sun?

•35. Two satellites, A and B, are in different circular orbits about the earth. The orbital speed of satellite A is twice that of satellite B. Find the ratio (T_A/T_B) of the periods of the satellites.

•36. To create artificial gravity, the space station shown in the drawing is rotating at a rate of 1.00 rpm. The radii of the cylindrically shaped chambers have the ratio $r_A/r_B = 4.00$. Each chamber A simulates an acceleration due to gravity of 10.0 m/s^2. Find values for (a) r_A, (b) r_B, and (c) the acceleration due to gravity that is simulated in chamber B.



27) 4.2×10^4 m/s

28) 262 m

29) 1.33×10^4 m/s

30) 1.54×10^9 m

31) 27.5 days

32) 2.99×10^4 m/s
2.01×10^{30} kg

33) 2.45×10^4 N

34) 223 days

35) 0.125

36) 912 m, 228 m, 2.5 m/s^2

A. P. PHYSICS

① A small coin is placed on the outer edge of a record 26 cm in diameter. If the coefficient of static n between the coin and the record is 0.2, what is the maximum period of rotation of the turntable before coin slips off? What is its frequency in rev · min^{-1}?

② A circular track of 120 m radius on a level road is banked for a velocity of 10 m · s^{-1}. What should be the minimum coefficient of friction between the tires and the road for an automobile rounding the curve at 25 m · s^{-1}? CLUE: THE FIRST PART OF THE problem ASSUMES NO FRICTION IS present. YOU CAN DETERMINE θ FROM THIS. IN THE SECOND PART A FRICTION FORCE IS ADDED (POINTING DOWNHILL) THAT ALLOWS FOR THE HIGHER SPEED)

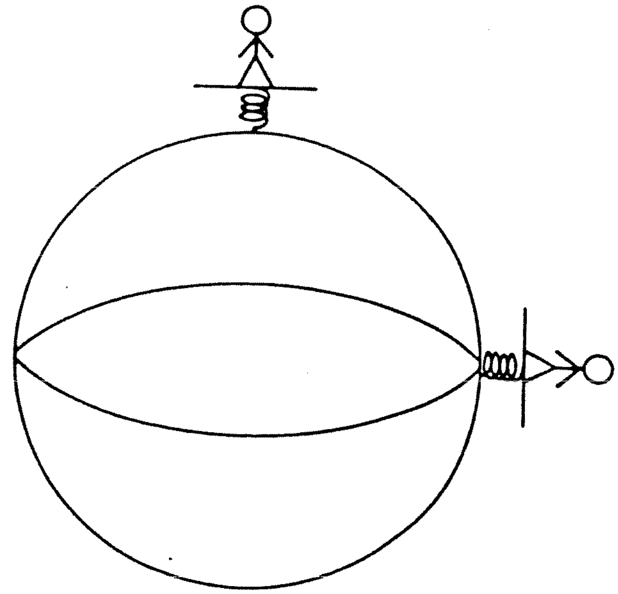
③ A highway curve has a radius of 500 m. At what angle should it be banked so that a car traveling at 90 km · hr^{-1} will not skid?

④

A cord is tied to a bucket of water and the bucket is swung in a vertical circle of radius 0.75 m. Determine the minimum velocity of the bucket if no water is to spill out of it.

⑤

Compare the weight of an 80 kg explorer at the North Pole with her weight at the equator. Assume that the earth is spherical and therefore *g* has the same value everywhere on the earth's surface.



ANSWers.

1) $T = 1.62s$
$f = 37$ RPM

② $\mu_s = .4$[illegible]

③ 7.29°

④ $v = 2.71$ m/s

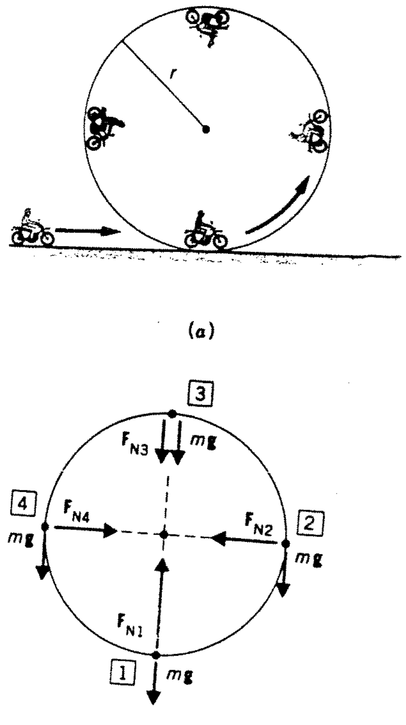
⑤ $W_{\text{North Pole}} = 784N$

$W_{\text{equator}} = 781.3N$

Dibble /
Honors Physics

*5.7 VERTICAL CIRCULAR MOTION

Fig 5-15



Motorcycle stunt drivers often perform a feat in which they drive their cycles around a vertical circular track, as in Figure 5.15*a*. Usually, the speed varies in this stunt, decreasing as the cycle moves upward and increasing as the cycle comes downward. When the speed of travel on a circular path changes from moment to moment, the motion is said to be "nonuniform." Nonetheless, we can use the concepts that apply to uniform circular motion in order to gain considerable insight into the motion that occurs on a vertical circle.

As the speed changes in the motorcycle trick, the magnitude of the centripetal force also changes. There are four points on the circle, however, where the centripetal force can be identified easily, as Figure 5.15*b* indicates. As you look at Figure 5.15*b*, keep in mind that the centripetal force is not a new and separate force of nature. Instead, at each point the centripetal force is the net sum of all the force components oriented along the radial direction and points toward the center of the circle. The drawing shows only the weight of the cycle plus rider (magnitude = mg) and the normal force pushing on the cycle (magnitude = F_N). The propulsion and braking forces are omitted for simplicity and, in any event, do not act in the radial direction. The magnitude of the centripetal force at each of the four points is given below in terms of mg and F_N:

$$(1)\ F_{c1} = \frac{mv_1^2}{r} = F_{N1} - mg$$

$$(2)\ F_{c2} = \frac{mv_2^2}{r} = F_{N2}$$

$$(3)\ F_{c3} = \frac{mv_3^2}{r} = F_{N3} + mg$$

$$(4)\ F_{c4} = \frac{mv_4^2}{r} = F_{N4}$$

As the cycle goes around, the magnitude of the normal force changes. It changes because the speed changes and because the weight does not have the same effect at every point on the circle. At the bottom, the normal force and the weight oppose one another, giving a centripetal force of magnitude $F_{N1} - mg$. At the top, the normal force and the weight reinforce each other to provide a centripetal force whose magnitude is $F_{N3} + mg$. At points 2 and 4 on either side, only F_{N2} and F_{N4} provide the centripetal force. The weight is tangent to the circle at points 2 and 4 and has no component pointing toward the center. If the speed at each of the four points is known, along with the mass and the radius, the normal forces can be determined from the equations above.

PROBLEM SOLVING INSIGHT

The centripetal force is the name given to the net force that points toward the center of a circular path. As shown here, there may be several forces that contribute to this net force.

Riders who perform the loop-the-loop trick know that they must have at least a minimum speed at the top of the circle to remain on the track. This speed can be determined by considering the centripetal force at point 3. The speed v_3 in the equation $mv_3^2/r = F_{N3} + mg$ is a minimum when F_{N3} is zero. Then, the speed is given by $v_3 = \sqrt{rg}$. At this speed, the track does not exert a normal force to keep the cycle on the circle, because the weight mg provides all the centripetal force. For a radius of 9.0 m, for example, this expression predicts a minimum speed of 9.4 m/s (21 mi/h). Under these conditions, the rider experiences an apparent weightlessness like that discussed in Section 5.6, because for an instant the rider and the cycle are falling freely toward the center of the circle.

Net Incom

(*a*) A vertical loop-the-loop motorcycle stunt. (*b*) The normal force $\mathbf{F}_N$ and of the cycle and the rider are shown here at four locations.

AP Physics B DiBucci

Section 4.5 Tangential and Radial Acceleration

$\boxed{35.}$ Figure P4.35 represents, at a given instant, the total acceleration of a particle moving clockwise in a circle of radius 2.50 m. At this instant of time, find (a) the centripetal acceleration, (b) the speed of the particle, and (c) its tangential acceleration.

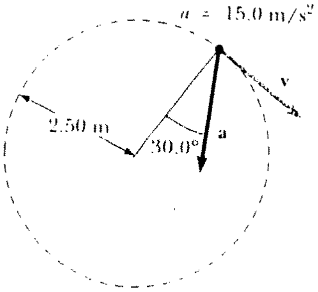


FIGURE P4.35

36. A point on a rotating turntable 20.0 cm from the center accelerates from rest to 0.700 m/s in 1.75 s. At t = 1.25 s, find the magnitude and direction of (a) the centripetal acceleration, (b) the tangential acceleration, and (c) the total acceleration of the point.

$\boxed{37}$ A train slows down as it rounds a sharp, level turn, slowing from 90.0 km/h to 50.0 km/h in the 15.0 s that it takes to round the bend. The radius of the curve is 150 m. Compute the acceleration at the moment the train speed reaches 50.0 km/h.

38. A pendulum of length 1.00 m swings in a vertical plane (Fig. P4.16). When the pendulum is in the two horizontal positions $\theta = 90°$ and $\theta = 270°$, its speed is 5.00 m/s. (a) Find the magnitude of the centripetal acceleration and tangential acceleration for these positions. (b) Draw vector diagrams to determine the direction of the total acceleration for these two positions. (c) Calculate the magnitude and direction of the total acceleration.

39. A student attaches a ball to the end of a string 0.600 m in length and then swings the ball in a vertical circle. The speed of the ball is 4.30 m/s at its highest point and 6.50 m/s at its lowest point. Find its acceleration at (a) its highest point and (b) its lowest point.

40. A ball swings in a vertical circle at the end of a rope 1.50 m long. When it is 36.9° past the lowest point on its way up, the ball's total acceleration is $(-22.5\mathbf{i} + 20.2\mathbf{j})$ m/s^2. For that instant, (a) sketch a vector diagram showing the components of its acceleration, (b) determine the magnitude of its centripetal acceleration, and (c) determine the magnitude and direction of its velocity.

4.5

35) 13.0 m/s^2,
5.7 m/s, 7.5 m/s^2

36) 0.40 m/s^2 Forward
1.25 m/s^2 Center
1.31 m/s^2 Forward
and 72.3° Inward

37) 1.48 m/s^2

38) 25 m/s^2
9.8 m/s^2
26.8 m/s^2
21.4°

39) 30.8 m/s^2 Downward
70.4 m/s^2 upward

40) 25.6 m/s^2
6.2 m/s at 36.9°
Above the horizontal

41)

11. An air puck of mass 0.250 kg is tied to a string and allowed to revolve in a circle of radius 1.00 m on a horizontal, frictionless table. The other end of the string passes through a hole in the center of the table and a mass of 1.00 kg is tied to it. The suspended mass remains in equilibrium while the puck revolves. (a) What is the tension in the string? (b) What is the central force acting on the puck? (c) What is the speed of the puck?

12. The speed of the tip of the minute hand on a town clock is 1.75 × 10^{-3} m/s. (a) What is the speed of the tip of the second hand of the same length? (b) What is the centripetal acceleration of the tip of the second hand?

13. A coin placed 30.0 cm from the center of a rotating, horizontal turntable slips when its speed is 50.0 cm/s. (a) What provides the central force when the coin is stationary relative to the turntable? (b) What is the coefficient of static friction between coin and turntable?

Section 6.2 Nonuniform Circular Motion

14. A car traveling on a straight road at 9.00 m/s goes over a hump in the road. The hump may be regarded as an arc of a circle of radius 11.0 m. (a) What is the apparent weight of a 600-N woman in the car as she rides over the hump? (b) What must be the speed of the car over the hump if she is to experience weightlessness? (That is, her apparent weight is zero.)

15. A pail of water is rotated in a vertical circle of radius 1.00 m. What is the minimum speed of the pail at the top of the circle if no water is to spill out?

16. A hawk flies in a horizontal arc of radius 12.0 m at a constant speed of 4.00 m/s. (a) Find its centripetal acceleration. (b) It continues to fly along the same horizontal arc but increases its speed at the rate of 1.20 m/s². Find the acceleration (magnitude and direction) under these conditions.

17. A 40.0-kg child sits in a swing supported by two chains, each 3.00 m long. If the tension in each chain at the lowest point is 350 N, find (a) the child's speed at the lowest point and (b) the force of the seat on the child at the lowest point. (Neglect the mass of the seat.)

17A. A child of mass *m* sits in a swing supported by two chains, each of length *R*. If the tension in each chain at the lowest point is *T*, find (a) the child's speed at the lowest point and (b) the force of the seat on the child at the lowest point. (Neglect the mass of the seat.)

A 0.40-kg object is swung in a vertical circular path on a string 0.50 m long. If a constant speed of 4.0 m/s is maintained, what is the tension in the string when the object is at the top of the circle?

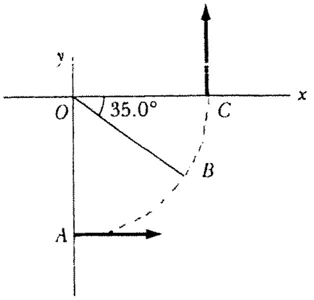


FIGURE P6.19

19. A car initially traveling eastward turns north by traveling in a circular path at uniform speed as in Figure P6.19. The length of the arc *ABC* is 235 m, and the car completes the turn in 36.0 s. (a) What is the acceleration when the car is at *B* located at an angle of 35.0°? Express your answer in terms of the unit vectors **i** and **j**. Determine (b) the car's average speed and (c) its average acceleration during the 36.0-s interval.

20 A roller-coaster vehicle has a mass of 500 kg when fully loaded with passengers (Fig. P6.20). (a) If the vehicle has a speed of 20.0 m/s at point *A*, what is the force exerted by the track on the vehicle at this point? (b) What is the maximum speed the vehicle can have at *B* and still remain on the track?

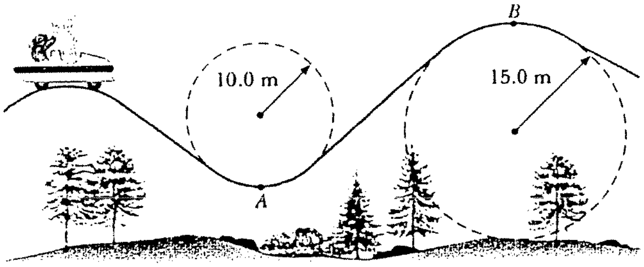


FIGURE P6.20

21. Tarzan (m = 85.0 kg) tries to cross a river by swinging from a vine. The vine is 10.0 m long, and his speed at the bottom of the swing (as he just clears the water) is 8.00 m/s. Tarzan doesn't know that the vine has a breaking strength of 1000 N. Does he make it safely across the river?

11) 9.8N
9.8N
6.26m/s

12) 0.005 m/s
1.11×10^{-2} m/s²

13) 0.0850

14) 149N
10.4m/s²

15) 13.3m/s

16) 1.33m/s²
1.79 m/s²

17) 4.81m/s
700N

18) 8.88N

19) -0.163 m/s² $\hat{i}$ + 0.233 m/s² $\hat{j}$
-0.181 m/s² $\hat{i}$ + 0.181 m/s² $\hat{j}$

20) 2.49×10^4 N
12.1m/s

c) 8.45 m/s²

V>14m/s

21) 1.38 kN > 1000N

22) 18.62 m
B) Mg Downward

AP Physics

DiBucci

PROBLEMS

Section 6.1 Newton's Second Law Applied to Uniform Circular Motion

1. A toy car moving at constant speed completes one lap around a circular track (a distance of 200 m) in 25.0 s. (a) What is the average speed? (b) If the mass of the car is 1.50 kg, what is the magnitude of the central force that keeps it in a circle?
2. In a cyclotron (one type of particle accelerator), a deuteron (of atomic mass 2 u) reaches a final speed of 10% of the speed of light while moving in a circular path of radius 0.48 m. The deuteron is maintained in the circular path by a magnetic force. What magnitude of force is required?
3. The wheels of a certain roller coaster are both above and below the rails as shown in Figure P6.3 so that the car will not leave the rails. If the mass supported by this particular wheel is 320 kg and the radius of this section of track is 15 m, (a) what is the magnitude and direction of the force that the track exerts on the wheel when the speed of the car is 20 m/s? (b) What would be the net force exerted on a 60-kg person riding in the car? (c) What supplies this force?

