1. A constant force of 10.0 N, 225° acts on an object as it moves 5.0 m, 120°. Determine the work done on the object by the force.

2. Find the work done by gravity on a book that weighs 15 N if it is moved 2.0 m in the following directions: (a) 270°, (b) 300°, (c) 330°, (d) 0°, (e) 30°, (f) 60°, (g) 90°.

3. A block with mass 4.00 kg is pushed at a constant speed up a ramp that is 5.00 m long and 2.50 m high (tilted at 30.0°). The coefficient of friction is 0.300. (a) Find the amount of work done on the block by each force: gravity, normal, friction, and applied. (b) The block is then released and slides to the bottom – again find the work done by each force.

4. An object moves on the x-axis and is subject to a force given by $F(x) = (4\ \mathrm{N/m^3})x^3$. Find the work done by this force is the object moves: (a) from $x = 0$ m to $x = 3$ m, (b) from $x = 0$ m to $x = 6$ m, (c) from $x = 6$ m to $x = -2$ m.

5. A spring of length 50.0 cm is characterized by the constant $k = 80.0$ N/m. Determine the work required to: (a) compress it to a length of 40.0 cm, and (b) compress it farther, from a length of 40.0 cm to 20.0 cm.

6. Starting from rest, a 5.0 kg sled is pulled across a level surface by an applied force of 27 N, 35°. This force acts as the sled is pulled a distance of 2.00 m. The coefficient of friction is 0.25. Determine the speed attained by the sled.

7. A bullet of mass 5.0 grams is fired at speed 270 m/s into a tree. The bullet penetrates the wood to a depth of 4.0 cm. Determine the average force that the bullet exerts on the tree as it bores into it.

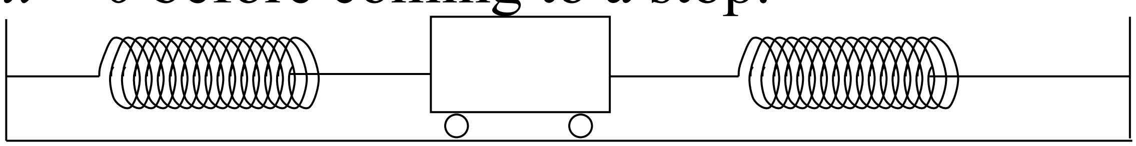
8. A ball of mass 0.600 kg is thrown straight upward by a kid. The kid exerts a force of 135 N upward, pushing the ball a distance of 0.400 m before it leaves his hand. (a) Find the speed of the ball just as it leaves his hand. (b) Find the speed of the ball when it has moved upward 2.00 m. (c) How high will the ball travel in the air?

9. A board 1.60 m long is propped up at one end by a table 0.60 m high. A 40$\underline{0}$ gram block is set into motion sliding down the ramp. It has speed 2.00 m/s at the top of the ramp and speed 3.00 m/s at the bottom. (a) Determine the amount of friction. (b) If launched sliding <u>up</u> the ramp, what minimum speed at the bottom would "propel" it to the top?

10. Total friction on a 1993 Ford Festiva can be modeled by three formulas. Rolling resistance: $F_R = (0.024)\ mg$. Air resistance: $F_A = (0.361\ \text{kg/m})\ v^2$. Engine friction: $F_E = (155\ \text{N})\ n$, where n = gear ratio. The total mass, including driver, is right at $10\underline{0}0$ kg. Assuming the engine is 38% efficient and a gallon of gas has 120.6 MJ of energy, determine the fuel economy in miles per gallon for the following cases: (a) v = 55 mph, n = 0.692 (5th gear), (b) v = 75 mph, n = 0.692, (c) v = 55 mph, n = 0.861 (4th gear), and (d) v = 55 mph, n = 0.692, and m = $14\underline{0}0$ kg (includes three passengers).

11. Determine the work done by the engine/transmission of the car (m = $10\underline{0}0$ kg) in the previous problem: (a) as it *accelerates* from 0 to 25.0 m/s in 10.0 s going through gears 1 to 5 (n = 3.454 to 0.692), (b) as it travels an equal distance at *constant speed* 25.0 m/s.

