Physics 2 - Classical Mechanics (with Mr. Lim)
Practice questions - Circular Motion and Gravitation

INSTRUCTIONS: For each problem, draw an FBD, showing the forces involved. (You may or may not draw a diagram of the situation, depending on the question.) Show all your solutions and box your answers. Answer the problems in your notebook and submit a photocopy of your solutions, diagrams and answers during class (I will check that the photocopy is indeed from your notebook.)

Uniform Circular Motion

1. Calculate the centripetal force acting on a 1.5 kg object whirling at a speed of 2.3 m/s in a horizontal circle of radius 0.60 m. **13 N**
2. A car traveling at 14 m/s goes around an unbanked curve in the road that has a radius of 96 m. What is the centripetal acceleration? **20 m/s^2**
3. A plane makes a complete circle with a radius of 3622 m in 2.10 min. What is the speed of the plane? **181 m/s**
4. Calculate the centripetal force acting on a 925 kg car as it rounds an unbanked curve with a radius of 75 m at a speed of 22 m/s. **6.0 x 10^3 N**
5. A small plane makes a complete circle with a radius of 3282 m in 2.0 min. What is the centripetal acceleration of the plane? **9.0 m/s^2**
6. A car with a mass of 822 kg rounds an unbanked curve in the road at a speed of 28.0 m/s. If the radius of the curve is 105 m, what is the average centripetal force exerted on the car? **6.14 x 10^3 N**
7. An amusement park ride has a radius of 2.8 m. If the time of one revolution of a rider is 0.98 s, what is the speed of the rider? **18 m/s**
8. An electron (m = 9.11 x 10^{-31} kg) moves in a circle whose radius is 2.00 x 10^{-2} m. If the force acting on the electron is 4.60 x 10^{-14} N, what is the speed of the electron? **3.18 x 10^7 m/s**
9. A 925 kg car rounds an unbanked curve at a speed of 25 m/s. If the radius of the curve is 72 m, what is the minimum coefficient of friction between the car and the road required so that the car does not skid? **0.88**
10. A 2.7 x 10^3 kg satellite orbits the earth at a distance of 1.8 x 10^7 m from the earth's center at a speed of 4.7 x 10^3 m/s. What is the force acting on the satellite by the earth? **3.3 x 10^3 N**
11. An athlete whirls a 3.7 kg shot (for the shotput event) in a horizontal circle with a radius of 0.90 m. If the period of rotation is 0.30 s,
    a. What is the speed of the shot when released? **19 m/s**
    b. What is the centripetal force acting on the shot while it is rotated? **1.5 x 10^3 N**
    c. How far would the shot travel horizontally if it is released 1.2 m above the level ground? **9.3 m**
12. Calculate (a) the speed and (b) acceleration of a point on the circumference of a 33 1/3 phonograph record. The diameter of the record us 30.0 cm. (NOTE: 33 1/3 is the frequency that it turns – 33 1/3 revolutions per minute) **0.524 m/s, 1.83 m/s^2**
13. A string requires a 135 N force in order to break it. A 2.00 kg mass is tied to this string and whirled in a horizontal circle with a radius of 1.10 m. What is the maximum speed that the mass can be whirled without breaking the string? **8.62 m/s**
14. A 932 kg car is traveling around an unbanked curve that has a radius of 82 m. What is the maximum speed that this car can round this curve without skidding
    a. if the coefficient of friction is 0.95? **28 m/s**
    b. if the coefficient of friction is 0.40? **18 m/s**

Vertical Circular Motion

15. An object is swung in a vertical circle with a radius of 0.75 m. What is the minimum speed of the object at the top of the motion for the object to remain in its circular motion? **2.7 m/s**
16. A string requires a 135 N force in order to break it. A 2.00 kg mass is tied to this string and whirled in a vertical circle with a radius of 1.10 m. What is the maximum speed that this mass can be whirled without breaking the string? **7.97 m/s**

17. A 1.7 kg object is swung from the end of a 0.60 m string in a vertical circle. If the time of one revolution is 1.1 s, what is the tension in the string (assume uniform speed)
    a. when it is a the top? **17 N**
    b. when it is at the bottom? **5.0×10^7 N**
18. An 826 kg car traveling at a speed of 14.0 m/s goes over a hill. If the radius of the hill's curvature is 61.0 m, what is the force exerted on the road by the car at the crest of the hill? **5.45×10^3 N**
19. You are riding your bike on a track that forms a vertical circular loop. If the diameter of the loop is 10.0 m, how fast would you have to be traveling when you reached the top of the loop so that you would not fall? **7.00 m/s**
20. You are rotating a bucket of water in a vertical circle. Assuming that the radius of the rotation of the water is 0.95 m, what is the minimum velocity of the bucket at the top of its swing if the water is not to spill? **3.1 m/s**
21. A student has a weight of 655 N. While riding on a roller coaster this same student has an apparent weight of 1.96×10^3 N at the bottom of the dip that has a radius of 18.0 m. What is the speed of the roller coaster? **18.8 m/s**
22. An amusement park ride spins in a vertical circle. If the diameter of this ride is 5.80 m, what minimum speed must the ride travel so that a 75.0 kg student will remain against the wall when he is in the high position? **5.33 m/s**
23. A string requires a 186 N force in order to break. A 1.50 kg mass is tied to this string and whirled in a vertical circle with a radius of 1.90 m. What is the maximum speed that this mass can be whirled without breaking the string? **14.7 m/s**
24. A 2.2 kg object is whirled in a vertical circle whose radius is 1.0 m. If the time of one revolution is 0.97 s, what is the tension in the string (assume uniform speed)
    a. when it is at the top? **70.7 N**
    b. when it is at the bottom? **114 N**
25. A wheel-shaped space station whose radius is 48 m produces artificial gravity by rotating. How fast must this station rotate so that the crew members have the same apparent weight in this station as they have on earth? **22 m/s**
26. A 915 kg car goes over a hill. If the radius of this curve is 43 m, how fast must the car travel so that it exerts no force on the road at the crest? **21 m/s**