FIGURE P6.3

4. In a hydrogen atom, the electron in orbit around the proton feels an attractive force of about 8.20×10^{-8} N. If the radius of the orbit is 5.30×10^{-11} m, what is the frequency in revolutions per second? See the front cover for additional data.
5. A 3.00-kg mass attached to a light string rotates on a horizontal, frictionless table. The radius of the circle is 0.800 m, and the string can support a mass of 25.0 kg before breaking. What range of speeds can the mass have before the string breaks?
6. A satellite of mass 300 kg is in a circular orbit around the Earth at an altitude equal to the Earth's mean radius (see Example 6.5). Find (a) the satellite's orbital speed, (b) the period of its revolution, and (c) the gravitational force acting on it.
7. While two astronauts were on the surface of the Moon, a third astronaut orbited the Moon. Assume the orbit to be circular and 100 km above the surface of the Moon. If the mass and radius of the Moon are 7.40×10^{22} kg and 1.70×10^{6} m, respectively, determine (a) the orbiting astronaut's acceleration, (b) his orbital speed, and (c) the period of the orbit.

(Problem 6) *(NASA/Peter Arnold, Inc.)*

8. An automobile moves at constant speed over the crest of a hill. The driver moves in a vertical circle of radius 18.0 m. At the top of the hill, she notices that she barely remains in contact with the seat. Find the speed of the vehicle.

8A. An automobile moves at constant speed over the crest of a hill. The driver moves in a vertical circle of radius *R*. At the top of the hill, she notices that she barely remains in contact with the seat. Find the speed of the vehicle.

9. A crate of eggs is located in the middle of the flat bed of a pickup truck as the truck negotiates an unbanked curve in the road. The curve may be regarded as an arc of a circle of radius 35 m. If the coefficient of static friction between crate and truck is 0.60, what must be the maximum speed of the truck if the crate is not to slide?
10. A 55-kg ice skater is moving at 4.0 m/s when she grabs the loose end of a rope the opposite end of which is tied to a pole. She then moves in a circle of radius 0.80 m around the pole. (a) Determine the force exerted by the rope on her arms. (b) Compare this force with her weight.

1) 8.0 m/s, 3.02 N
2) 6.22×10^{-12} N
3) 5400 N Down
1600 N, Weight + Seat Belt
4) 6.56×10^{15} rev/s

5) $0 < V < 8.08$ m/s
6) 5.59×10^{3} m/s
239 min
735 N
7) 1.52 m/s²
1,660 m/s
6,820 s

8) 13.3 m/s
9) $V \le 14.3$ m/s
10) 1100 N
2.04 Times

Circular Motion Review Problems

AP Physics B

1, A roller-coaster vehicle has a mass of 500 kg when fully loaded with passengers (Fig. P6.20). (a) If the vehicle has a speed of 20.0 m/s at point *A*, what is the force exerted by the track on the vehicle at this point? (b) What is the maximum speed the vehicle can have at *B* and still remain on the track?

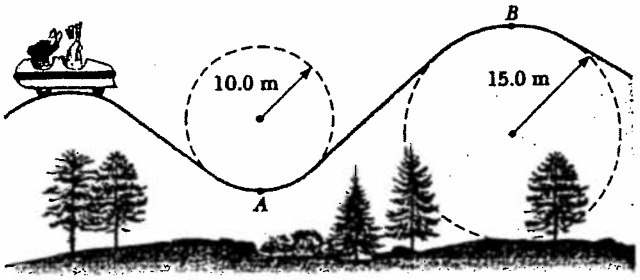


FIGURE P6.20

2. A model airplane of mass 0.75 kg flies in a horizontal circle at the end of a 60-m control wire, with a speed of 35 m/s. Compute the tension in the wire if it makes a constant angle of 20° with the horizontal. The forces exerted on the airplane are the pull of the control wire, its own weight, and aerodynamic lift, which acts at 20° inward from the vertical as shown in Figure P6.43.

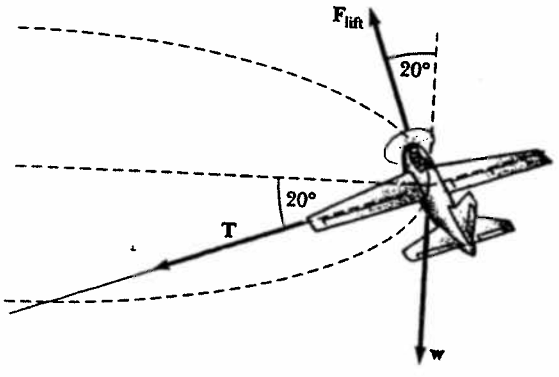


FIGURE P6.43

An amusement park ride consists of a large vertical cylinder that spins about its axis fast enough that any person inside is held up against the wall when the floor drops away (Fig. P6.49). The coefficient of static friction between person and wall is μ_s, and the radius of the cylinder is R. (a) Show that the maximum period of revolution necessary to keep the person from falling is $T = (4\pi^2 R\mu_s/g)^{1/2}$. (b) Obtain a numerical value for T if $R = 4.00$ m and $\mu_s = 0.400$. How many revolutions per minute does the cylinder make?

2.54 s,

FIGURE P6.49

4.

A child's toy consists of a small wedge that has an acute angle θ (Fig. P6.44). The sloping side of the wedge is frictionless, and the wedge is spun at a constant speed by rotating a rod that is firmly attached to it at one end. Show that, when the mass m rises up the wedge a distance L, the speed of the mass is

$$v = \sqrt{gL \sin \theta}$$

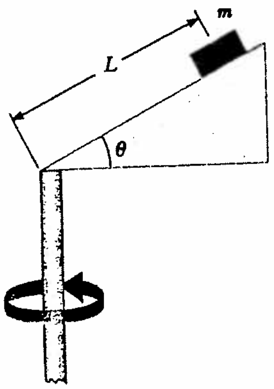


FIGURE P6.44

Planetary Motion and Kepler's laws

DiBucci

DATE ________ PERIOD ________ NAME ____________________________________

EXPERIMENT 8.1 Kepler's Laws

Purpose

Plot a planetary orbit and apply Kepler's Laws.

Concept and Skill Check

The motion of the planets has intrigued astronomers since they first gazed at the stars, moon, and planets filling the evening sky. But the old ideas of eccentrics and equants (combinations of circular motions) did not provide an accurate accounting of planetary movements. Johannes Kepler adopted the Copernican theory that Earth revolves around the sun (heliocentric, or sun-centered, view) and closely examined Tycho Brahe's meticulously recorded observations on Mars' orbit. With these data, he concluded that Mars' orbit was not circular and that there was no point around which the motion was uniform. When elliptical orbits were accepted, all the discrepancies found in the old theories of planetary motion were eliminated. From his studies, Kepler derived three laws that apply to the behavior of every satellite or planet orbiting another massive body.

1. The paths of the planets are ellipses, with the center of the sun at one focus.
2. An imaginary line from the sun to a planet sweeps out equal areas in equal time intervals, as shown in Figure 1.
3. The ratio of the squares of the periods of any two planets revolving about the sun is equal to the ratio of the cubes of their respective average distances from the sun. Mathematically, this relationship can be expressed as

$$\frac{T_a^2}{T_b^2} = \frac{r_a^3}{r_b^3}.$$

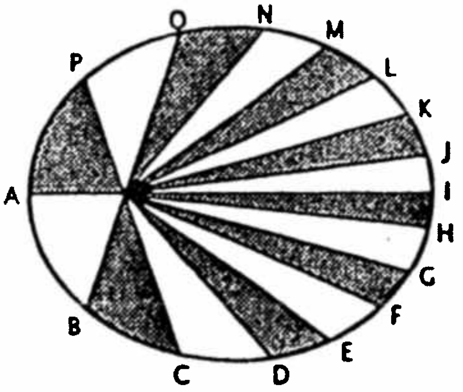


Figure 1. Kepler's law of areas.

In this experiment, you will use heliocentric data tables to plot the positions of Mercury on polar graph paper. Then you will draw Mercury's orbit. The distance from the sun, the radius vector, is compared to Earth's average distance from the sun, which is defined as 1 astronomical unit or 1 AU. The angle, or longitude, between the planet and a reference point in space is measured from the zero degree point, or vernal equinox.

Materials

polar graph paper sharp pencil metric ruler

Procedure

1. Orient your polar graph paper so that the zero degree point is on your right as you view the graph paper. The sun is located at the center of the paper. Label the sun without covering the center mark. Move about the center in a counter-clockwise direction as you measure and mark the longitude.
2. Select an appropriate scale to represent the values for the radius vectors of Mercury's positions. Since Mercury is closer to the sun than is Earth, the value of the radius vector will always be less than 1 AU. In this step, then, each concentric circle could represent one-tenth of an AU.

EXPERIMENT 8.1

Kepler's Laws

NAME ______________________________

3. Table 1 provides the heliocentric positions of Mercury over a period of several months. Select the set of data for October 1 and locate the given longitude on the polar graph paper. Measure out along the longitude line an appropriate distance, in your scale, for the radius vector for this date. Make a small dot at this point to represent Mercury's distance from the sun. Write the date next to this point.
4. Repeat the procedure, plotting all given longitudes and associated radius vectors.
5. After plotting all the data, carefully connect the points of Mercury's positions and sketch the orbit of Mercury.

Observations and Data

Table 1

Some Heliocentric Positions for Mercury for 0^h Dynamical Time*

Date	Radius vector (AU)	Longitude (degrees)
Oct. 1, 1990	0.319	114
3	0.327	126
5	0.336	137
7	0.347	147
9	0.358	157
11	0.369	166
13	0.381	175
15	0.392	183
17	0.403	191
19	0.413	198
21	0.423	205
23	0.432	211
25	0.440	217
27	0.447	223
29	0.453	229
31	0.458	235
Nov. 2	0.462	241
4	0.465	246
6	0.466	251
8	0.467	257
10	0.466	262
12	0.464	268
14	0.462	273
Nov. 16	0.458	280
18	0.452	285
20	0.447	291
22	0.440	297
24	0.432	304
26	0.423	310
28	0.413	317
30	0.403	325
Dec. 2	0.392	332
4	0.380	340
6	0.369	349
8	0.357	358
10	0.346	8
12	0.335	18
14	0.326	29
16	0.318	41
18	0.312	53
20	0.309	65
22	0.307	78
24	0.309	90
26	0.312	102
28	0.319	114
30	0.327	126

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*Adapted from *The Astronomical Almanac for the Year 1990*, U.S. Government Printing Office, Washington, D.C., 20402, p. E9.

EXPERIMENT
8.1 Kepler's Laws

NAME ____

Analysis

1. Does your graph of Mercury's orbit support Kepler's law of orbits?

2. Draw a line from the sun to Mercury's position on December 20. Draw a second line from the sun to Mercury's position on December 30. The two lines and Mercury's orbit describe an area swept by an imaginary line between Mercury and the sun during the ten-day interval of time. Lightly shade this area. Over a small portion of an ellipse, the area can be approximated by assuming the ellipse is similar to a circle. The equation that describes this value is

$$\text{area} = (\theta/360°)\pi r^2,$$

where r is the average radius for the orbit.

Determine θ by finding the difference in degrees between December 20 and December 30. Measure the radius at a point midway in the orbit between the two dates. Calculate the area in AUs for this ten-day period of time.

3. Select two additional ten-day periods of time at points distant from the interval in Question 2 and shade these areas. Calculate the area in AUs for each of these ten-day periods.

4. Find the average area for the three periods of time from Questions 2 and 3. Calculate the relative error between each area and the average. Does Kepler's law of areas apply to your graph?

5. Calculate the average radius for Mercury's orbit. This can be done by averaging all the radius vectors or, more simply, by averaging the longest and shortest radii that occur along the major axis. The major axis is shown in Figure 2. Recall that the sun is at one focus; the other focus is located at a point that is the same distance from the center of the ellipse as the sun, but in the opposite direction.

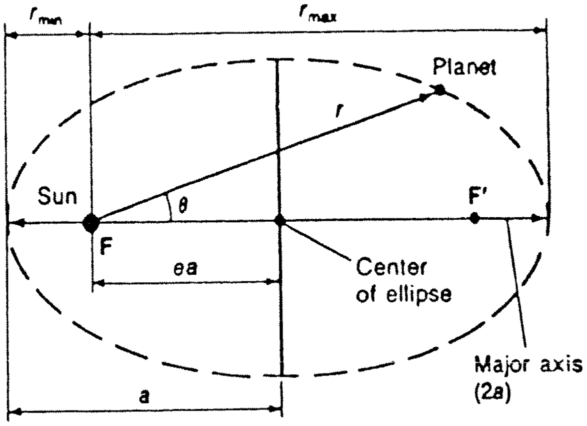


Figure 2. **The major axis passes through the two foci (F and F') and the center of the ellipse. The value *ea* determines the location of the foci; *e* is the eccentricity of the orbit. If $e = 0$, the orbit is a circle, and the foci merge at one, central point.**

From Table 1, find the longest radius vector. Then, align a metric ruler so that it describes a straight line passing through the point on the orbit that represents the longest radius vector and through the center of the sun to a point opposite on the orbit. Find the shortest radius vector by reading the longitude at this opposite point and consulting Table 1 for the corresponding radius vector. Average these two radius vector values. Using the values for Earth's average radius (1.0 AU), Earth's period (365.25 days), and your calculated average radius of Mercury's orbit, apply Kepler's third law to find the period of Mercury. Show your calculations.

6. Refer again to the graph of Mercury's orbit that you plotted. Count the number of days required for Mercury to complete one orbit of the sun; recall that this orbital time is the period of Mercury. Is there a difference in the two values (from Questions 5 and 6) for the period of Mercury? Calculate the relative difference in these two values. Are the results from your graph consistent with Kepler's law of periods?

EXPERIMENT
8.1 Kepler's Laws

NAME ______________________

Application

There has been some discussion about a hypothetical planet **X** that is on the opposite side of the sun from Earth and that has an average radius of 1.0 AU. If this planet exists, what is its period? Show your calculations.

Extension

Using the data in Table 2, plot the radius vectors and corresponding longitudes for Mars. Does the orbit you drew support Kepler's law of ellipses? Select three different areas and find the area per day for each of these. Does Kepler's law of areas apply to your model of Mars?

Table 2

Some Heliocentric Positions for Mars for 0^h Dynamical Time*

Date	Radius vector (AU)	Longitude (degrees)
Jan. 1, 1990	1.548	231
17	1.527	239
Feb. 2	1.507	247
18	1.486	256
Mar. 6	1.466	265
22	1.446	274
Apr. 7	1.429	283
23	1.413	293
May 9	1.401	303
25	1.391	313
June 10	1.384	323
26	1.381	333
July 12	1.382	343
28	1.387	353
Aug. 13	1.395	3
29	1.406	13
Sept 14	1.420	23
30	1.436	32
Oct. 16	1.455	42
Nov. 1	1.474	51
17	1.495	60
Dec. 3	1.516	68
19	1.537	76
Jan. 4, 1991	1.557	84

*Adapted from *The Astronomical Almanac for the Year 1990*, U.S. Government Printing Office, Washington, D.C., 20402, p. E12.

