PH 220 Homework Assignment Chapter on Conservation of Energy – 27 Problems Total

1. A spring has a spring constant $\left(k = 97.4\ {}^{N}/_{m}\right)$. How much potential energy is stored if the spring is stretched a distance of $0.872\ m$?

Solution for Problem 1

2. A spring has an initial length of $0.380\ m$ when it is hanging from a hook and has no weight attached to it. A weight with a mass of $3.63\ kg$ is attached to the spring and the spring stretches a distance of $0.362\ m$ making the entire length of the spring now $0.742\ m$. What is the spring constant of the spring?

Solution for Problem 2

3. A $1540\ kg$ vehicle is traveling horizontally with a speed of $83.4\ {}^{m}/_{s}$ when it strikes a large coiled spring and compresses the spring until the vehicle is brought to rest. If the spring has a constant of $3.27 \times 10^{5}\ {}^{N}/_{m}$, what is the distance needed to bring the vehicle to rest?

Solution for Problem 3

4. An object has a potential energy function given by:

$$U = (4xz + 3xy^2 - 7yz^3)\ J$$

What is the force associated with this potential energy?

Solution for Problem 4

5. A one dimensional particle is subjected to a force described as:

$$\overrightarrow{F(y)} = A\cos(ky)\ \widehat{(j)}$$

Where A and k are constants. A boundary condition on potential energy is that

$$U(y = 0) = 0$$

What is the potential energy function?

Solution for Problem 5

6. High jumpers bend their body to minimize the amount of distance the center of mass needs to move vertically. The increase in gravitational potential energy comes from the high jumper's kinetic energy before they jump. Assume the high jumper starts with an initial speed of $6.63\ ^{\mathrm{m}}/_{\mathrm{s}}$ and crosses over the high jump bar with a speed of $0.650\ ^{\mathrm{m}}/_{\mathrm{s}}$. Assume the high jumper has a mass of $57.9\ \mathrm{kg}$. How high does the jumper raise their center of mass?

<u>**Solution for Problem 6**</u>

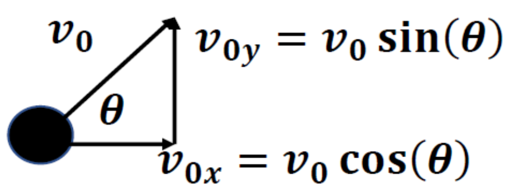
7. John has a mass of $67.4\ \mathrm{kg}$. He steps off a high platform and falls under gravity a distance of $3.36\ \mathrm{m}$. John is wearing a bungee cord harness which gets taut at that distance. Once the bungee cord is taut treat it as a spring with a spring constant of $4.67 \times 10^{3}\ ^{\mathrm{N}}/_{\mathrm{m}}$.

(a) What is John's speed when he reaches the point at which the bungee cord became taut?

(b) How far will the bungee cord stretch to bring John momentarily to rest?

<u>**Solution for Problem 7**</u>

8. A ball is launched with a velocity of $\overrightarrow{v_0} = 13.7\ ^{\mathrm{m}}/_{\mathrm{s}}$ @ $57.9°$ above the horizontal. The mass of the ball is $0.380\ \mathrm{kg}$. Using conservation of energy methods determine:

