Chapter 5
Work, Energy, Power, and Simple Machines
5.1 Work-Constant Force   Homework # 34

I

01. How much work is done when a 3.25-kg book is __________ at constant speed for a distance of 2.25 m?
    a.) lifted vertically   b.) pushed across a floor with a frictional force of 6.45 N
    c.) pushed across a floor with a coefficient of friction of 0.22

02. A boy pulls with a 92.5-N force on the handle of a 27.5 kg wagon while the handle makes an angle of 35.0°. If friction is negligible, and the boy pulls the wagon around the block a total distance of 215.6 m, how much work has the boy done?

03. How much work did a horse do that pulled a 225-kg wagon 52.5 km without acceleration with an effective coefficient of friction of 0.060?

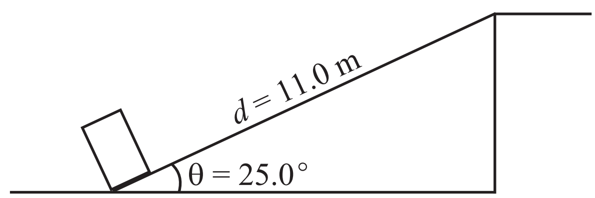
04. A car does 7.25×10^4 J of work in traveling 2.35 km at a constant speed. What was the average force of friction (from all sources) acting on the car?

05. How far must a 212-kg pile driver fall if it is capable of doing 12,500 J of work?

06. What minimum work is done in pushing a 65.0-kg crate up a 25.0° incline with negligible friction that is 11.0 m long? See diagram to the right and below.

II

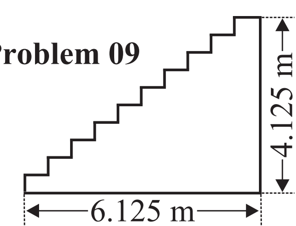
07. A 277.6-kg piano slides down an 11.0-m long ramp that makes a 25.0° angle and is kept from accelerating by a man pushing up along the incline (see diagram to the right). The effective coefficient of friction is 0.42. What is the minimum work done by the man on the piano when he reaches the ground?



Problems 06, 07, and 08

08. A man pushes a 62.3-kg clothes dryer up an 11.0-m long ramp that makes a 25.0° angle with the ground to get it to the second floor (see diagram above). He pushes with a force of 430 N parallel to the incline. The coefficient of sliding friction between the ramp and the dryer is 0.24.
    a.) How much work was done by the man in reaching the second floor?
    b.) How much work was done by the gravity when the dryer reached the second floor?
    c.) How much work was done by the friction when the dryer reached the second floor?
    d.) What was the **NET** work done on the dryer when it reached the second floor?

Problem 09



09. A woman walks a flight of stairs 4.125 m high and 6.125 m in breadth carrying a 38.6-N bag of groceries. What is the minimum work done by the woman on the bag of groceries? See diagram above.

10. In pedaling a bicycle, a particular cyclist exerts a downward force of 82.5 N during each stroke. If the diameter of the circle traced by each pedal is 36.6 cm, calculate how much work is done during each stroke.

11. Eight bricks, each 6.00 cm thick with a mass of 1.25 kg, lie on a flat table. What minimum work is required to stack them one on top of another?

ANSWERS: **01.** a.) 71.7 J b.) 14.5 J c.) 15.8 J **02.** 16,336 J **03.** 6.95×10^3 kJ **04.** 30.9 N **05.** 6.02 m **06.** 2961 J **07.** -1256 J **08.** a.) 4730 J b.) -2838 J c.) -1461 J d.) 431 J **09.** 159 J **10.** 30.2 J **11.** 20.6 J