7.7. KEPLER'S LAWS OF PLANETARY MOTION

After years of analyzing the astronomical data taken by Tycho Brahe, early in the seventeenth century Johannes Kepler announced three laws that described the motion of planets around the sun. The first two laws were published in 1609 and the third in 1619. These laws, called *Kepler's laws*, may be stated as follows:

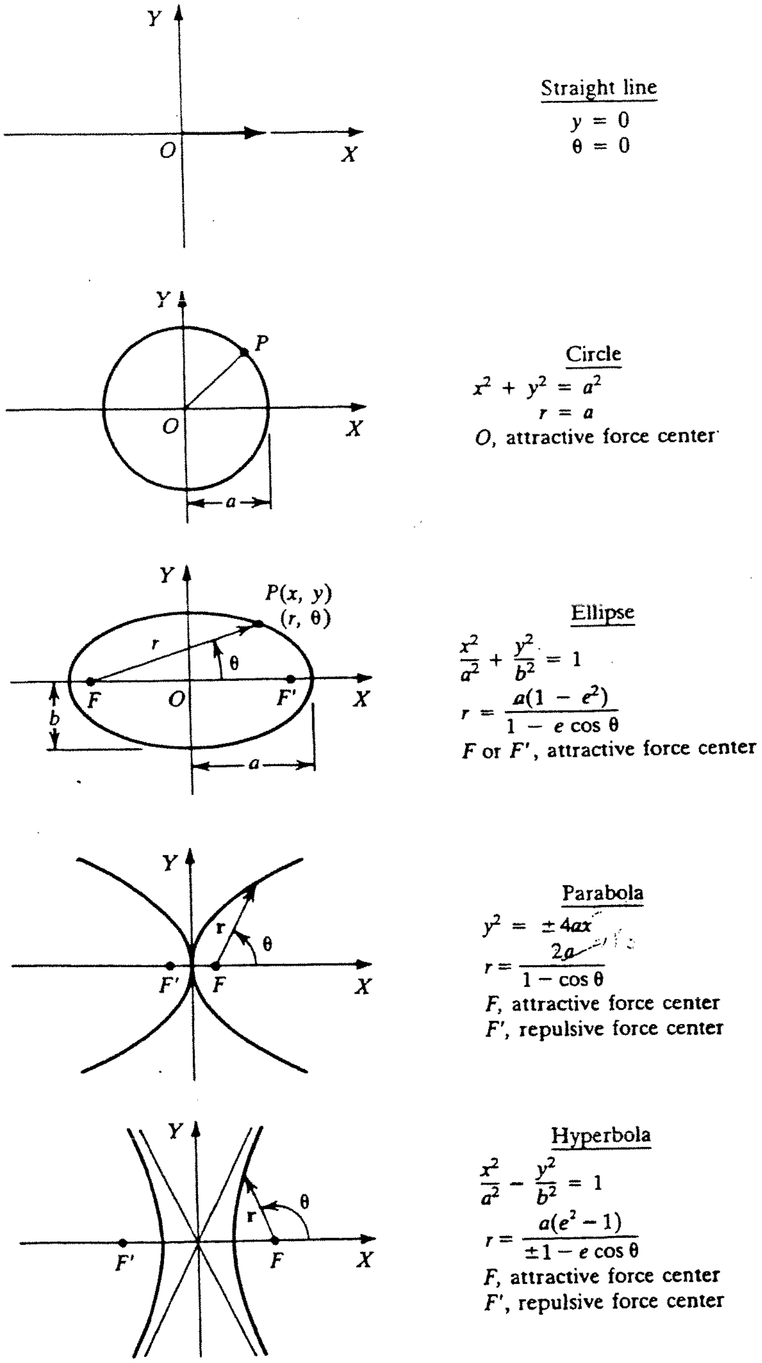
I. *Law of Orbits*: *Planets move in elliptical orbits with the sun at one focus.*

II. *Law of Areas*: *A line (or position vector) joining any planet to the sun sweeps out equal areas in equal intervals of time.*

III. *Law of Periods*: *The square of the period of revolution of any planet is proportional to the cube of the semimajor axis of the orbit.*

Newton's law of universal gravitation was given shortly after Kepler's laws, and it provided the theoretical description of the motion of planets, consistent with experimental facts. There is a fundamental difference between Newton's laws of motion and Kepler's laws. Newton's laws are about motion and force, in general, and as such implicitly involve an interaction between objects, whereas Kepler's laws describe the motion of a planetary system and do not involve interaction. Newton's laws are *dynamic*, giving relations between force, mass, distance, and time, whereas Kepler's laws are *kinematic*, giving the relation between distance and time. Kepler's laws should apply not only to a solar system but to moons going around planets and to artificial satellites. In addition, Kepler's laws are valid whenever an inverse square force law is involved.

We have already seen that the first of these laws, the law of orbits, follows directly from Newton's law of gravitation, that is, from the inverse square nature of the force of gravitation. The second law, the law of areas, results from the fact that the angular momentum remains constant. We have already shown this to be true (see Section 7.3), because gravitational force is a conservative force; hence angular momentum is conserved. In this section, we prove the third law, the law of periods.



Straight line

$y = 0$

$\theta = 0$

Circle

$x^2 + y^2 = a^2$

$r = a$

O, attractive force center

Ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

$$r = \frac{a(1 - e^2)}{1 - e \cos \theta}$$

F or F', attractive force center

Parabola

$y^2 = \pm 4ax$

$$r = \frac{2a}{1 - \cos \theta}$$

F, attractive force center

F', repulsive force center

Hyperbola

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

$$r = \frac{a(e^2 - 1)}{\pm 1 - e \cos \theta}$$

F, attractive force center

F', repulsive force center

Figure 7.20 Shapes of different orbits and their equations in rectangular and plane polar coordinates.

TABLE 7.1. Kepler's Third Law Applied to Planets and Satellites

	e	a ($\times 10^7$ km)	T (yr)	a^3/T^2
Planets				
Mercury	0.206	5.79	0.24	3.39×10^{18}
Venus	0.007	10.82	0.62	3.31×10^{18}
Earth	0.017	14.96	1.00	3.36×10^{18}
Mars	0.093	22.79	1.88	3.37×10^{18}
Jupiter	0.048	77.83	11.86	3.37×10^{18}
Saturn	0.055	142.7	29.46	3.36×10^{18}
Uranus	0.047	286.9	84.01	3.36×10^{18}
Neptune	0.009	449.8	164.97	3.37×10^{18}
Pluto	0.249	590.0	248.4	3.35×10^{18}
Satellites				
Cosmos 382	0.260	18,117	143	2.91×10^{8}
ATS 2	0.455	24,123	219.7	2.91×10^{8}
Explorer 28	0.952	273,740	8.4×10^{13}	2.91×10^{8}

$$r_{\min} = r_2 = r_0 \frac{1+e}{1+e} = r_0 = -\frac{L^2}{mK}\frac{1}{1+e} \tag{7.108}$$

while the maximum value of r is obtained from Eqs. (7.104) and (7.105) by substituting $\theta = \pi$ and $\cos\theta = -1$ and using the value of r_0 from Eq. (7.107); that is,

$$r_{\max} = r_1 = r_0 \frac{1+e}{1-e} = -\frac{L^2}{mK}\frac{1}{1-e} \tag{7.109}$$

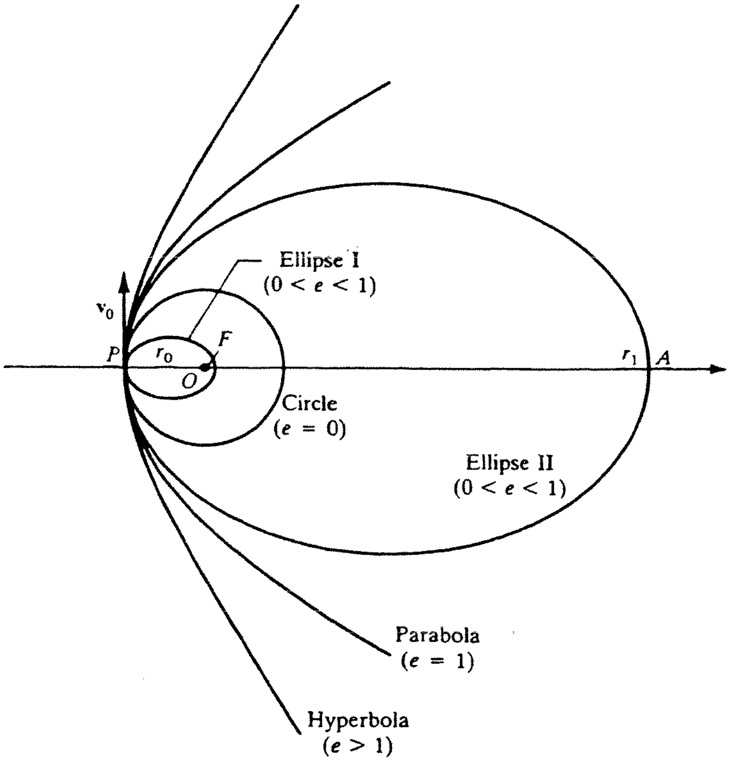
We can solve Eq. (7.107) to obtain e; that is,

$$e = -\frac{L^2}{mKr_0} - 1 \tag{7.110}$$

Combining Eqs. (7.106) and (7.103), we get

$$e = \sqrt{1 + \frac{2EL^2}{mK^2}} \tag{7.111}$$

Thus we have obtained the values of r_1 (=maximum radius), r_2 (=r_0 = minimum radius), A, and e given by Eqs. (7.109), (7.108), (7.103), and (7.111), respectively. As shown in Fig. 7.18, the value of e determines the shape of the orbit.



$$e = -\frac{AL^2}{mK} = -\frac{L^2}{mKr_0} - 1 = \sqrt{1 + \frac{2EL^2}{mK^2}}$$

Figure 7.18 The value of the eccentricity e determines the shape of the orbit.

From Fig. 7.17, for $E_m = V_0$, the different orbits are

$V_0 < E < 0$,	$0 < e < 1$,	ellipse
$E = V_0$,	$e = 0$,	circle (special case of ellipse)
$E = 0$,	$e = 1$,	parabola
$E > 0$,	$e > 1$,	hyperbola
$E < V_0$,	$e < 0$,	not allowed

These orbits are shown in Figs. 7.18 and 7.20.

(a) *Ellipse*: An ellipse is a curve traced by a point so that the sum of its distances from two fixed points F and F' (called *foci*) is constant; that is (Figs. 7.19 and Fig. 7.20),

$$r + r' = 2a$$

Using Fig. 7.19, one obtains the following equation of an ellipse in polar coordinates with the origin at one focus:

$$r = \frac{a(1 - e^2)}{1 - e\cos\theta} \tag{7.112}$$

where a, the semimajor axis, is related to the minimum radius r_0 by the relation

$$r_0 = a(1 - e) \tag{7.113}$$

while the semiminor axis b is given by

$$b = a(1 - e^2)^{1/2} \tag{7.114}$$

where $e < 1$. We can further calculate the length of the major axis in terms of the energy of a particle. According to Eqs. (7.107), (7.108), and (7.109),

$$2a = r_{\text{min}} + r_{\text{max}} = -\frac{2L^2}{mK}\,\frac{1}{1 - e^2} \tag{7.115a}$$

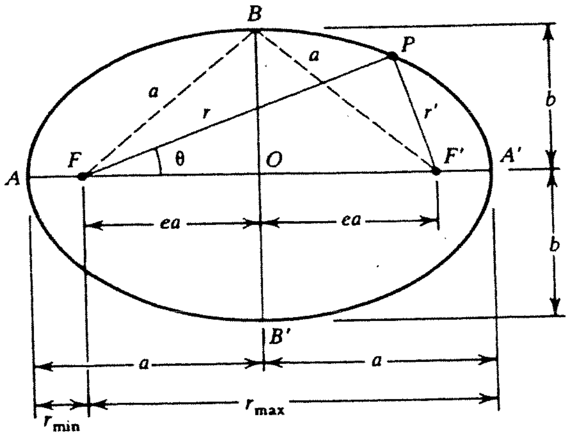
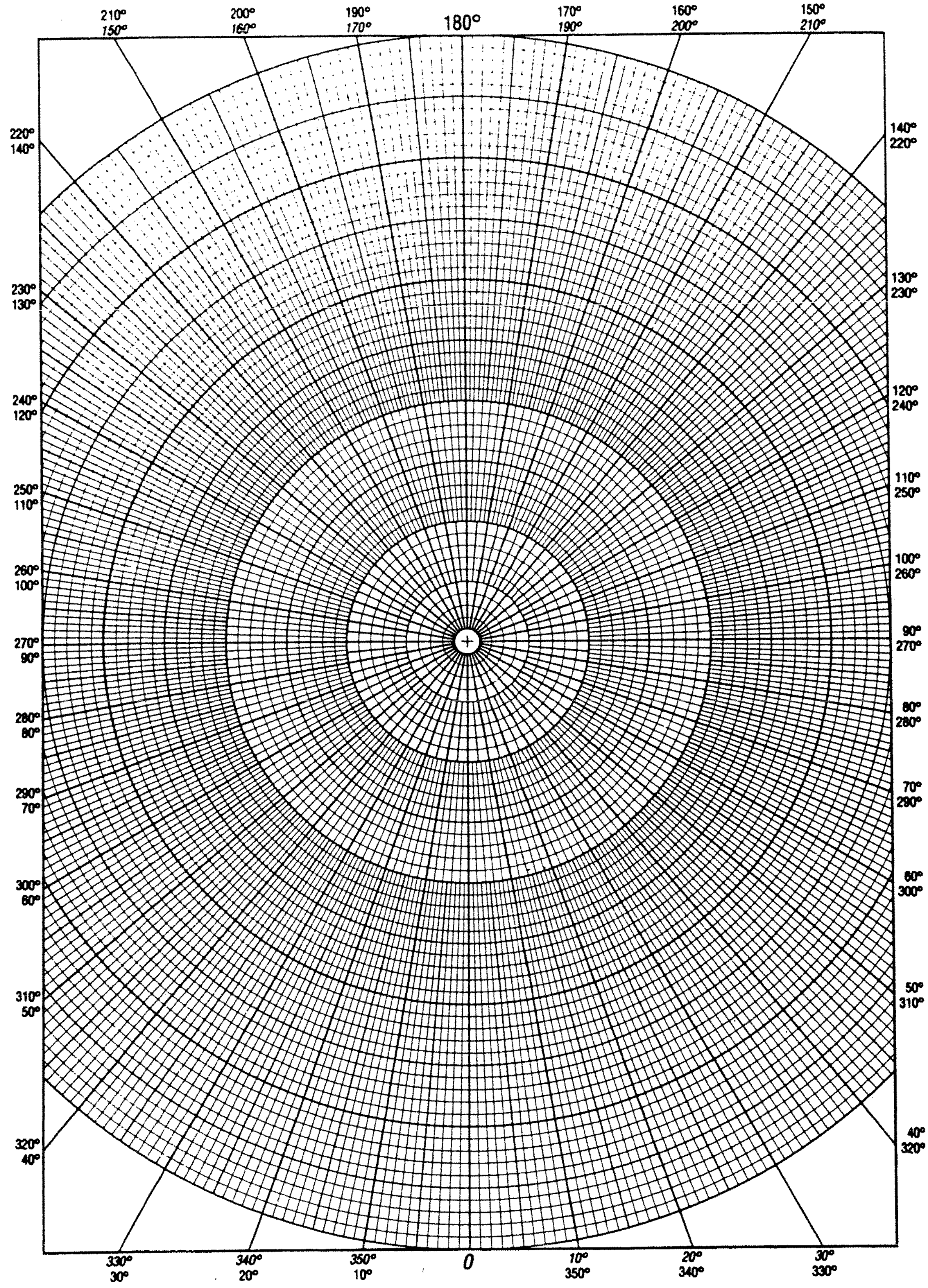


Figure 7.19 Definitions of different quantities in elliptical orbits.