12. A cart of mass m is attached to springs as shown in the diagram below and is free to move horizontally on the track where μ is the coefficient of friction. The springs behave as a single spring with constant k. Suppose the cart is moved to a position x_o relative to its equilibrium position ($x = 0$) and released from rest. (a) Determine the position at which its speed first reaches zero after its release. (b) Determine how many times the car will pass by $x = 0$ before coming to a stop.



13. Robotic space probes are often basically dropped onto the surface of a planet, moon, etc. The impact may be cushioned by springs, air bags, etc. In order for the probe to survive impact there cannot be excessive deceleration. Model the cushioning force with $F = kx$. Solve for the maximum deceleration in terms of g, k, and v, the impact speed.

14. A pendulum of length L is released from a horizontal position and swings downward. At the instant it reaches the low point of the swing the string is disconnected and the mass falls a distance L to the floor. Find the position and velocity of impact.

15. A pendulum of length L is set into motion such that it follows an oval path. The object's minimum and maximum horizontal distance from the centerline of the oval are x and y. Solve for the maximum speed in terms of the minimum speed.

16. A tennis ball with mass 57.0 grams is attached to the end of a string of length 40.0 cm and twirled clockwise in a vertical circle at the minimum rate that will prevent the string from going slack. (a) Find the total energy of the ball relative to the center of the circle. (b) Find the minimum and maximum speed of the ball. (c) Find the tension in the string and the acceleration of the ball at the instant it reaches the "10 o'clock" position.

17. A compact object of mass *m* hangs on the end of a string and swings back and forth like a pendulum. The amplitude of the swing is 60°. Derive an expression relating the maximum tension in the string to the minimum tension in the string as it oscillates.

18. The mass of the space shuttle was 79000 kg and it orbited at a uniform altitude of 350 km. Ignore air resistance and the rotation of the earth. (a) Find the work required to put the shuttle into orbit. (b) To return to earth, the shuttle fired thrusters to reduce its orbital speed by 91 m/s. Calculate the speed of the space shuttle when it landed.

19. The actual landing speed of the space shuttle is $1\underline{0}0$ m/s. Use relevant information from the previous problem. (a) Determine the work done by the earth's atmosphere during the shuttle's return to the surface. (b) Estimate the amount of work done by the rocket engines to put the shuttle into orbit. (c) Conceptual question: What difference does the earth's rotation make?

20. The International Space Station had a mass of 218800 kg and an altitude of 335 km in June 2007. However, due to atmospheric drag its altitude decreased by about 0.11 km/day. (a) Find the total energy as a function of orbital radius. (b) Find the energy loss that occurs in one day. (c) Find the average force of drag on ISS.

21. The gravitational field inside the earth may be modeled by $g = \alpha r^2 + \beta r$, where r = distance from center, $\alpha = -2.851 \times 10^{-13}\ \mathrm{m^{-1}s^{-2}}$, and $\beta = 3.354 \times 10^{-6}\ \mathrm{s^{-2}}$. (This model allows for the increasing density towards the earth's core using $\rho(r) = (-0.00136\ \mathrm{kg/m^4})\, r + 12000\ \mathrm{kg/m^3}$). (a) Use the function $g(r)$ to determine the potential energy function for an object located inside the earth. Use the earth's center as a reference point. (b) Supposing an object could fall through a tunnel from the surface to the center of the earth what would be its final speed? (c) What would be the escape speed for an object to be shot out of this tunnel and leave Earth's gravity?

22. Consider the task of sending an object to the Moon. Ignore the motion of both the Earth and the Moon. (a) Find a potential energy function based on the combined gravity of Earth and Moon. (b) In order to get to the Moon what is the minimum initial kinetic energy and speed for a spacecraft of mass 1000.0 kg leaving Earth. (c) What will be the kinetic energy and speed of such a craft when it reaches the surface of the Moon. (d) Repeat for the spacecraft returning to Earth.

23. Estimate the impact speed and energy of Apophis in “megatons” (1 megaton of TNT = 4.2×10^{15} J). Mass = 2.1×10^{10} kg, average distance from Sun = 138 Gm, angle between orbital paths at intersection = 11°. Find the speed of Apophis at Earth’s orbit, find the speed relative to Earth, take this to be the “initial” speed “at infinity” and compute speed relative to Earth as it reaches the surface (accounting for Earth’s gravity).