Banked Curves

27. Calculate the angle at which a frictionless curve must be banked if a car is to round it safely at a speed of 22 m/s (79 km/h). The radius of the curve is 475 m. **5.9°**
28. A car is rounding a 515 m frictionless curve in the highway. If the curve is banked at an angle of 12.0°, what is the maximum speed of the car? **32.8 m/s (118 km/h)**
29. What is the maximum speed of a car rounding a 125 m curve in the highway under very icy conditions if the banking angle is 20.0°? **21.1 m/s**
30. A 745 m curve on a racetrack is to be banked for cars traveling at 90.0 m/s. At what angle should it be banked if it is going to be used under very icy conditions? **47.9°**
31. An airplane traveling at a speed of 115 m/s makes a complete horizontal turn in 2.00 min. What is the banking angle? **31.5°**
32. A car rounds a very icy curve in the highway which is banked at an angle of 18° while traveling at a speed of 28 m/s (100 km/h). What is the minimum radius of the curve? **2.5×10^2 m**
33. An airplane flying at a speed of 205 m/s makes a complete horizontal turn while banking at 29.0°. What is the radius of the turn? **7.73×10^3 m**

Kepler's Laws

34. Knowing that the earth's orbital radius is 1.49×10^{11} m and its period of revolution is 1.00 year, calculate the period of revolution of Jupiter, whose orbital radius is 7.78×10^{11} m. **11.9 years**

35. Calculate Kepler's constant of a satellite of the earth, knowing that the moon's orbital radius is 3.84×10^{8} m and that its period of revolution around the earth is 2.36×10^{6} s (27.3 days). **9.84×10^{-14} s^2/m^2**

36. Knowing that the earth's orbital radius is 1.49×10^{11} m and its period of revolution around the sun is 1.00 year, calculate the period of revolution of the planet Mercury whose orbital radius is 5.79×10^{10} m. **0.242 years**

37. Using Kepler's constant calculated in question #35, calculate the orbital radius of an artificial satellite whose period of revolution around the earth is 1.43×10^{4} s (3.96 h). **1.28×10^{7} m**

38. You wish to place a geostationary satellite (a satellite that remains in the same position above the earth). Using Kepler's constant found in question #35, calculate the distance above the earth's surface that this satellite must be placed. (Note: the earth's radius is 6.37×10^{6} m) **3.61×10^{7} m**

39. If a satellite of the sun has an orbital radius twice that of the earth, how does its period of revolution compare with that of the earth? **2.83 years**

Newton's Law of Universal Gravitation

40. Calculate the gravitational force between two objects when they are 7.50×10^{-1} m apart. Each object has a mass of 5.00×10^{1} kg. **2.96×10^{-7} N**

41. Calculate the gravitational force on a 6.0×10^{2} kg spacecraft that is 1.6×10^{4} km above the surface of the earth. (Note: the mass of the earth is 5.98×10^{24} kg) **4.8×10^{2} N**

42. Two students are sitting 1.50 m apart. One student has a mass of 70.0 kg and the other has a mass of 52.0 kg. What is the gravitational force between them? **1.08×10^{-7} N**

43. What gravitational force does the moon produce on the earth if the centers of the earth and moon are 3.88×10^{8} m apart and the moon has a mass of 7.34×10^{22} kg? **1.94×10^{20} N**

44. If the gravitational force between two objects of equal mass is 2.30×10^{-8} N when the objects are 10 m apart, what is the mass of each object? **1.86×10^{2} kg**

45. Calculate the gravitational force on a 6.50×10^{2} kg spacecraft that is 4.15×10^{6} m above the surface of the earth. **2.34×10^{3} N**

46. The gravitational force between two objects that are 2.1×10^{-1} m apart is 3.2×10^{-6} N. If the mass of one object is 5.5×10^{1} kg, what is the mass of the other object? **3.8×10^{1} kg**

47. If two objects, each with a mass of 2.0×10^{2} kg, produce a gravitational force between them of 3.7×10^{-6} N, what is the distance between them? **8.5×10^{-1} m**

48. What is the gravitational force on a 70.0 kg object standing on the earth's surface? **6.88×10^{2} N**

49. What is the gravitational force on a 35.0 kg object standing on the earth's surface? (Use your answer in #48 to reduce your calculations.) **3.44×10^{2} N**