EXPERIMENT

8.1 Kepler's Laws

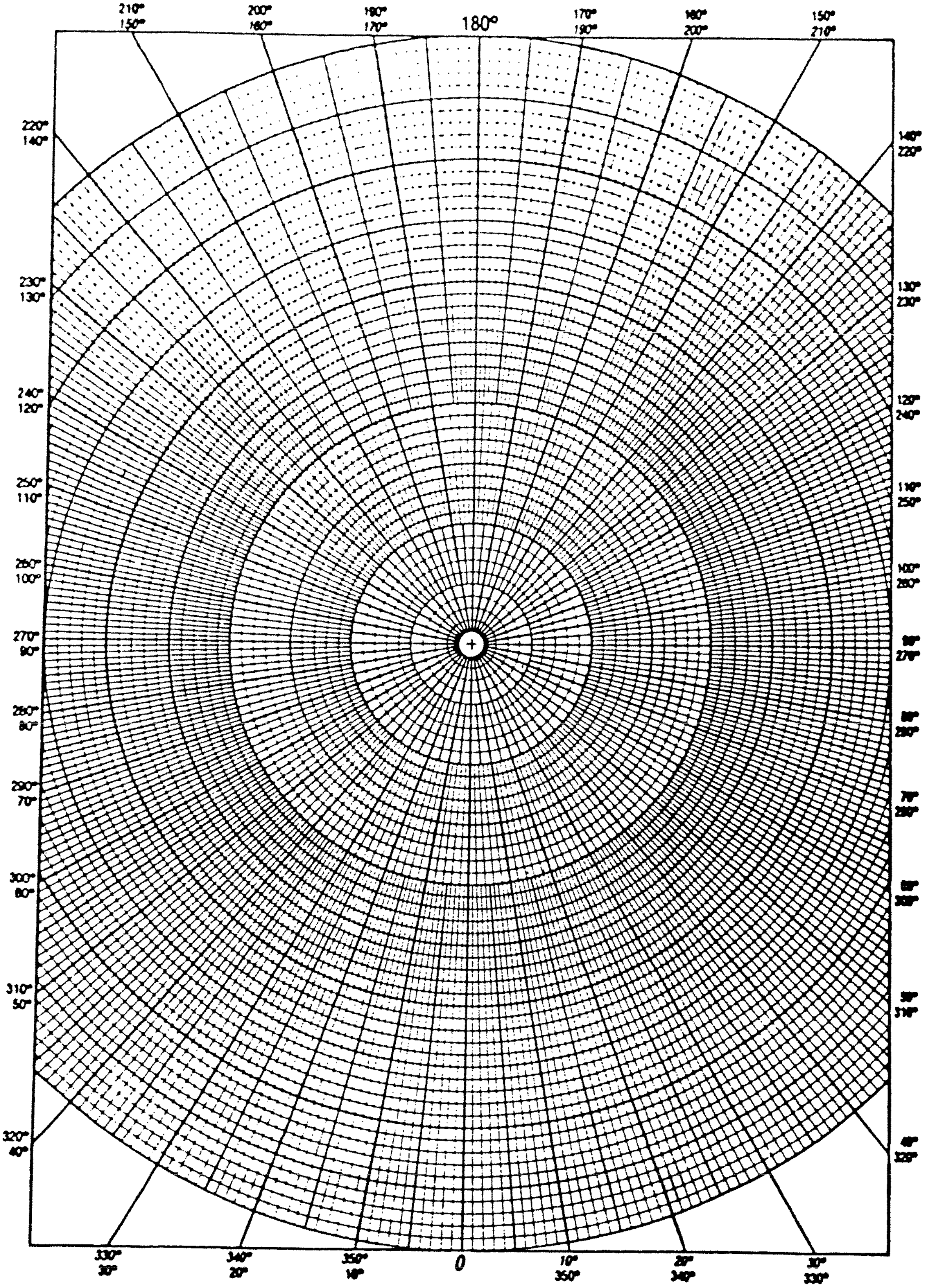
NAME ____



EXPERIMENT

8.1 Kepler's Laws

NAME ______________________________



Section 4.7 The Gravitational Force

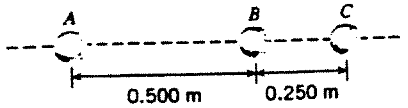
19. The mass of one small ball is 0.001 50 kg, and the mass of another is 0.870 kg. If the center-to-center distance between these two balls is 0.100 m, find the magnitude of the gravitational force that each exerts on the other.

20. A rock of mass 45 kg accidentally breaks loose from the edge of a cliff and falls straight down. The magnitude of the air resistance that opposes its downward motion is 250 N. What is the magnitude of the acceleration of the rock?

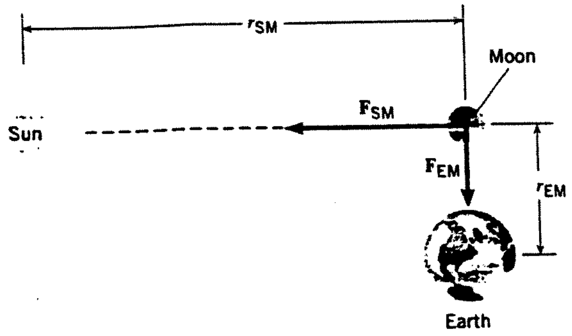
21. **ssm** In preparation for this problem, review Conceptual Example 7. A space traveler whose mass is 115 kg leaves earth. What are his weight and mass (a) on earth and (b) in interplanetary space where there are no nearby planetary objects?

22. On earth, two parts of a space probe weigh 11 000 N and 3400 N. These parts are separated by a center-to-center distance of 12 m and may be treated as uniform spherical objects. Find the magnitude of the gravitational force that each part exerts on the other out in space, far from any other objects.

23. The drawing shows three particles far away from any other objects and located on a straight line. The masses of these particles are $m_A = 363$ kg, $m_B = 517$ kg, and $m_C = 154$ kg. Find the magnitude and direction of the net gravitational force acting on (a) particle A, (b) particle B, and (c) particle C.



24. The drawing (not to scale) shows one alignment of the sun, earth, and moon. The gravitational force $\mathbf{F}_{SM}$ that the sun exerts on the moon is perpendicular to the force $\mathbf{F}_{EM}$ that the earth exerts on the moon. The masses are: mass of sun = 1.99×10^{30} kg, mass of earth = 5.98×10^{24} kg, mass of moon = 7.35×10^{22} kg. The distances shown in the drawing are $r_{SM} = 1.50 \times 10^{11}$ m and $r_{EM} = 3.85 \times 10^{8}$ m. Determine the magnitude of the net gravitational force on the moon.



25. **ssm** Mars has a mass of 6.46×10^{23} kg and a radius of 3.39×10^{6} m. (a) What is the acceleration due to gravity on Mars? (b) How much would a 65-kg person weigh on this planet?

26. As pointed out in the text, your weight W_M on the moon is approximately one-sixth of its value W_E on the earth. The masses and radii of the moon and the earth are given on the inside of the front cover. Use these data and calculate a more exact value (to 3 significant digits) for the ratio W_M/W_E.

27. The mass of a robot is 5450 kg. This robot weighs 3620 N more on planet A than it does on planet B. Both planets have the same radius of 1.33×10^{7} m. What is the difference $M_A - M_B$ in the masses of these planets?

28. A space traveler weighs 580 N on earth. What will the traveler weigh on another planet whose radius is three times that of the earth and whose mass is twice that of the earth?

29. **ssm** Synchronous communications satellites are placed in a circular orbit that is 3.59×10^{7} m above the surface of the earth. What is the magnitude of the acceleration due to gravity at this distance?

***30.** Three uniform spheres are located at the corners of an equilateral triangle. Each side of the triangle has a length of 1.20 m. Two of the spheres have a mass of 2.80 kg each. The third sphere (mass unknown) is released from rest. Considering only the gravitational forces that the spheres exert on each other, what is the magnitude of the initial acceleration of the third sphere?

***31.** At a distance H above the surface of a planet, the true weight of a remote probe is one percent less than its true weight on the surface. The radius of the planet is R. Find the ratio H/R.

***32.** A spacecraft is on a journey to the moon. The masses of the earth and moon are, respectively, 5.98×10^{24} kg and 7.35×10^{22} kg. The distance between the centers of the earth and th moon is 3.85×10^{8} m. At what point, as measured from the cen ter of the earth, does the gravitational force exerted on the craft b the earth balance the gravitational force exerted by the moon This point lies on a line between the centers of the earth and th moon.

***33.** **ssm www** Several people are riding in a hot-air balloon The combined mass of the people and balloon is 310 kg. The balloon is motionless in the air, because the downward-acting weigh of the people and balloon is balanced by an upward-acting "buoy ant" force. If the buoyant force remains constant, how much mas should be dropped overboard so the balloon acquires an upwar acceleration of 0.15 m/s^2?

***34.** Jupiter is the largest planet in our solar system, having mass and radius that are, respectively, 318 and 11.2 times that o earth. Suppose that an object falls from rest near the surface o each planet, and that each object falls the same distance befor striking the ground. Determine the ratio of the time of fall o Jupiter to that on earth.

****35.** Two particles are located on the x axis. Particle 1 has a mas m and is at the origin. Particle 2 has a mass $2m$ and is at $x = +L$ Where on the x axis should a third particle be located so that th magnitude of the gravitational force on *both* particle 1 and particl 2 doubles? Express your answer in terms of L. *Note that there a two answers.*

19-35 on next page

19) 8.70×10^{-12} N

20) 4.2 m/s

21) 115 kg, 1.13×10^{3} N
W=0, M = 115 kg

22) 1.8×10^{-7} N

23) 5.67×10^{-5} N right

24) 4.77×10^{20} N

25) 3.75 M/s, 2.4×10^{2} N

26) 0.165

27) 1.76×10^{24} kg

28) 130 N

29) 0.223 M/s^2

30) 2.55×10^{-10} M/s^2

31) 0.0050

32) 3.46×10^{8} M

33) 4.7 kg

34) 0.628

35) 0.414 L or -2.414 L

Motion in the Heavens and on Earth

PROBLEMS

8.1 Motion in the Heavens and on Earth

Use $G = 6.670 \times 10^{-11}$ $Nm^2 kg^2$

① Jupiter is 5.2 times farther than Earth is from the sun. Find Jupiter's orbital period in earth years.

2. Uranus requires 84 years to circle the sun. Find Uranus' orbital radius as a multiple of Earth's orbital radius.

3. Venus has a period of revolution of 225 earth days. Find the distance between the sun and Venus, as a multiple of Earth's orbital radius.

4. If a small planet were located 8.0 times as far from the sun as Earth, how many years would it take the planet to orbit the sun?

5. A satellite is placed in an orbit with a radius that is half the radius of the moon's orbit. Find its period in units of the period of the moon.

6. An apparatus like the one Cavendish used to find *G* has a large lead ball that is 5.9 kg in mass and a small one that is 0.047 kg. Their centers are separated by 0.055 m. Find the force of attraction between them.

7. Use the data in Table 8–1 to compute the gravitational force the sun exerts on Jupiter.

8. Tom has a mass of 70.0 kg and Sally has a mass of 50.0 kg. Tom and Sally are standing 20.0 m apart on the dance floor. Sally looks up and she sees Him. She feels an attraction. If the attraction is gravitation, find its size. Assume both can be replaced by spherical masses.

9. Two balls have their centers 2.0 m apart. One has a mass of 8.0 kg. The other has a mass of 6.0 kg. What is the gravitational force between them?

10. Two bowling balls each have a mass of 6.8 kg. They are located next to one another with their centers 21.8 cm apart. What gravitational force do they exert on each other?

11. Sally has a mass of 50.0 kg and Earth has a mass of 5.98×10^{24} kg. The radius of Earth is 6.371×10^{6} m.
  a. What is the force of gravitational attraction between Sally and Earth?
  b. What is Sally's weight?

12. The gravitational force between two electrons 1.00 m apart is 5.42×10^{-71} N. Find the mass of an electron.

13. Two spherical balls are placed so their centers are 2.6 m apart. The force between the two balls is 2.75×10^{-12} N. What is the mass of each ball if one ball is twice the mass of the other ball?

14. Using the fact that a 1.0-kg mass weighs 9.8 N on the surface of Earth and the radius of Earth is roughly 6.4×10^{6} m,
  a. calculate the mass of Earth.
  b. calculate the average density of Earth.

15. The moon is 3.9×10^{5} km from Earth's center and 1.5×10^{8} km from the sun's center. If the masses of the moon, Earth, and sun are 7.3×10^{22} kg, 6.0×10^{24} kg, and 2.0×10^{30} kg, respectively, find the ratio of the gravitational forces exerted by Earth and the sun on the moon.

1. 12 yrs
2. 19 r_E
3. 0.724 r_E
4. 23 yrs
5. 0.35 T_m
6. 6.1×10^{-9} N
7. 4.17×10^{23} N
8. $5.84 \cdot \times 10^{-10}$ N

9. 8.0×10^{-10} N
10. 6.5×10^{-8} N
11. **a.** 491 N
b. 490 N
12. 9.01×10^{-31} kg
13. $m_1 = 0.37$ kg
$m_2 = 0.75$ kg
14. **a.** 6.0×10^{24} kg
b. 5.5×10^{3} kg/m^3
15. 1.0 to 2.3
16. 100 N
17. 1.989×10^{30} kg
18. 5.6×10^{26} kg
19. 6.3×10^{24} kg
very close

20. **a.** 3.07×10^{3} m/s; **b.** 24.0 h
21. **a.** 1.2×10^{2} min; **b.** 1.6×10^{3} m/s
22. **a.** 0.2 m/s^2; **b.** 2×10^{1} N
23. **a.** 1.80×10^{3} N; **b.** 800 N
24. 2.65×10^{3} km
25. **a.** 7.0 s; **b.** 2.8 s
26. 6.68 N/kg
27. **a.** 2.0×10^{20} N;
b. 0.0028 N/kg
28. 352 N

16. A force of 40.0 N is required to pull a 10.0-kg wooden block at a constant velocity across a smooth glass surface on Earth. What force would be required to pull the same wooden block across the same glass surface on the planet Jupiter?

17. Use the information for Earth from Table 8–1 to calculate the mass of the sun using Newton's variations of Kepler's third law.

18. Mimas, a moon of Saturn, has an orbital radius of 1.87×10^{8} m and an orbital period of about 23 h. Use Newton's version of Kepler's third law and these data to find the mass of Saturn.

19 Use Newton's version of Kepler's third law to find the mass of Earth. The moon is 3.9×10^{8} m away from Earth and the moon has a period of 27.33 days. Compare this mass to the mass found in Problem 14.

8.2 Using the Law of Universal Gravitation

20. A geosynchronous satellite appears to remai over one spot on Earth. A geosynchronou satellite has an orbital radius of 4.23×10^{7} m
  a. Calculate its speed in orbit.
  b. Calculate its period.

21. On July 19, 1969, Apollo II's orbit around th moon was adjusted to an average orbit c 111 km. The radius of the moon is 1785 kn and the mass of the moon is 7.3×10^{22} kg.
  a. How many minutes did it take to orbi once?
  b. At what velocity did it orbit the moon?

22. The asteroid Ceres has a mass 7×10^{20} k and a radius of 500 km.
  a. What is *g* on the surface?
  b. How much would a 85-kg astronaut weig on Ceres?

23 The radius of Earth is about 6.40×10^{3} kn A 7.20×10^{3}-N spacecraft travels away fro Earth. What is the weight of the spacecraft the following distances from Earth's surface
  a. 6.40×10^{3} km **b.** 1.28×10^{4} km

24. How high does a rocket have to go abov Earth's surface until its weight is half what would be on Earth?

25. The formula for the period of a pendulum, is $T = 2\pi\sqrt{l/g}$.
  a. What would be the period of a 2.0 m lon pendulum on the moon's surface? Th moon's mass is 7.34×10^{22} kg and its ra dius is 1.74×10^{6} m.
  b. What is the period of this pendulum o Earth?

26. A 1.25-kg book in space has a weight c 8.35 N. What is the value of the gravitationa field at that location?

27. The moon's mass is 7.34×10^{22} kg and it i 3.8×10^{8} m away from Earth. Earth's mas can be found in Table 8–1.
  a. Calculate the gravitational force of attrac tion between the two.
  b. Find Earth's gravitational field at the moon

28. Earth's gravitational field is 7.83 N/kg at th altitude of the space shuttle. What is the siz of the force of attraction between a student mass of 45.0 kg, and Earth?