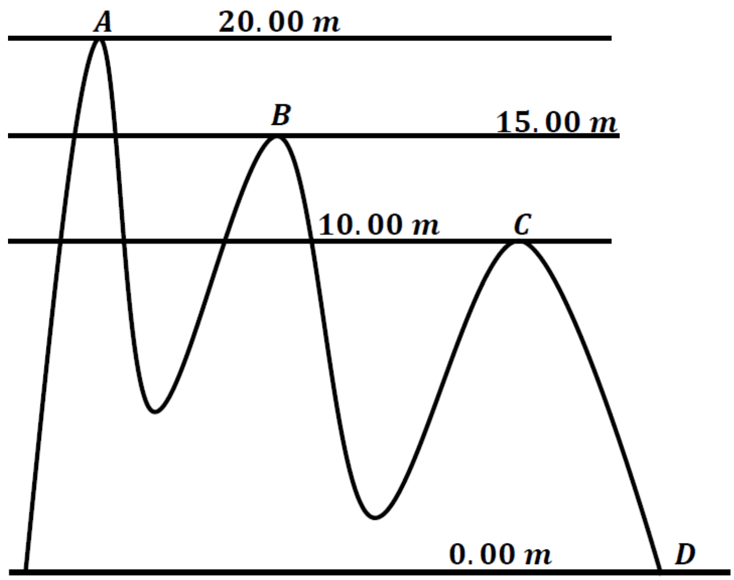


(a) What is the greatest height above the launch point does this ball reach?

(b) What is the velocity of the ball at this highest point?

<u>**Solution for Problem 8**</u>

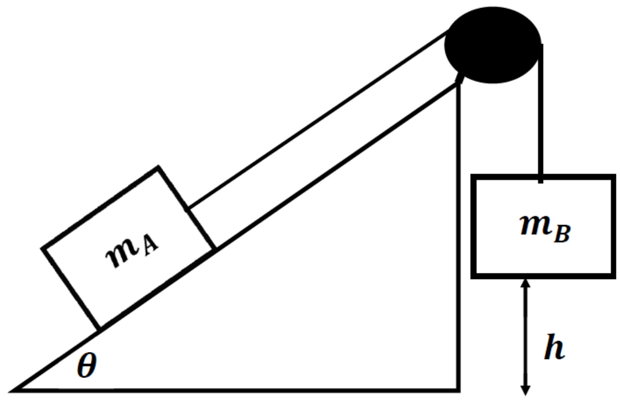
9. A small child roller coaster track shown is shown below.



A cart is raised to position A and released from rest. Assuming no friction between the cart and the roller coaster, find the speed of the cart at points B, C, and D.

<u>Solution for Problem 9</u>

10. Two masses are shown below. They are connected by a stretchless, massless and unbreakable cable. $m_A = 2.89\ kg$ is at rest on a smooth inclined plane which makes an angle $\theta = 31.0°$ with respect to the horizontal. $m_B = 4.19\ kg$ is attached to the other end of the cable and begins a height $h = 1.34\ m$ above the floor. The two masses are then allowed to move which results in m_B falling to the floor, while m_A is pulled up the inclined plane.



Use Conservation of Energy to find the final speeds of the masses just before m_B hits the floor.

Find the acceleration of the masses.

Use kinematics to find the final speeds of the masses just before m_B hits the floor.

Solution for Problem 10

11. A mass (m) is at rest on a horizontal frictionless surface. It is attached to a horizontal spring with a spring constant (k). The mass is displaced an initial distance (x_0) and at the same time provided an initial speed (v_0). Use energy methods to find:

(a) The maximum speed the mass will obtain during its motion.

(b) The maximum stretch from its equilibrium point during its motion.

Solution for Problem 11

12. As a safety feature in an elevator, consider an elevator car which has a combined mass of the car and the maximum number of passengers (m). Assume the elevator car is a distance h above the uncompressed spring when the elevator cable breaks. What should the spring constant (k) be so that the maximum acceleration the passengers undergo is no more than $4.00\ g$?

Solution for Problem 12

13. Two eighteen-wheel trucks fully loaded have a mass of $8.85 \text{ x } 10^3 \text{ kg}$ each. They are traveling down the highway in opposite directions each a speed of $33.4\ ^{\text{m}}/_{\text{s}}$. They collide and come to a complete stop. How much thermal energy is created in the collision?