50. What is the gravitational force on a 70.0 kg object that is 6.37×10^{6} m above the earth's surface. **1.72×10^{2} N**

51. What is the gravitational force on a 70.0 kg object that is 3.18×10^{6} m (Note: this is one-half the radius of the earth) above the earth's surface? **3.06×10^{2} N**

52. Three objects, each with a mass of 10.0 kg, are placed in a straight line 5.00×10^{-1} m apart from each other. What is the net gravitational force on the center object due to the other two objects? **0**

53. Three objects, A, B and C are placed in order 5.00×10^{-1} m apart from each other along a straight line. If A and B have equal masses of 10.0 kg and C has a mass of 15.0 kg, what is the net gravitational force on B due to A and C? **1.33×10^{-8} N**

54. The gravitational force between two small masses A and B when placed a short distance apart is 3.24×10^{-7} N. What is the gravitational force between these objects if the masses of both A and B are doubled and the distance between them is tripled? **1.44×10^{-7} N**

Gravitational Fields

55. Calculate the gravitational field strength on the surface of the earth. **9.83 N/kg**

56. On the surface of the earth an object has a weight (force due to gravity) of 76.3 N and a mass of 7.78 kg. Using this information, what is the gravitational field strength on the surface of the earth? **9.81 N/kg**

57. Calculate the gravitational field strength on the surface of Mars. Mars has a radius of 3.43×10^6 m and a mass of 6.37×10^{23} kg. **3.61 N/kg**

58. At what distance from the earth's surface is the gravitational field strength 7.33 N/kg? **1.01×10^6 m**

59. On the surface of Planet X an object has a weight of 63.5 N and a mass of 22.5 kg. What is the gravitational field strength on the surface of Planet X? **2.82 N/kg**

60. On the surface of Planet Y, which has a mass of 4.83×10^{24} kg, an object has a weight of 50.0 N and a mass of 30.0 kg. What is the radius of the planet? **1.39×10^7 m**

61. What is the gravitational field strength 1.27×10^7 m (Note: this is twice the earth's radius) above the earth's surface? **1.09 N/kg**

62. Planet B has a mass of 4.00×10^{22} kg and a radius of 6.0×10^5 m. What is the gravitational field strength on the surface of planet B? **7.4 N/kg**

63. Two planets A and B have the same mass. However the gravitational field strength on the surface of planet A is 1.20 times the gravitational field strength on the surface of planet B. How does the radius of planet A compare with the radius of planet B? **0.913 times**

64. What is the weight of a 20.0 kg object on the surface of the moon? The mass of the moon is 7.34×10^{22} kg and the radius of the moon is 1.74×10^6 m. **32.3 N**

Launching: Escape Speed

65. What is the escape speed from the moon's surface? **1.68×10^3 m/s**

66. What is the escape speed from Jupiter's surface? ($R = 7.18 \times 10^7$ m, $m = 1.9 \times 10^{27}$ kg) **4.20×10^4 m/s**

67. What is the acceleration due to gravity (gravitational field strength) on a planet that has an escape speed of 9.0×10^3 m/s and a radius of 7.2×10^6 m? **11 m/s^2**

68. What is the mass of a planet that has a radius of 2.57×10^6 m and an escape speed of 2.92×10^3 m/s? **3.29×10^{20} kg**

Satellites in Orbit **7.6×10^3 m/s**

69. Calculate the speed of an artificial satellite in an orbit around the earth with a radius of 6.9×10^6 m.

70. Geosynchronous satellites are used for communications. They are satellites that do not change position with respect to the earth. What is the height of such a satellite above the earth's surface? **3.59×10^7 m**

71. Calculate the speed of the moon in its orbit around the earth. (radius of moon's orbit = 3.85×10^8 m, moon's mass = 7.4×10^{22} kg) **1.02×10^3 m/s**

72. Calculate the speed of a satellite orbiting the earth at a height of 4.4×10^5 m above the earth's surface. (Note: remember to consider the earth's radius of 6.4×10^6 m) **7.6×10^3 m/s**

73. Calculate the orbital speed of a satellite 5.0×10^6 m above the surface of Jupiter ($R_J = 7.18 \times 10^7$ m, $m_J = 1.90 \times 10^{27}$ kg) **4.1×10^4 m/s**

74. Calculate the speed of the earth in its orbit around the sun. (radius of the earth's orbit = 1.49×10^{11} m, $m_S = 1.98 \times 10^{30}$ kg) **2.98×10^4 m/s**

75. Using $T = 2\pi R^{(3/2)} / \sqrt{(Gm_S)}$, calculate the time of one revolution (length of a year) on Mars. ($m_M = 6.4 \times 10^{23}$ kg, $m_S = 1.98 \times 10^{30}$ kg, radius of Mars' orbit = 2.3×10^{11} m) **6.0×10^7 s or 1.9 years**

76. Using Kepler's Laws, calculate the time of one revolution (length of a year) on Mars. (radius of the earth's orbit = 1.5×10^{11} m, radius of Mars' orbit = 2.3×10^{11} m) **1.9 years**