50. An object is on a frictionless inclined plane. The plane is inclined at an angle of 30° with the horizontal. What is the object's acceleration?

a) 0.50 g
b) 0.56 g
c) 0.87 g
d) 1.0 g

Answer: a Difficulty: 2

51. A person on a scale rides in an elevator. If the mass of the person is 60.0 kg and the elevator accelerate downward with an acceleration of 4.90 m/s^2, what is the reading on the scale?

a) 147 N
b) 294 N
c) 588 N
d) 882 N

Answer: b Difficulty: 2

52. A person on a scale rides in an elevator. If the mass of the person is 60.0 kg and the elevator accelerate upward with an acceleration of 4.90 m/s^2, what is the reading on the scale?

a) 147 N
b) 294 N
c) 588 N
d) 882 N

Answer: d Difficulty: 2

55. An object of mass 6000 kg rests on the flatbed of a truck. It is held in place by metal brackets that can exert a maximum horizontal force of 9000 N. When the truck is traveling 15 m/s, what is the minimum stopping distance if the load is not to slide forward into the cab?

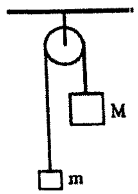
a) 15 m
b) 30 m
c) 75 m
d) 150 m

Answer: c Difficulty: 2

56. An object of mass 6000 kg rests on the flatbed of a truck. It is held in place by metal brackets that can exert a maximum horizontal force of 9000 N. When the truck is traveling 15 m/s, what is the minimum stopping time if the load is not to slide forward into the cab?

a) 5.0 s
b) 10 s
c) 13 s
d) 23 s

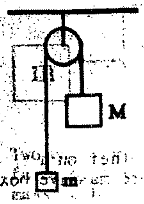
Answer: b Difficulty: 2



57. In the Atwood machine shown, if M = 0.60 kg and m = 0.40 kg, what is the magnitude of the acceleration of the system? (Ignore friction and the mass of the pulley.)

a) 5.3 m/s^2
b) 4.5 m/s^2
c) 0.89 m/s^2
d) 1.2 m/s^2

Answer: c Difficulty: 2



58. In the Atwood machine shown, if $M = 0.60$ kg and $m = 0.40$ kg, what is the tension in the string? (Ignore friction and the mass of the pulley.)

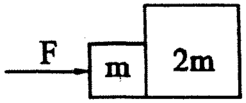
a) 4.9 N
b) 5.3 N
c) 7.1 N
d) 7.5 N

Answer: b Difficulty: 2

59. A stack of books rests on a level frictionless surface. A force F acts on the stack, and it accelerates at 3.0 m/s^2. A 1.0 kg book is then added to the stack. The same force is applied, and now the stack accelerates at 2.0 m/s^2. What was the mass of the original stack?

a) 1.0 kg
b) 2.0 kg
c) 3.0 kg
d) None of the above.

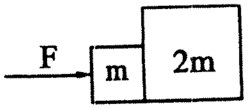
Answer: b Difficulty: 2



60. Two boxes of masses m and 2m are in contact with each other on a frictionless surface. What is the acceleration of the more massive box?

a) F/m
b) F/(2m)
c) F/(3m)
d) F/(4m)

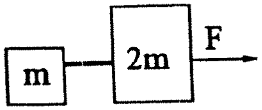
Answer: c Difficulty: 2



61. Two boxes of masses m and 2m are in contact with each other on a frictionless surface. What is the net force on the more massive box?

a) 2/3 F
b) F
c) 3/2 F
d) 2F

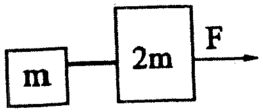
Answer: a Difficulty: 2



62. Two boxes of masses m and 2m are connected by a rope. If the forward force on the more massive box is F, what is the tension in the connecting rope?

a) 3F
b) F
c) F/2
d) F/3

Answer: d Difficulty: 2



63. Two boxes of masses m and 2m are connected by a rope. If the forward force on the more massive box is F, what is the acceleration of the less massive box?

a) F/(3m)
b) F/(2m)
c) F/m
d) 2F/m

Answer: a Difficulty: 2

64. An antitank weapon fires a 3.00-kg rocket which acquires a speed of 50.0 m/s after traveling 90.0 cm down a launching tube. Assuming the rocket was accelerated uniformly, what is the average force acted on it?

a) $4.17X10^3$ N
b) $3.62X10^3$ N
c) $2.82X10^3$ N
d) $2.00X10^3$ N

Answer: a Difficulty: 2

65. A sports car of mass 1000 kg can accelerate from rest to 27 m/s in 7.0 s. What is the average forward force on the car?

a) $2.6X10^2$ N
b) $3.9X10^3$ N
c) $2.7X10^4$ N
d) $1.9X10^5$ N

Answer: b Difficulty: 1

66. A 10-kg mass slides down a flat hill that makes an angle of 10° with the horizontal. If friction is negligible, what is the resultant force on the sled?

a) 1.7 N
b) 17 N
c) 97 N
d) 98 N

Answer: b Difficulty: 2

67. An object of mass m is hanging by a string from the roof of an elevator. The elevator is moving up at constant speed. What is the tension in the string?

a) Less than mg.
b) Exactly mg.
c) Greater than mg.
d) Cannot determine without knowing the speed.

Answer: b Difficulty: 2

68. An object of mass m is hanging by a string from the roof of an elevator. The elevator is moving upward, but slowing down. What is the tension in the string?

a) Less than mg.
b) Exactly mg.
c) Greater than mg.
d) Zero.

Answer: a Difficulty: 2

69. A student pulls a box of books on a smooth horizontal floor with a force of 100 N in a direction of 37° above the horizontal. If the mass of the box and the books is 40.0 kg, what is the acceleration of the box?

a) 1.5 m/s^2
b) 1.9 m/s^2
c) 2.0 m/s^2
d) 3.3 m/s^2

Answer: c Difficulty: 2

70. A student pulls a box of books on a smooth horizontal floor with a force of 100 N in a direction of 37.0° above the horizontal. If the mass of the box and the books is 40.0 kg, what is the normal force on the box?

a) 292 N
b) 312 N
c) 332 N
d) 392 N

Answer: c Difficulty: 2

71. Sue and Sean are having a tug-of-war by pulling on opposite ends of a 5.0-kg rope. Sue pulls with a 15-N force. What is Sean's force if the rope accelerates toward Sue at 2.0 m/s^2?

a) 3.0 N
b) 5.0 N
c) 25 N
d) 50 N

Answer: b Difficulty: 2

72. The coefficient of static and kinetic frictions between a 3.0-kg box and a desk are 0.40 and 0.30, respectively. What is the net force on the box when a 10-N horizontal force is applied to the box?

a) zero
b) 8.8 N
c) 12 N
d) 1.2 N

Answer: a Difficulty: 1

73. The coefficient of static and kinetic frictions between a 3.0-kg box and a desk are 0.40 and 0.30, respectively. What is the net force on the box when a 15-N horizontal force is applied to the box?

a) zero
b) 8.8 N
c) 12 N
d) 6.2 N

Answer: d Difficulty: 1

74. An object slides on a level surface in the +x direction. It slows and comes to a stop with a constant acceleration of $-2.45\ m/s^2$. What is the coefficient of kinetic friction between the object and the floor?

a) 0.25
b) 0.50
c) 4.9
d) Impossible to determine without knowing the mass of the object.

Answer: a Difficulty: 2

75. During a hockey game, a puck is given an initial speed of 10 m/s. It slides 50 m on the ice before it stops. What is the coefficient of kinetic friction between the puck and the ice?

a) 0.090
b) 0.10
c) 0.11
d) 0.12

Answer: b Difficulty: 2

76. An object is placed on an inclined plane. The angle of incline is gradually increased until the object begins to slide. The angle at which this occurs is θ. What is the coefficient of static friction between the object and the plane?

a) $\sin\theta$
b) $\cos\theta$
c) $\tan\theta$
d) $1/\tan\theta$

Answer: c Difficulty: 3

77. A 10-kg box sitting on a horizontal surface is pulled by a 5.0-N force. A 3.0-N friction force retards the motion. What is the acceleration of the object?

a) $0.20\ m/s^2$
b) $0.30\ m/s^2$
c) $0.50\ m/s^2$
d) $5.0\ m/s^2$

Answer: a Difficulty: 2

78. Its more difficult to start moving a heavy carton from rest than it is to keep pushing it with constant velocity, because

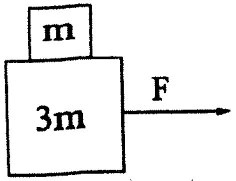
a) the normal force is greater when the carton is at rest.
b) $\mu s < \mu k$
c) initially, the normal force is not perpendicular to the applied force.
d) $\mu k < \mu s$

Answer: d Difficulty: 1

79. A packing crate slides down an inclined ramp at constant velocity. Thus we can deduce that

a) a frictional force is acting on it.
b) a net downward force is acting on it.
c) it may be accelerating.
d) it is not acted on by appreciable gravitational force.

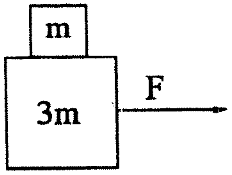
Answer: a Difficulty: 1



80. Two boxes of masses m and 3m are stacked. The surface between the more massive box and the horizontal surface is smooth and the surface between the boxes is rough. If the less massive box does not slide on the more massive box, what is the static friction force on the less massive box?

a) F
b) F/2
c) F/3
d) F/4

Answer: d Difficulty: 3



81. Two boxes of masses m and 3m are stacked. The surface between the more massive box and the horizontal surface is smooth and the surface between the boxes is rough. If the less massive box does not slide on the more massive box, what is the coefficient of static friction between the boxes?

a) F/(4mg)
b) F/(3mg)
c) F/(2mg)
d) F/(mg)

Answer: a Difficulty: 3

82. An object with a mass m slides down a rough 37° inclined plane where the coefficient of kinetic friction is 0.20. What is the acceleration of the object?

a) 4.3 m/s^2
b) 5.9 m/s^2
c) 6.6 m/s^2
d) 7.8 m/s^2

Answer: a Difficulty: 3

83. An object with a mass m slides down a rough 37° inclined plane where the coefficient of kinetic friction is 0.20. If the plane is 10 m long and the mass starts from rest, what will be its speed at the bottom of the plane?

a) 12 m/s
b) 11 m/s
c) 9.7 m/s
d) 9.3 m/s

Answer: d Difficulty: 3

84. The coefficients of static and kinetic frictions for plastic on wood are 0.50 and 0.40, respectively. How much horizontal force would you need to apply to a 3.0 N plastic calculator to start it moving from rest?

a) 0.15 N
b) 1.2 N
c) 1.5 N
d) 2.7 N

Answer: c Difficulty: 1

85. A horizontal force accelerates a box from rest across a horizontal surface (friction is present) at a constant rate. The experiment is repeated, and all conditions remain the same with the exception that the horizontal force is doubled. What happens to the box's acceleration?

a) It increases to more than double its original value.
b) It increases to exactly double its original value.
c) It increases to less than double its original value.
d) It increases somewhat.

Answer: a Difficulty: 2

86. During the investigation of a traffic accident, police find skid marks 90.0 m long. They determine the coefficient of friction between the car's tires and the roadway to be 0.500 for the prevailing conditions. Estimate the speed of the car when the brakes were applied.

a) 9.49 m/s
b) 21.0 m/s
c) 29.7 m/s
d) 42.0 m/s

Answer: c Difficulty: 2

87. A bulldozer drags a log weighing 500 N along a rough surface. The cable attached to the log makes an angle of 30.0° with the ground. The coefficient of static friction between the log and the ground is 0.500. What minimum tension is required in the cable in order for the log to begin to move?

a) 224 N
b) 268 N
c) 289 N
d) 500 N

Answer: a Difficulty: 3

88. A wooden block slides directly down an inclined plane, at a constant velocity of 6.0 m/s. What is the coefficient of kinetic friction, if the plane makes an angle of 25° with the horizontal?

a) 0.47
b) 0.42
c) 0.37
d) 0.91

Answer: a Difficulty: 2

89. A rope one meter long rests on a table where the coefficient of friction is 0.50. What maximum length of rope can hang over the side before the whole rope will slip off?

a) 33 cm
b) 40 cm
c) 50 cm
d) 67 cm

Answer: a Difficulty: 3

Chapter 5: Circular Motion; Gravitation

MULTIPLE CHOICE

1. An object moves with a constant speed of 20 m/s on a circular track of radius 100 m. What is the acceleration of the object?

a) zero
b) 0.40 m/s^2
c) 2.0 m/s^2
d) 4.0 m/s^2

Answer: d Difficulty: 1

2. The maximum speed around a level curve is 30.0 km/h. What is the maximum speed around a curve with twice the radius? (Assume all other factors remain unchanged.)

a) 42.4 km/h
b) 45.0 km/h
c) 60.0 km/h
d) 120 km/h

Answer: a Difficulty: 2

3. A point on a wheel rotating at 5.00 rev/s is located 0.200 m from the axis. What is the centripetal acceleration?

a) 0.050 m/s^2
b) 1.35 m/s^2
c) 48.0 m/s^2
d) 198 m/s^2

Answer: d Difficulty: 2

4. A car goes around a 150 m radius curve with a constant speed of 30 m/s. What is its acceleration?

a) 0
b) 0.17 m/s^2
c) 5.0 m/s^2
d) 6.0 m/s^2

Answer: d Difficulty: 1

5. The banking angle in a turn on the Olympic bobsled track is not constant, but increases upward from the horizontal. Coming around a turn, the bobsled team will intentionally "climb the wall," then go lower coming out of the turn. Why do they do this?

a) To give the team better control, because they are able to see ahead of the turn.
b) To prevent the bobsled from turning over.
c) To take the turn at a faster speed.
d) To reduce the g-force on them.