24. An asteroid orbits a star of mass M, initially at distance a from the star. Derive an expression for its speed at a later time at distance r from the star.

Suppose the initial speed is: $v = \sqrt{\frac{GM}{a}}$.

25. A spacecraft can travel an elliptical path from Earth to Mars. During this trip it orbits the Sun. (a) Given that Mars is 1.524 A.U. from the Sun, determine the time for the spacecraft's journey. (b) Determine the speed relative to Mars upon its arrival (ignore Mars' gravity).

26. A particle of mass 3.0 kg moves along the x-axis under the influence of a conservative force given by $F = -x^3 + 8$, (force in newtons, position in meters). The particle begins at the origin with initial velocity 4.0 m/s, left. (a) Determine a potential energy function relative to position at which $F = 0$. (b) Find the total energy of the particle. (c) Find the maximum speed it attains. (d) What is the greatest distance from the origin reached by the particle?

27. A particle of mass 2.00 kg is free to move along the x-axis. The particle's potential energy is given by $U(x) = x^3 - 3x + 3$, where x is position in meters and U is energy in joules. The particle begins at rest at the origin. (a) Determine the particle's maximum speed, maximum position, and maximum magnitude acceleration. (b) What initial speed given to the particle would prevent it from oscillating? (c) If the particle has speed 3.00 m/s at the origin what will be its speed at $x = -3.00$ m?

28. A car with a 140 hp engine and mass 1700 kg accelerates from 0 to 25 m/s, during which friction averages 750 N. (a) Estimate the time assuming a constant acceleration. (b) If the efficiency of the car is 25% how much gasoline is required (1 gallon = 120 MJ)?

29. An elevator system is designed to lift the loaded car, $m = 3500$ kg, a distance of 60.0 m in 20.0 seconds. The drive system has efficiency 60.0%. (a) Find the average power output required. (b) Find the average electrical power required to lift the elevator. (c) Find the instantaneous electrical power input if the car is moving upward at 2.5 m/s and accelerating 1.2 m/s^2.

30. A crane lifts a junked car of mass 1950 kg at a speed of 0.500 m/s. Determine the power of the crane.

31. A certain small car has mass 1100 kg and total friction can be modeled by $f = 350 + 0.40v^2$. The car's speed increases according to $v = 7.0t^{0.5}$ until reaching 25 m/s at which point it cruises at constant speed. (a) Find the power output while cruising at 25 m/s. (b) Find the instantaneous power output at $v = 15$ m/s. (c) Determine the work done by the engine as the car gets up to speed.

Answers:

1. −13 J
2. a. $3\underline{0}$ J
   b. 26 J
   c. 15 J
   d. 0
   e. –15 J
   f. –26 J
   g. $–3\underline{0}$ J
3.
4.
5.
6.
7.
8.
9.
10.
11.
12. a. $x = 2\mu mg/k - x_o$
    b. integer part of $n = k|x_o|/2\mu mg$

13. $a = \sqrt{g^2 + \frac{kv^2}{m}}$

14.

15.

16. a. 0.335 J

b. 1.98 m/s, 4.43 m/s

c. 0.834 N, 21.4 m/s^2, 306.6°

17. $T_{max} = 4T_{min}$ ($= 2mg$)

18. a. 2.6×10^{12} J

b. 8020 m/s

19. a. -2.5×10^{12} J

b. 5.1×10^{12} J

c.

20. a. $E = -\frac{GMm}{2r}$

b. 110 MJ

c. 0.16 N

21. a. $U(r) = m(\alpha\, r^3/3 + \beta\, r^2/2)$

b. 9.33 km/s

c. 14.6 km/s

22.

23.

24. $v = \sqrt{GM\left(\frac{2}{r} - \frac{1}{a}\right)}$

25. a. 259 days

b. 2650 m/s

26. a. $U = 0.25x^4 - 8x + 12$

b. 36 J

c. 4.9 m/s

d. 3.8 m

27.a. 1.41 m/s, 1.73 m, 3.00 m/s^2

b. 1.41 m/s

c. 5.20 m/s

28. a. 5.6 s

b. 0.020 gal (2.5 oz or 5.0 tbs)

29. a. 103 kW

b. 172 kW

c. 16$\underline{0}$ kW

30. 9560 W

31. a. 15 kW

b. 34 kW

c. 450 kJ