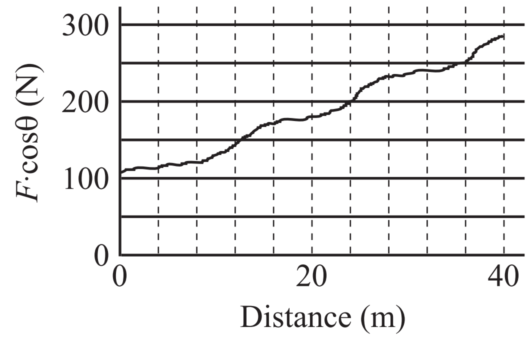
Chapter 5
Work, Energy, Power, and Simple Machines
5.2 Work-Varying Force Homework # 35

II

01. Use the graph to the right to estimate the work done in moving a 5.65-kg object from 6.0 m to 30.0 m. Use at least five intervals.

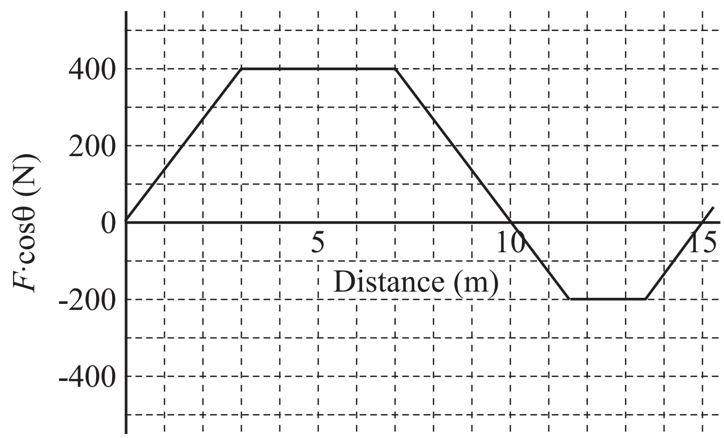
02. Use the graph to the right to estimate the work done in moving a 12.6-kg object from 0.0 m to 40.0 m. Use at least five intervals.

Problems 01 and 02



03. Use the graph to the right to answer the following.
    a.) Estimate the work done for the first 3.0 m.
    b.) Estimate the work done for the first 10.0 m.
    c.) Estimate the work done for the first 11.5 m.
    d.) Estimate the work done for the first 15.0 m.

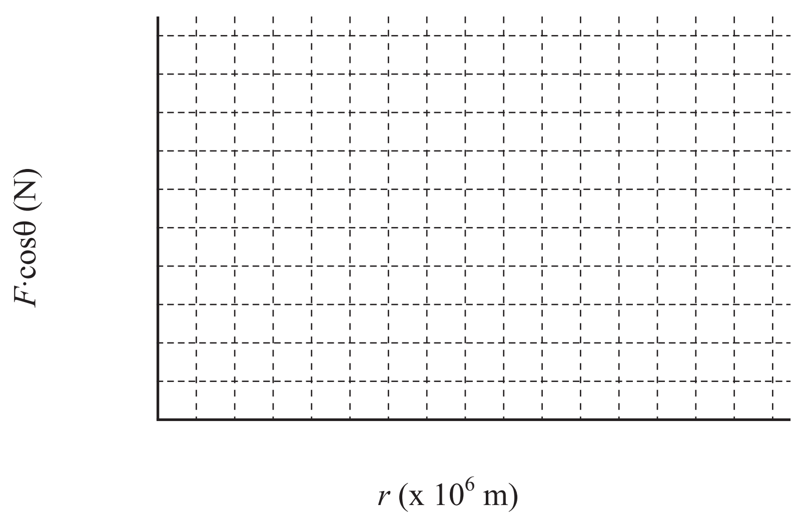
Problem 03



III

04. A 1000-kg space vehicle falls vertically from a height of 3000 km above the earth's surface. Determine, approximately, how much work is done by the force of gravity in bringing the vehicle to the earth's surface. (Use the graph to the right to construct an $F \cdot \cos\theta$-vs-r graph, where r is the distance from the earth's center. Then determine the work graphically. Also, see Homework #26 in "Chapter 4-Circular Motion & Gravitation" for the table of "Planetary Data")