Answer: c Difficulty: 1

6. A roller coaster car is on a track that forms a circular loop in the vertical plane. If the car is to just maintain contact with track at the top of the loop, what is the minimum value for its centripetal acceleration at this point?

a) g downward
b) 0.5g downward
c) g upward
d) 2g upward

Answer: a Difficulty: 2

7. A car is negotiating a flat curve of radius 50 m with a speed of 20 m/s. The centripetal force provided by friction is $1.2X10^4$ N. What is the mass of the car?

a) 500 kg
b) 1000 kg
c) 1500 kg
d) 2000 kg

Answer: c Difficulty: 2

8. What is the centripetal acceleration of a point on the perimeter of a bicycle wheel of diameter 70 cm when the bike is moving 8.0 m/s?

a) 91 m/s^2
b) $1.8X10^2$ m/s^2
c) $2.1X10^2$ m/s^2
d) $2.7X10^2$ m/s^2

Answer: b Difficulty: 2

9. Two horizontal curves on a bobsled run are banked at the same angle, but one has twice the radius of the other. The safe speed (no friction needed to stay on the run) for the smaller radius curve is v. What is the safe speed on the larger radius curve?

a) approximately 0.707v
b) 2v
c) approximately 1.41v
d) 0.5v

Answer: c Difficulty: 2

10. What force is needed to make an object move in a circle?

a) kinetic friction
b) static friction
c) centripetal force
d) weight

Answer: c Difficulty: 1

11. How many revolutions per minute must a circular, rotating spacestation of radius 1000 m rotate to produce an artificial gravity of $9.80 m/s^2$?

a) 0.65 rpm
b) 0.75 rpm
c) 0.85 rpm
d) 0.95 rpm

Answer: d Difficulty: 2

12. A horizontal curve on a bobsled run is banked at a 45° angle. When a bobsled rounds this curve at the curve's safe speed (no friction needed to stay on the run), what is its centripetal acceleration?

a) 1.0 g
b) 2.0 g
c) 0.5 g
d) None of the above

Answer: a Difficulty: 2

13. A car traveling 20 m/s rounds an 80-m radius horizontal curve with the tires on the verge of slipping. How fast can this car round a second curve of radius 320 m? (Assume the same coefficient of friction between the car's tires and each road surface.)

a) 20 m/s
b) 40 m/s
c) 80 m/s
d) 160 m/s

Answer: b Difficulty: 1

14. A roller coaster car (mass = M) is on a track that forms a circular loop (radius = r) in the vertical plane. If the car is to just maintain contact with the track at the top of the loop, what is the minimum value for its speed at that point?

a) rg
b) $(rg)^{1/2}$
c) $(2rg)^{1/2}$
d) $(0.5rg)^{1/2}$

Answer: b Difficulty: 2

15. A motorcycle has a mass of 250 kg. It goes around a 13.7 m radius turn at 96.5 km/h. What is the centripetal force on the motorcycle?

a) 719 N
b) $2.95X10^3$ N
c) $1.31X10^4$ N
d) $4.31X10^4$ N

Answer: c Difficulty: 2

16. A 0.50-kg mass is attached to the end of a 1.0-m string. The system is whirled in a horizontal circular path. If the maximum tension that the string can withstand is 350 N. What is the maximum speed of the mass if the string is not to break?

a) 700 m/s
b) 26 m/s
c) 19 m/s
d) 13 m/s

Answer: b Difficulty: 2

17. The maximum force a pilot can stand is about seven times his weight. What is the minimum radius of curvature that a jet plane's pilot, pulling out of a vertical dive, can tolerate at a speed of 250 m/s?

a) 4.25 m
b) 3.64 m
c) 1060 m
d) 911 m

Answer: c Difficulty: 2

18. A jet plane flying 600 m/s experiences an acceleration of 4g when pulling out of the dive. What is the radius of curvature of the loop in which the plane is flying?

a) 640 m
b) 1200 m
c) 7100 m
d) 9200 m

Answer: d Difficulty: 1

19. A pilot makes an outside vertical loop (in which the center of the loop is beneath him) of radius 3200 m. At the top of his loop he is pushing down on his seat with only one-half of his normal weight. How fast is he going?

a) 5.0 m/s
b) 25 m/s
c) 125 m/s
d) 625 m/s

Answer: c Difficulty: 1

20. A car goes around a curve of radius r at a constant speed v. Then it goes around a curve of radius 2r at speed 2v. What is the centripetal acceleration on the car as it goes around the second curve, compared to the first?

a) one fourth as big
b) one half as big
c) twice as big
d) four times as big

Answer: c Difficulty: 2

21. A car goes around a curve of radius r at a constant speed v. What is the direction of the net force on the car?

a) toward the curve's center
b) away from the curve's center
c) toward the front of the car
d) toward the back of the car

Answer: a Difficulty: 2

22. If a car goes around a curve at half the speed, the centripetal force on the car is
a) twice as big.
b) Four times as big.
c) half as big.
d) one-fourth as big.

Answer: d Difficulty: 1

23. A car goes around a curve of increasing radius. What happens to the centripetal force on the car?

a) It decreases.
b) It increases.
c) It remains constant.
d) It is impossible to predict because it depends on other factors not given here.

Answer: a Difficulty: 1

24. Suppose a satellite were orbiting the Earth just above the surface. What is its centripetal acceleration?

a) smaller than g
b) equal to g
c) larger than g
d) Impossible to say without knowing the mass.

Answer: b Difficulty: 2

25. A car goes around a flat curve of radius 50 m at a speed of 14 m/s. What must be the minimum coefficient of friction between the tires and the road for the car to make the turn?

a) 0.20
b) 0.40
c) 0.60
d) 0.80

Answer: c Difficulty: 2

26. A pilot executes a vertical dive, then follows a semi-circular arc until it is going straight up. Just as the plane is at its lowest point, the force on him is

a) less than mg, and pointing up.
b) less than mg, and pointing down.
c) more than mg, and pointing up.
d) more than mg, and pointing down.

Answer: c Difficulty: 2

27. A car goes around a curve of radius r at a constant speed v. Then it goes around a curve of radius 2r at speed v. What is the centripetal force on the car as it goes around the second curve, compared to the first?

a) one-fourth as big
b) one-half as big
c) twice as big
d) four times as big

Answer: b Difficulty: 2

28. What minimum banking angle is required for an olympic bobsled to negotiate a 100-m radius turn at 35 m/s without skidding? (Ignore friction.)

a) 31°
b) 41°
c) 51°
d) 61°

Answer: c Difficulty: 2

29. A stone, of mass m, is attached to a strong string and whirled in a vertical circle of radius r. At the exact top of the path the tension in the string is 3 times the stone's weight. The stone's speed at this point is given by

a) $2(gr)^{1/2}$
b) $(2gr)^{1/2}$
c) $(gr)^{1/2}$
d) 2gr

Answer: a Difficulty: 2

30. Consider a particle moving with constant speed such that its acceleration of constant magnitude is always perpendicular to its velocity.

a) It is moving in a straight line.
b) It is moving in a circle.
c) It is moving in a parabola.
d) None of the above is definitely true all of the time.

Answer: b Difficulty: 2

31. A coin of mass m rests on a turntable a distance r from the axis of rotation. The turntable rotates with a frequency of f. What is the minimum coefficient of static friction between the turntable and the coin if the coin is not to slip?

a) $(4\pi^2f^2r)/g$
b) $(4\pi^2fr^2)/g$
c) $(4\pi f^2r)/g$
d) $(4\pi fr^2)/g$

Answer: a Difficulty: 2

32. A car is moving with a constant speed v around a level curve. The coefficient of friction between the tires and the road is 0.40. What i the minimum radius of the curve if the car is to stay on the road?

a) $0.40v^2/g$
b) v^2/g
c) $2.5v^2/g$
d) $2v^2/g$

Answer: c Difficulty: 2

33. An object moves in a circular path at a constant speed. Consider the direction of the object's velocity and acceleration vectors.

a) Both vectors point in the same direction.
b) The vectors point in opposite directions.
c) The vectors are perpendicular.
d) The question is meaningless, since the acceleration is zero.

Answer: c Difficulty: 2

34. A curve of radius 80 m is banked at 45°. Suppose that an ice storm hits, and the curve is effectively frictionless. What is the safe spee with which to take the curve without either sliding up or down?

a) 9.4 m/s
b) 28 m/s
c) $7.8X10^2$ m/s
d) The curve cannot be taken safely.

Answer: b Difficulty: 2

35. A car of mass m goes around a banked curve of radius r with speed v. If the road is frictionless due to ice, the car can still negotiate the curve if the horizontal component of the normal force on the car from the road is equal in magnitude to
a) mg/2
b) mg
c) mv^2/r
d) $\tan[v^2/(rg)]$

Answer: c Difficulty: 2

36. A frictionless curve of radius 100 m, banked at an angle of 45°, may be safely negotiated at a speed of

a) 22 m/s
b) 31 m/s
c) 44 m/s
d) 67 m/s

Answer: b Difficulty: 2

37. An object moving with constant speed in a circular path experiences

a) free fall.
b) constant acceleration.
c) linear acceleration.
d) centripetal acceleration.

Answer: d Difficulty: 1

38. Is it possible for an object moving around a circular path to have both centripetal and tangential acceleration?

a) No, because then the path would not be a circle.
b) No, an object can only have one or the other at any given time.
c) Yes, this is possible if the speed is constant.
d) Yes, this is possible if the speed is changing.

Answer: d Difficulty: 2

39. The hydrogen atom consists of a proton of mass $1.67\text{X}10^{-27}$ kg and an orbiting electron of mass $9.11\text{X}10^{-31}$ kg. In one of its orbits, the electron is $5.3\text{X}10^{-11}$ m from the proton. What is the mutual attractive forces between the electron and proton?

a) $1.8\text{X}10^{-47}$ N
b) $3.6\text{X}10^{-47}$ N
c) $5.4\text{X}10^{-47}$ N
d) $7.0\text{X}10^{-47}$ N

Answer: b Difficulty: 1

40. The mass of the moon is $7.4\text{X}10^{22}$ kg and its mean radius is $1.75\text{X}10^{3}$ km. What is the acceleration due to gravity at the surface of the moon?

a) $2.8\text{X}10^{6}$ m/s^2
b) 9.80 m/s^2
c) 1.6 m/s^2
d) 0.80 m/s^2

Answer: c Difficulty: 1

41. The gravitational attractive force between two masses is F. If the masses are moved to half of their initial distance, what is the gravitational attractive force?

a) F/4
b) F/2
c) 2F
d) 4F

Answer: d Difficulty: 2

42. The gravitational attractive force between two masses is F. If the masses are moved to twice of their initial distance, what is the gravitational attractive force?

a) F/4
b) F/2
c) 2F
d) 4F

Answer: a Difficulty: 2

43. For a spacecraft going from the earth toward the sun, at what distance from the earth will the gravitational forces due to the sun and the earth cancel?
earth's mass: $M_e = 5.98\text{X}10^{24}$ kg
sun's mass: $M_s = 1.99\text{X}10^{30}$ kg
earth-sun distance: $r = 1.50\text{X}10^{11}$ m

a) $1.30\text{X}10^{8}$ m
b) $2.60\text{X}10^{8}$ m
c) $1.30\text{X}10^{10}$ m
d) $2.60\text{X}10^{10}$ m

Answer: b Difficulty: 2

44. A satellite encircles Mars at a distance above its surface equal to 3 times the radius of Mars. The acceleration of gravity of the satellite, as compared to the acceleration of gravity on the surface of Mars, is

a) zero.
b) the same.
c) one-third as much.
d) one-sixteenth as much

Answer: d Difficulty: 2

45. A hypothetical planet has a mass of half that of the earth and a radius of twice that of the earth. What is the acceleration due to gravity on the planet in terms of g, the acceleration due to gravity at the earth?

a) g
b) g/2
c) g/4
d) g/8

Answer: d Difficulty: 2

46. By how many newtons does the weight of a 100-kg person change when he goes from sea level to an altitude of 5000 m? (The mean radius of the earth is $6.38X10^6$ m.)

a) 0.6 N
b) 1.6 N
c) 2.6 N
d) 3.6 N

Answer: b Difficulty: 3

47. An object weighs 432 N on the surface of the earth. The earth has radius r. If the object is raised to a height of 3r above the earth's surface, what is its weight?

a) 432 N
b) 48 N
c) 27 N
d) 0 N

Answer: c Difficulty: 2

48. A satellite is in a low circular orbit about the earth (i.e, it just skims the surface of the earth). How long does it take to make one revolution around the earth? (The mean radius of the earth is $6.38X10^6$ m.)

a) 81 min
b) 85 min
c) 89 min
d) 93 min

Answer: b Difficulty: 2

49. A satellite is in a low circular orbit about the earth (i.e, it just skims the surface of the earth). What is the speed of the satellite? (The mean radius of the earth is $6.38X10^6$ m.)

a) 5.9 km/s
b) 6.9 km/s
c) 7.9 km/s
d) 8.9 km/s

Answer: c Difficulty: 2

50. The acceleration of gravity on the moon is one-sixth what it is on earth. The radius of the moon is one-fourth that of the earth. What is the moon's mass compared to the earth's?

a) 1/6
b) 1/16
c) 1/24
d) 1/96

Answer: d Difficulty: 2

51. The radius of the earth is R. At what distance above the earth's surface will the acceleration of gravity be 4.9 m/s^2?

a) 0.41 R
b) 0.50 R
c) 1.00 R
d) 1.41 R

Answer: a Difficulty: 2

52. A spaceship is traveling to the moon. At what point is it beyond the pull of earth's gravity?

a) When it gets above the atmosphere.
b) When it is half-way there.
c) When it is closer to the moon than it is to earth.
d) It is never beyond the pull of earth's gravity.

Answer: d Difficulty: 2

53. Satellite A has twice the mass of satellite B, and rotates in the same orbit.

a) The speed of B is twice the speed of A.
b) The speed of B is half the speed of A.
c) The speed of B is one-fourth the speed of A.
d) The speed of B is equal to the speed of A.

Answer: d Difficulty: 1

54. Two planets have the same surface gravity, but planet B has twice the radius of planet A. If planet A has mass m, what is the mass of planet B?

a) 0.707m
b) m
c) 1.41m
d) 4m

Answer: d Difficulty: 2

55. Two planets have the same surface gravity, but planet B has twice the mass of planet A. If planet A has radius r, what is the radius of planet B?

a) 0.707r
b) r
c) 1.41r
d) 4r

Answer: c Difficulty: 2

56. At a distance of 14000 km from some planet's center, the acceleration of gravity is 32 m/s^2. What is the acceleration of gravity at a point 28000 km from the planet's center?

a) 8.0 m/s^2
b) 16 m/s^2
c) 128 m/s^2
d) Cannot be determined from the information given.

Answer: a Difficulty: 2

57. The acceleration of gravity on the moon is one-sixth what it is on earth. An object of mass 72 kg is taken to the moon. What is its mass there?

a) 12 kg
b) 72 kg
c) 72 N
d) 12 N

Answer: b Difficulty: 2

58. Consider a small satellite moving in a circular orbit (radius r) about a spherical planet (mass M). Which expression gives this satellite's orbital velocity?

a) $v = GM/r$
b) $(GM/r)^{1/2}$
c) GM/r^2
d) $(GM/r^2)^{1/2}$

Answer: b Difficulty: 2

59. Two objects gravitationally attract each other. If the distance between their centers is cut in half, the gravitational force between them

a) quadruples.
b) doubles.
c) is cut in half.
d) is cut to one fourth.

Answer: a Difficulty: 1

60. A spherically symmetric planet has four times the earth's mass and twice its radius. If a jar of peanut butter weighs 12 N on the surface of the earth, how much would it weigh on the surface of this planet?

a) 6.0 N
b) 12 N
c) 24 N
d) 36 N

Answer: b Difficulty: 2

61. A spherically symmetric planet has twice the earth's mass and twice its radius. If a jar of peanut butter weighs 12 N on the surface of the earth, how much would it weigh on the surface of this planet?

a) 6.0 N
b) 12 N
c) 24 N
d) 36 N

Answer: a Difficulty: 2

62. A satellite is in circular orbit 230 km above the surface of the earth. It is observed to have a period of 89 min. What is the mass of the earth? (the mean radius of the earth is $6.38X10^6$ m.)

a) $5.0X10^{24}$ kg
b) $5.5X10^{24}$ kg
c) $6.0X10^{24}$ kg
d) $6.5X10^{24}$ kg

Answer: c Difficulty: 2

63. Europa, a moon of Jupiter, has an orbital diameter of $1.34X10^{9}$ m, and a period of 3.55 days. What is the mass of Jupiter?

a) $1.83X10^{27}$ kg
b) $1.85X10^{27}$ kg
c) $1.87X10^{27}$ kg
d) $1.89X10^{27}$ kg

Answer: d Difficulty: 2

64. An astronaut goes out for a "space-walk" at a distance above the earth equal to the radius of the earth. What is her acceleration due to gravity?

a) zero
b) g
c) g/2
d) g/4

Answer: d Difficulty: 2

65. Two objects, with masses m_1 and m_2, are originally a distance r apart. The magnitude of the gravitational force between them is F. The masses are changed to $2m_1$ and $2m_2$, and the distance is changed to 4r. What is the magnitude of the new gravitational force?

a) F/16
b) F/4
c) 16F
d) 4F

Answer: b Difficulty: 2

66. The earth has radius r. A satellite of mass 100 kg is at a point 3r above the earth's surface. What is the satellite's weight?

a) 61 N
b) 110 N
c) 9000 N
d) 16000 N

Answer: a Difficulty: 2

67. Two objects attract each other gravitationally. If the distance between their centers doubles, the gravitational force

a) quadruples.
b) doubles.
c) is cut in half.
d) is cut to a fourth.