Solution for Problem 13

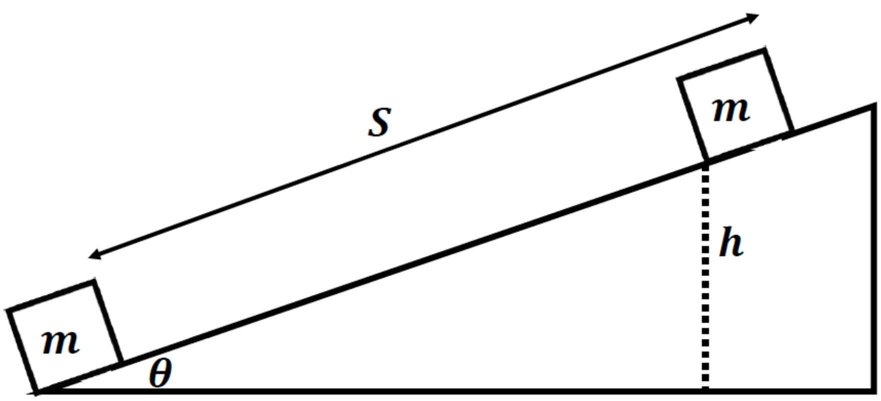
14. A mass $(\text{m} = 11.0 \text{ kg})$ starting from rest, slides down a ramp which is 3.18 m long and makes an angle $\theta = 41.0°$. The speed at the bottom of the ramp is $4.26\ ^{\text{m}}/_{\text{s}}$. How much work was done by friction as the mass slid down the ramp?

Solution for Problem 14

15. A ping pong ball has a mass of 0.010 kg. It is dropped from rest, from a height of 1.23 m above a floor. Just before the ball hits the floor it passes through a photogate and is recorded traveling a speed of $1.41\ ^{\text{m}}/_{\text{s}}$. What is the average force of air resistance acting on the ping pong ball?

Solution for Problem 15

16. A snowboarder is moving horizontally with a speed of $13.0\ ^{\text{m}}/_{\text{s}}$ when she reaches a hill inclined with an angle $(\theta = 21.0°)$. She glides a distance $(\text{S} = 14.0 \text{ m})$ up the incline when she stops. What is the average coefficient of kinetic friction between the snowboard and the snow?



Solution for Problem 16

17. Demonstrate the general form of gravitational energy

$$U_{Grav} = -G\frac{m_1 m_2}{r_{12}}$$

Becomes mgh when m_1 is the mass of the Earth and the second mass is near the surface of the Earth.

Solution for Problem 17

18.

(a) Assume that gravitational potential energy satisfies $U = 0$, if $r = \infty$, prove that the total mechanical energy of a satellite with mass m, orbiting at a distance r from the center of the Earth (m_E) is

$$E = -\frac{1}{2}\frac{Gm_E m}{r}$$

(b) If friction causes the value of the energy E to decrease slowly, kinetic energy must actually increase if the orbit is to remain a circle.

Solution for Problem 18

19. A small rock $(m = 685.\,\mathrm{kg})$ is traveling with a speed of $85.0\ {}^{m}/_{s}$ when it is $925.\,\mathrm{km}$ above the surface of the Earth. At this point the rock is falling vertically straight down. As unrealistic as it would be, ignore air resistance. When the rock strikes the Earth, it lands in a sand pit and it travels $4.50\ \mathrm{m}$ through the sand as the rock is brought to rest.

(a) What was the speed of the rock just before it struck the sand?

(b) How much work did the sand do in bringing the rock to rest?

(c) What was the average force exerted by the sand on the rock?

(d) How much thermal energy was produced as the rock was brought to rest?

Solution for Problem 19

20. How much work is required to change a satellite of mass m from orbiting in a radius of $1.5R_E$ to an orbit of radius $4.0R_E$? R_E is the radius of the Earth.

Solution for Problem 20

21. A crane is powered by a $2250.\,\mathrm{W}$ motor. How long will it take to raise a pallet $(\mathrm{m} = 400.\,\mathrm{kg})$ up a distance of $23.0\ \mathrm{m}$?