Answer: d Difficulty: 1

68. A planet is discovered to orbit around a star in the galaxy Andromeda, with the same orbital diameter as the earth around our sun. If that star has 4 times the mass of our Sun, what will the period of revolution of that new planet be, compared to the earth's orbital period?

a) One-fourth as much
b) One-half as much
c) Twice as much
d) Four times as much

Answer: b Difficulty: 2

69. As a rocket moves away from the Earth's surface, the rocket's weight

a) increases.
b) decreases.
c) remains the same.
d) depends on how fast it is moving.

Answer: b Difficulty: 1

70. Two objects, with masses m_1 and m_2, are originally a distance r apart. The gravitational force between them has magnitude F. The second object has its mass changed to $2m_2$, and the distance is changed to r/4. What is the magnitude of the new gravitational force?

a) F/32
b) F/16
c) 16F
d) 32F

Answer: d Difficulty: 2

71. Compared to its mass on the earth, the mass of an object on the moon is

a) less.
b) more.
c) the same.
d) half as much.

Answer: c Difficulty: 1

72. What is the gravitational force on a 70-kg person, due to the moon? The mass of the moon is $7.36X10^{22}$ kg and the distance to the moon is 3.82X10 m.

a) 0.24 N
b) 0.024 N
c) 0.0024 N
d) 0.00024 N

Answer: c Difficulty: 1

73. The speed of Halley's comet, while traveling in its elliptical orbit around the sun,

a) is constant.
b) increases as it nears the sun.
c) decreases as it nears the sun.
d) is zero at two points in the orbit.

Answer: b Difficulty: 2

74. Who was the first person to realize that the planets move in elliptical paths around the sun?

a) Kepler
b) Brahe
c) Einstein
d) Copernicus

Answer: a Difficulty: 1

75. Two moons orbit a planet in nearly circular orbits. Moon A has orbital radius r, and moon B has orbital radius 4r. Moon A takes 20 days to complete one orbit. How long does it take moon B to complete an orbit?

a) 20 days
b) 80 days
c) 160 days
d) 320 days

Answer: c Difficulty: 2

76. Let the average orbital radius of a planet be r. Let the orbital period be T. What quantity is constant for all planets orbiting the sun?

a) T/R
b) T/R^2
c) T^2/R^3
d) T^3/R^2

Answer: c Difficulty: 2

77. The average distance from the earth to the sun is defined as one "astronomical unit" (AU). An asteroid orbits the sun in one-third of a year. What is the asteroid's average distance from the sun?

a) 0.19 AU
b) 0.48 AU
c) 2.1 AU
d) 5.2 AU

Answer: b Difficulty: 2

78. The planet Jupiter is 7.78×10^{11} m from the sun. How long does it take for Jupiter to orbit once about the sun? (The distance from the earth to the sun is 1.50×10^{11} m.)

a) 1 yr
b) 3 yr
c) 6 yr
d) 12 yr

Answer: d Difficulty: 2

79. It takes the planet Jupiter 12 years to orbit the sun once. What is the average distance from Jupiter to the sun? (The distance from the earth to the sun is 1.5×10^{11} m.)

a) 3.9×10^{11} m
b) 5.2×10^{11} m
c) 7.9×10^{11} m
d) 9.7×10^{11} m

Answer: c Difficulty: 2

80. The innermost moon of jupiter orbits the planet with a radius of 422 km and a period of 1.77 days. What is the mass of jupiter?

a) 1.3×10^{27} kg
b) 1.5×10^{27} kg
c) 1.7×10^{27} kg
d) 1.9×10^{27} kg

Answer: d Difficulty: 2

Worksheet AP Physics

2 Imagine that you are holding a book weighing 6 N at rest on the palm of your hand. Complete the following sentences:

a) A downward force of magnitude 6 N is exerted on the book by ______.

b) An upward force of magnitude ______ is exerted on ______ by the hand.

c) Is the upward force in part (b) the reaction to the downward force in part (a)?

d) The reaction to the force in part (a) is a force of magnitude ______, exerted on ______ by ______. Its direction is ______.

e) The reaction to the force in part (b) is a force of magnitude ______, exerted on ______ by ______. Its direction is ______.

f) The forces in parts (a) and (b) are equal and opposite because of Newton's ______ law.

g) The forces in parts (b) and (e) are equal and opposite because of Newton's ______ law.

Suppose now that you exert an upward force of magnitude 8 N on the book.

h) Does the book remain in equilibrium?

i) Is the force exerted on the book by the hand equal and opposite to the force exerted on the book by the earth?

j) Is the force exerted on the book by the earth equal and opposite to the force exerted on the earth by the book?

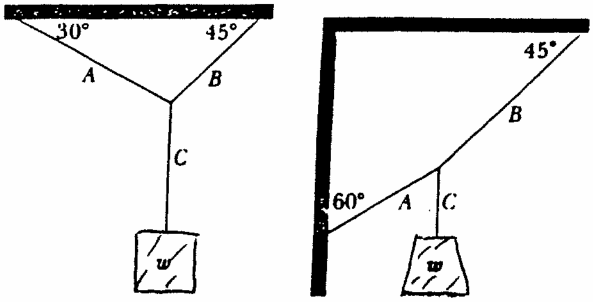
k) Is the force exerted on the book by the hand equal and opposite to the force exerted on the hand by the book?

Finally, suppose that you snatch your hand away while the book is moving upward.

l) How many forces then act on the book?

m) Is the book in equilibrium?

5–12 Find the tension in each cord in Fig. 5–18 if the weight of the suspended object is w.



(a) (b)

FIGURE 5–18

5–46

a) Block A in Fig. 5–28 weighs 100 N. The coefficient of static friction between the block and the surface on which it rests is 0.40. The weight w is 30.0 N, and the system is in equilibrium. Find the friction force exerted on block A.

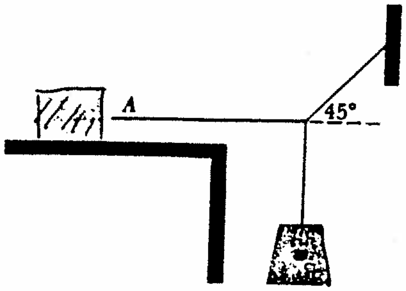


FIGURE 5–28

b) Find the maximum weight w for which the system will remain in equilibrium.

5–25 The first two steps in the solution of Newton's second law problems are to select an object for analysis and then to draw free-body diagrams for that object. Draw a free-body diagram for each of the following situations:

a) a mass M sliding down a frictionless inclined plane of angle θ;

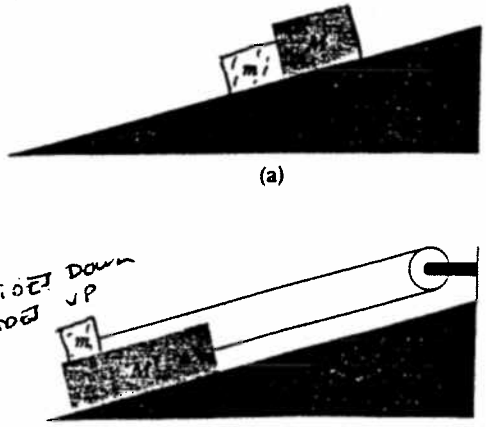
b) a mass M sliding up a frictionless inclined plane of angle θ;

c) a mass M sliding up an inclined plane of angle θ with kinetic friction present;

d) masses M and m sliding down an inclined plane of angle θ with friction present, as shown in Fig. 5–25a. Here draw free-body diagrams for both m and M. Identify the forces that are action–reaction pairs.

e) Draw free-body diagrams for masses m and M shown in Fig. 5–25b. Identify all action–reaction pairs. There are frictional forces between all surfaces in contact. The pulley is frictionless and massless.

In all cases, be sure you have the correct direction of the forces and are completely clear on what object is causing each force in your free-body diagram.



(a)

M SLIDES DOWN
m SLIDES UP

(b)

FIGURE 5–25

ANSWERS

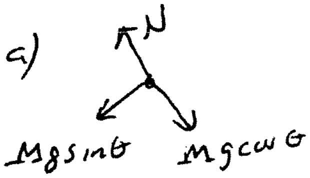
4-8)
- a) the earth
- b) 6 N, the book
- c) no
- d) 6 N, the earth, the book; upward
- e) 6 N, the hand, the book; downward
- f) first
- g) third
- h) no
- i) no
- j) yes
- k) yes
- l) gravity of the earth
- m) no

5-12) a) $T_A = .732w$ $T_B = .897w$ $T_c = w$

b) $T_A = 2.73w$ $T_B = 3.35w$ $T_c = w$

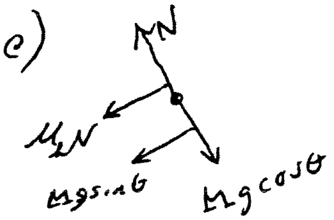
5-46) a) 30. N b) 40 N

5-27 a)

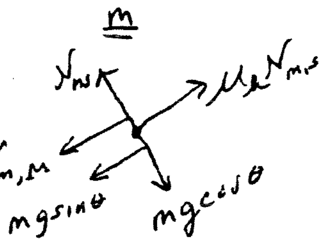


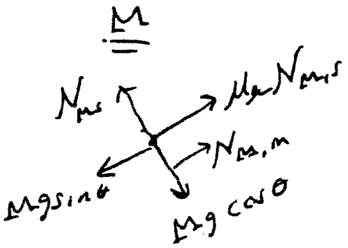
b) SAME AS A

c)

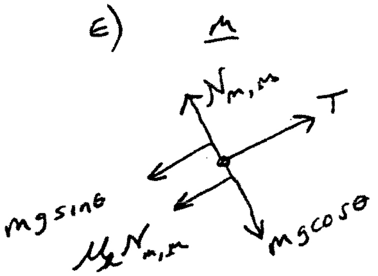


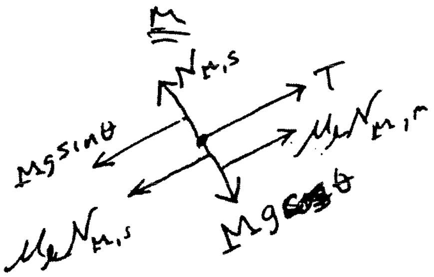
D)





E)

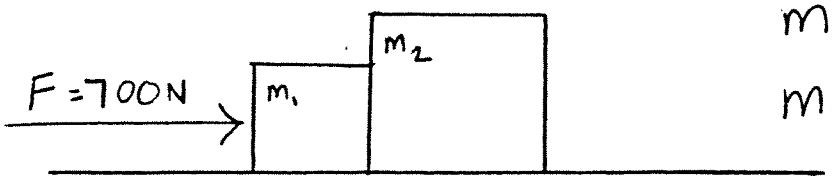




NAME: ______________________ DATE ____________

A.P. Physics B   Quiz: Newton's Laws AND Free Body Diagram

1. Consider the DIAGRAM Below:



$m_1 = 10\text{kg}$

$m_2 = 27\text{kg}$

- Coefficient Between m_1 AND the Surface $\mu_1 = 0.1$
- Coefficient Between m_2 AND the Surface $\mu_2 = 0.08$
- External Force on m_1 FROM the left $F = 700\text{N}$

A) Draw AN Accurate Free Body Diagram For each mass.

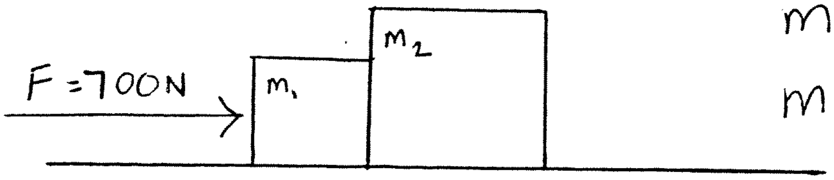
B) Calculate the Contact Force Between $M_1 + M_2$ and the Acceleration of the system.

Name: Key DATE ________

A.P. Physics B Quiz: Newton's Laws AND Free Body Diagrams

14 pts

1. Consider the Diagram Below:



$m_1 = 10$ kg

$m_2 = 27$ kg

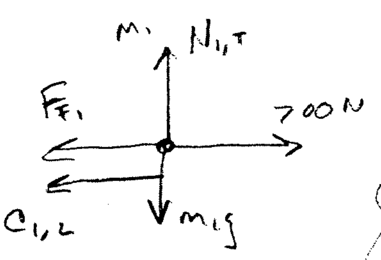
- Coefficient Between m_1 AND the surface $\mu_1 = 0.1$
- Coefficient Between m_2 AND the surface $\mu_2 = 0.08$
- External Force on m_1 FROM the left F = 700 N

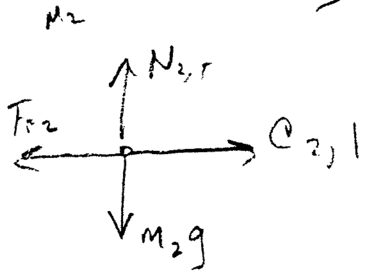
A) Draw AN Accurate Free Body Diagram For each mass. 5 pts

B) Calculate the Contact Force Between $M_1 + M_2$ and the Acceleration of the system. 5 pts

$\xrightarrow{a}$

$C_{21} = -C_{12}$





y

$N_{1,T} = m_1 g$

x

$-F_{F_1} - C_{1,2} + 700 = m_1 a$

$-\mu_1 m_1 g - C_{1,2} + 700 = m_1 a$

$_1 m_1 g - \left[M_2 a + \mu_2 M_2 g\right] + 700 = m_1 a$

$-\mu_1 m_1 g - M_2 a - \mu_2 M_2 g + 700 = m_1 a$

$-\mu_1 m_1 g - \mu_2 m_2 g + 700 = m_1 a + m_2 a$

$a = \dfrac{-\mu_1 m_1 g - \mu_2 m_2 g + 700}{\ }$ $= \boxed{+18 \text{ m/s}^2}$ /

y

$N_{2,T} = M_2 g$

x

$-F_{F_2} + C_{21} = M_2 a$

$-\mu_2 M_2 g + C_{21} = M_2 a$

$C_{21} = M_2 a + \mu_2 M_2 g$

$\boxed{= 507N}$ /

Name ______________________________ Per. ____ date _____
DiBucci

Applications of Newton's laws Worksheet

1. An 8.5-kg hanging block is connected by a string over a pulley to a 6.2-kg block sliding on a flat table (Fig. P5.47). If the coefficient of sliding friction is 0.20, find the tension in the string. T=42.16 N

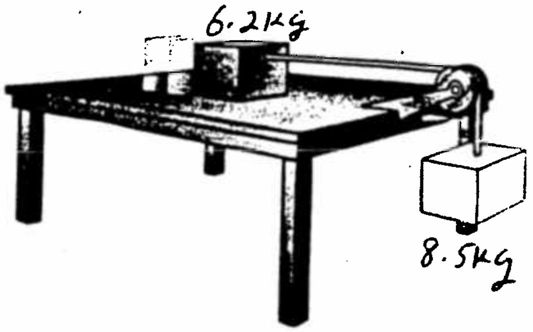


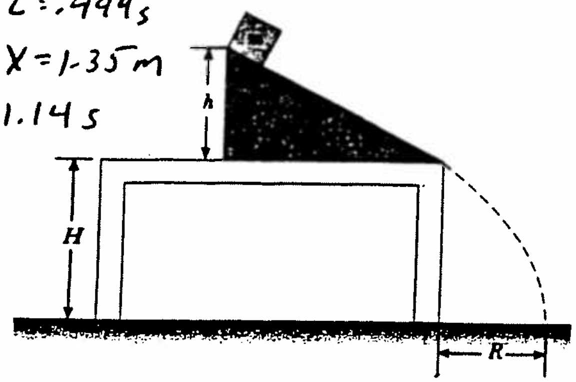
FIGURE P5.47

2. A block of mass m = 2.0 kg is released from rest h = 0.5 m from the surface of a table, at the top of a θ = 30° incline as shown in Figure P5.41. The incline is fixed on a table of height H = 2.0 m, and the incline is frictionless. (a) Determine the acceleration of the block as it slides down the incline. (b) What is the speed of the block as it leaves the incline? (c) How far from the table will the block hit the floor? (d) How much time has elapsed between the block is released and when it hits the floor? (e) Does the mass of the block affect any of the above calculations? 4.9 m/s²,

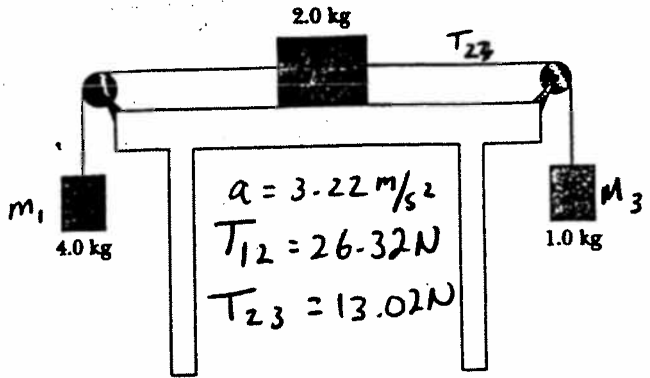
t = .499 s

X = 1.35 m

1.14 s



3. Three masses are connected on the table as shown in Figure P5.59. The table has a coefficient of sliding friction of 0.35. The three masses are 4.0 kg, 1.0 kg, and 2.0 kg, respectively, and the pulleys are frictionless. (a) Determine the acceleration of each block and their directions. (b) Determine the tensions in the two cords.