Solution for Problem 21

22. A semi-truck fully loaded has a mass of $3.63 \times 10^4\ \mathrm{kg}$. Its engine can deliver $1.16 \times 10^6\ \mathrm{W}$ of power. How long does it take for this truck to go from rest to a speed of $35.8\ ^{\mathrm{m}}/_{\mathrm{s}}$?

Solution for Problem 22

23. A water pump has a power rating of $67.3\ \mathrm{W}$. It needs to move water up to a storage tank located a height of $13.3\ \mathrm{m}$ above the water source. How many kilograms a minute can be pumped?

Solution for Problem 23

24. An object has a mass of $0.394\ \mathrm{kg}$ and has position along the x axis described by the expression:

$$\mathrm{x} = -1.23\mathrm{t}^3 + 9.81\mathrm{t}^2 + 51.2\mathrm{t}$$

x is in meters when t is in seconds.
Determine:

(a) The net rate of work done on the object at $\mathrm{t} = 3.00\ \mathrm{s}$.

(b) The net rate of work done on the object at $\mathrm{t} = 5.00\ \mathrm{s}$.

(c) The average net power input during the interval $0.00\ \mathrm{s} < \mathrm{t} < 3.00\ \mathrm{s}$.

(d) The average net power input during the interval $3.00\ \mathrm{s} < \mathrm{t} < 5.00\ \mathrm{s}$.

Solution for Problem 24

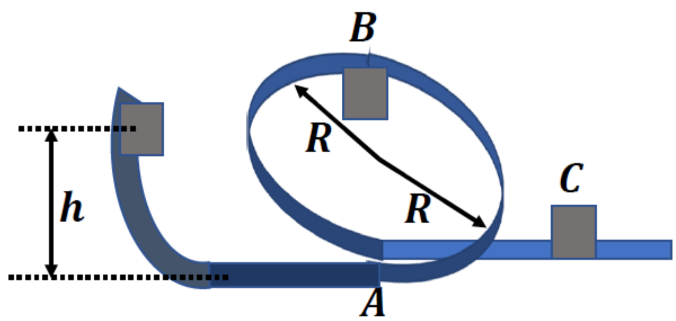
25. The Hoover Dam has a flow rate of $1.42 \times 10^7\ ^{\mathrm{kg}}/_{\mathrm{s}}$. The water falls about $92.7\ \mathrm{m}$ when the water strikes the turbine blades making them turn to produce electrical power.

(a) Determine the speed of the water just before it strikes the turbine blade. Ignore air resistance and consider the water comes over the dam with zero vertical speed.

(b) Approximate the rate of mechanical energy being transferred to the turbine blades if we assume the process is 60% efficient.

Solution for Problem 25

26. A “Loop de Loop” is shown below. The “Loop” has a radius R. A mass m slides along the frictionless track. The mass should remain in contact with the track at all times. Ignore any effects of air resistance.



(a) Determine the minimum height h above the bottom of the track the mass can be released from rest and it will make it around the “Loop”.

(b) Instead release the mass from a height $3h$, determine the Normal force the track exerts on the mass at location A, at the bottom of the “Loop”.

(c) Again, releasing the mass from the height 3h, determine the Normal force the track exerts on the mass at location B, at the top of the “Loop”.

(d) Again, releasing the mass from the height 3h, determine the speed of the mass at location C on the flat track after going through the “Loop de Loop”.

<u>**Solution for Problem 26**</u>

27. Humans gain energy for their bodies to function by eating food (or non-nutritious substances sometimes). Assume eating a candy bar provides all the energy contained within the candy bar $2.00 \text{ x } 10^5 \text{J}$. Assume your mass is 67.0 kg.

(a) How can you climb a ladder based on that “fuel”?

(b) If you stepped off the ladder at that height, ignoring air resistance, how fast would you be falling just before you hit the ground?

<u>**Solution for Problem 27**</u>

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This page last updated on March 4, 2024