$a = 3.22\ m/s^2$

$T_{12} = 26.32N$

$T_{23} = 13.02N$

4. Two blocks of mass 3.50 kg and 8.00 kg are connected by a massless string that passes over a frictionless pulley (Fig. P5.87). The inclines are frictionless. Find (a) the magnitude of the acceleration of each block and (b) the tension in the string.

T = 27.4 a = 2.2 m/s²

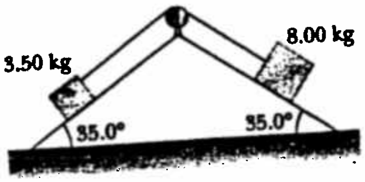


FIGURE P5.87

5. The system shown in Figure P5.87 has an acceleration of magnitude 1.5 m/s². Assume the coefficient of kinetic friction between block and incline is the same for both inclines. Find (a) the coefficient of kinetic friction and (b) the tension in the string.

$\mu = .628$

T = 42.5 N

Name ________________________________ Per. ____ date ____
DiBucci

Applications of Newton's laws Worksheet

1. An 8.5-kg hanging block is connected by a string over a pulley to a 6.2-kg block sliding on a flat table (Fig. P5.47). If the coefficient of sliding friction is 0.20, find the tension in the string. T=42.16N

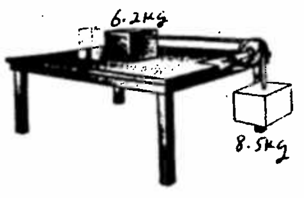


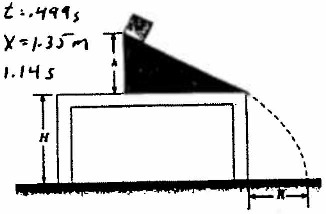
FIGURE P5.47

2, A block of mass m = 2.0 kg is released from rest h = 0.5 m from the surface of a table, at the top of a θ = 30° incline as shown in Figure P5.41. The incline is fixed on a table of height H = 2.0 m, and the incline is frictionless. (a) Determine the acceleration of the block as it slides down the incline. (b) What is the speed of the block as it leaves the incline? (c) How far from the table will the block hit the floor? (d) How much time has elapsed between when the block is released and when it hits the floor? (e) Does the mass of the block affect any of the above calculations? 4.9m/s²,

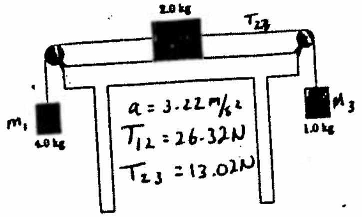
t=.499s

X=1.35m

1.14s



3. Three masses are connected on the table as shown in Figure P5.59. The table has a coefficient of sliding friction of 0.35. The three masses are 4.0 kg, 1.0 kg, and 2.0 kg, respectively, and the pulleys are frictionless. (a) Determine the acceleration of each block and their directions. (b) Determine the tensions in the two cords.



a = 3.22 m/s²

T_{12} = 26.32N

T_{23} = 13.02N

4. Two blocks of mass 3.50 kg and 8.00 kg are connected by a massless string that passes over a frictionless pulley (Fig. P5.87). The inclines are frictionless. Find (a) the magnitude of the acceleration of each block and (b) the tension in the string.

T=27.4 a=2.2 m/s²

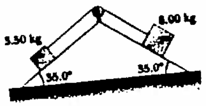


FIGURE P5.87

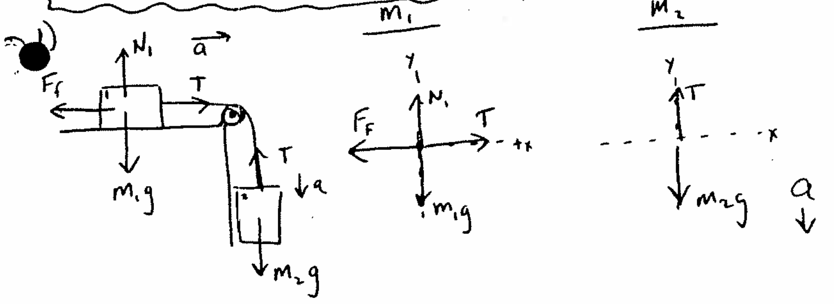
5. The system shown in Figure P5.87 has an acceleration of magnitude 1.5 m/s². Assume the coefficient of kinetic friction between block and incline is the same for both inclines. Find (a) the coefficient of kinetic friction and (b) the tension in the string.

μ=.628

T=42.5N

Solutions to Applications of Newton's Laws - DiBucci

1)



m_1

$\Sigma F_y = 0$

$N_1 - m_1 g = 0$

$\boxed{N_1 = m_1 g}$

$\Sigma F_x = m_1 a$

$T - F_F = M_1 a$

$T - \mu N_1 = M_1 a$

$T - \mu M_1 g = M_1 a$

$\boxed{T = M_1 a + \mu M_1 g}$

M_2

$\Sigma F_y = M_2(-a)$

$T - M_2 g = M_2(-a)$

$\boxed{T = -M_2 a + M_2 g}$

combine

$-M_2 a + M_2 g = M_1 a + \mu M_1 g$

$-M_2 a - M_1 a = \mu M_1 g - M_2 g$

$-a(M_2 + M_1) = g(\mu M_1 - M_2)$

$$a = \frac{g(M_2 - \mu M_1)}{(M_2 + M_1)}$$

$$a = \frac{(9.8)(8.5_{kg} - (.2)(6.2_{kg}))}{[8.5_{kg} + 6.2_{kg}]}$$

(1) $a = 4.84 m/s$

$\therefore$ $T = -M_2 a + M_2 g$

$= M_2(g - a) =$

$\boxed{T = 42.16N}$

continued μ-same for Both inclines

#1) $T - \mu N_1 - M_1 g \sin 35^\circ = M_1 a$

$T - \mu \underbrace{M_1 g \cos\theta}_{\text{From \#2}} - M_1 g \sin\theta = M_1 a$

$T = M_1 a + M_1 g \sin 35^\circ + \mu M_1 g \cos 35^\circ$ — 5)

#3) $M_2 g \sin 35^\circ - T - \mu N = M_2 a$

$M_2 g \sin 35^\circ - T - \mu \underbrace{m g \cos\theta}_{\#4} = M_2 a$

$-T = M_2 a + \mu m g \cos 35^\circ - M_2 g \sin 35^\circ$

$T = -M_2 a - \mu m_2 g \cos 35^\circ + M_2 g \sin 35^\circ$ –6

plus in #'s

5) $T = 5.25N + 19.6_N + \mu(28.1)$ ..

$T = 24.85_N + 28.1\mu$

#6 $T = -12N - \mu(64.2N) + 45N$

$T = 33N - \mu(64.2N)$

set equal

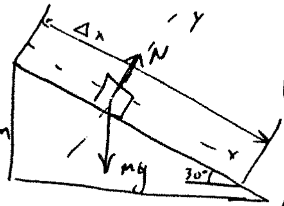
$24.85 + (28.1)\mu = 33N - (64.2)\mu$

$-8.15_N = -.92.3\mu$

$\mu = 0.088$

$T = 27.3N$

2)



$\Sigma F_x = ma_x$

$mg\sin\theta = m\,a$

$a = g\sin\theta$

$\sin 30 = \frac{.5}{\Delta x}$

$\Delta x = \frac{.5}{\sin\theta}$

$= .5/\sin 30° = 1m$

a) $a = g\sin\theta =$

$= 9.8\sin 30° = 4.9 m/s^2$

B) $V_f^2 = V_0^2 + 2a\Delta x$

$V_f = \sqrt{0 + 2(4.9 m/s^2)(\quad)} =$

$\boxed{3.13 m/s}$

c) $H = \Delta Y = -2M$

$\Delta Y = V_{0y}t - \frac{1}{2}gt^2$

$\Delta Y = V_{0y}t - \frac{1}{2}gt^2$

$-2m = (-3.13 m/s)(\sin 30°)t - 4.9t^2$

$-2 = -(1.57 m/s)t - 4.9t^2$

$-4.9t^2 - 1.57t + 2 = 0$

$\boxed{t = 0.499 s}$

$\Delta X = V_x t = (3.13 m/s)(\cos 30°)(.499 s)$

$\boxed{= 1.35 m}$

D)

)n incline

$\Delta x = v_0t + \frac{1}{2}at^2$

$1 = +\cancel{\frac{1}{2}}(4.9)t^2$

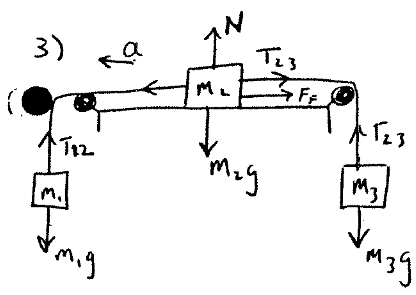
$t = \sqrt{.408 s^2}$

$= .639 s$

$T_{total} = .639s + 0.499s = \boxed{1.14 s}$

(2)

3)

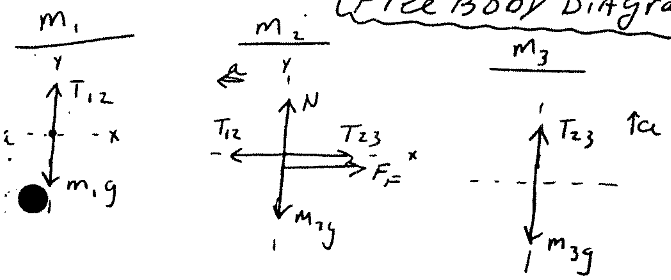


$M_1 = 4kg$

$M_2 = 2kg$

$M_3 = 1kg$

Free Body Diagrams



EQUATIONS

n_1

$\Sigma F_y = m_1(-a)$

$T_{12} - m_1 g = -m_1 a$

m_3

$T_{23} - M_3 g = M_3 (+a)$

m_2

$\Sigma F_y = 0$

$N - M_2 g = 0$

$\boxed{N = M_2 g}$

$\Sigma F_x = M_2(-a)$

$-T_{12} + T_{23} + F_F = m_2(-a)$

(3)

$\boxed{\text{3 Continued}}$

$$\begin{cases} T_{12} - m_1 g = -m_1 a & \text{———— (1)} \\ T_{23} - M_3 g = M_3 a & \text{———— (2)} \\ N = M_2 g & \text{———— (3)} \\ -T_{12} + T_{23} + F_F = -M_2 a & \xrightarrow{(4)} \text{START with this one} \end{cases}$$

$$-T_{12} + T_{23} + \mu \overset{\text{sub in eq. \# 3}}{N} = -M_2 a$$

$$-T_{12} + \underset{\text{sub in eq \# 2 [solve for } T_{23}]}{T_{23}} + \mu(M_2 g) = -M_2 a$$

$$-\underset{\text{sub in eq \# 1 solve for } T_{12}}{T_{12}} + [M_3 a + M_3 g] + \mu M_2 g = -M_2 a$$

$$-[-m_1 a + m_1 g] + m_3 a + m_3 g + \mu M_2 g = -M_2 a$$

$$m_1 a - m_1 g + m_3 a + m_3 g + \mu M_2 g = -M_2 a$$

Collect terms

$$m_1 a + m_2 a + m_3 a = +m_1 g - m_3 g - \mu m_2 g$$

$$a(m_1 + m_2 + m_3) = g(m_1 - m_3 - \mu m_2)$$

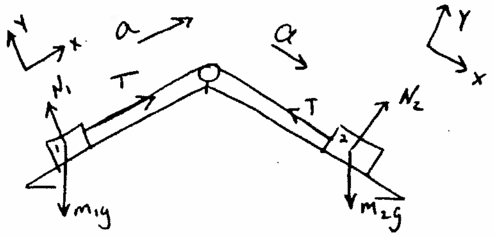
$$a = \frac{g(m_1 - m_3 - \mu m_2)}{(m_1 + m_2 + m_3)} = \boxed{3.22 \, m/s^2}$$

(4)

$$T_{12} = -m_1 a + m_1 g$$
$$= m(g-a) = (4kg)(9.8 - 3.22)$$
$$= 26.32N$$

$$T_{23} = m_3(a+g) = 13.02N$$

4.)



Axis System

$m_2 = 8kg$
$m_1 = 3.5kg$

m_1

$\Sigma F_x = m_1 a$

$-m_1 g \sin\theta_1 + T = m_1 a$

$\Sigma F_y = 0$
$N_1 - m_1 g \cos\theta_1 = 0$

m_2

$\Sigma F_x = m_2 a$

$-T + m_2 g \sin\theta_2 = m_2 a$

$\Sigma F_y = 0$
$N - m_2 g \cos\theta = 0$

EQUATIONS

$-m_1 g \sin 35° + T = m_1 a$ ——— (1)

$-T + m_2 g \sin 35° = m_2 a$ ——— (2)

$N_1 = m_1 g \cos 35°$ ——— (3)

$N_2 = m_2 g \cos 35°$ ——— (4)

4 continued

From #1
$T = m_1 a + m_1 g \sin 35°$
sub into eq #2

$-[m_1 a + m_1 g \sin 35°] + m_2 g \sin 35° = m_2 a$

$-m_1 a - m_1 g \sin 35° + m_2 g \sin 35° = m_2 a$

$-m_1 g \sin 35° + m_2 g \sin 35° = (m_1 + m_2) a$

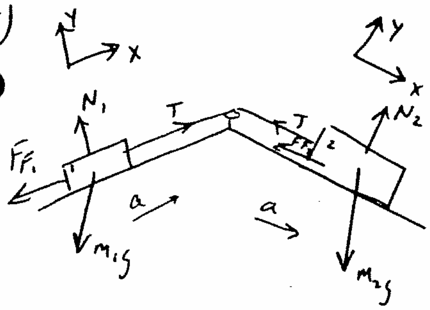
$$a = \frac{g \sin 35° (m_2 - m_1)}{(m_1 + m_2)}$$

$$a = \frac{9.8 \sin 35° (4.5kg)}{11.5kg} = \boxed{2.2 m/s^2}$$

$T = m_1(2.2) + m_1(9.8) \sin 35°$

$\boxed{T = 27.4N}$

5.)



$M_1 = 3.5kg$
$m_2 = 8kg$
$a = +1.5 m/s^2$
$\mu = ?$
$T = ?$

m_1

$T - F_{F_1} - m_1 g \sin 35° = m_1 a$ ——— (1)

$N_1 - m_1 g \cos\theta = 0$ ——— (2)

m_2

x: $m_2 g \sin 35° - T - F_{F_2} = m_2 a$ ——— (3)

y: $N - m_2 g \cos 35° = 0$ ——— (4)