Problem 04



ANSWERS: **01.** 4230 J **02.** 7428 J **03.** a.) 600 J b.) 2800 J c.) 2650 J d.) 2100 J **04.** 2.00×10^{10} J

Chapter 5
Work, Energy, Power, and Simple Machines
5.3 Kinetic Energy and the Work-Energy Theorem Homework # 36

I

01. What is the initial *KE* of a 0.450 mg flea that leaves the ground at 27.5 cm/s?

02. An electron ($m_e = 9.11 \times 10^{-31}$ kg) has 30.0 eV (1 eV = 1.6×10^{-19} J) of energy. How fast is it moving?

03. If the speed of a particle is doubled, by what factor has its *KE* increased?

04. If the *KE* of a particle is doubled, by what factor has its speed increased?

05. How much work does it take to accelerate an electron ($m = 9.11 \times 10^{-31}$ kg) from rest to 8.00×10^5 m/s?

06. How much work must be done to stop a 1250-kg car traveling at 90.0 km/h?

II

07. A 140-g baseball traveling 31.6 m/s moves a fielder's glove backward 14.7 cm when the ball is caught. What was the average force exerted by the ball on the glove?

08. If the speed of a car is increased by 50.0%, by what factor will its minimum braking distance be increased assuming all else is the same? Ignore the driver's reaction time.

09. In 1955 a paratrooper fell 370 m after jumping from an aircraft without his parachute opening. He landed in a snowbank, creating a crater 1.1 m deep, but survived with only minor injuries. Assuming the paratrooper's mass was 80 kg and his terminal velocity was 50 m/s, estimate __________.
    a.) the net work done on the paratrooper as the crater was created (beginning with his striking the snow)
    b.) the work done by the snow
    c.) the average force exerted on him by the snow to stop him
    d.) the work done on him by air resistance as he fell

10. A 230-kg load is lifted 18.0 m vertically upward with an acceleration of $a = 0.180g$ by a single cable. Determine __________.
    a.) the tension in the cable
    b.) the net work done on the load
    c.) the work done by the cable on the load
    d.) the work done by gravity on the load
    e.) the final speed of the load assuming it started from rest.

III

11. Car A has twice the mass of car B, but only half as much *KE*. When both cars increase their speed by 5.0 m/s, they have the same *KE*. What were the original speeds of the two cars?

ANSWERS: **01.** 1.70×10^{-8} J **02.** 3.25×10^6 m/s **03.** 4 **04.** $2^{\frac{1}{2}} = \sqrt{2}$ **05.** 2.92×10^{-19} J **06.** -3.91×10^5 J **07.** 476 N **08.** $(1.5)^2 = 2.25$ **09.** a.) -1.00×10^5 J b.) -1.01×10^5 J c.) 9.17×10^4 N d.) -1.9×10^5 J **10.** a.) 2660 N b.) 7303 J c.) 4.79×10^4 J d.) -4.06×10^4 J e.) 7.97 m/s **11.** $v_A = 3.54$ m/s, $v_B = 7.07$ m/s

Chapter 5
Work, Energy, Power, and Simple Machines
5.4 Potential Energy   Homework # 37

I

01. A spring has a spring constant, *k*, of 4350 N/m. How much must this spring be compressed to store 15.0 J?

02. A 4.45 kg monkey swings from one branch to another 1.25 m higher. What is the change in potential energy?

II

03. A 1.85-m tall person lifts a 345-g book so it is 2.32 m off the ground.
    a.) What is the potential energy of the book relative to the ground?
    b.) What is the potential energy of the book relative to the top of the person's head?
    c.) How is the work done by the person to lift the book affected by the answers in parts a.) and b.)?

04. A 76.4-kg hiker starts at an elevation of 1440 m and climbs to the top of a 3280-m peak.
    a.) What is the hiker's change in potential energy? b.) What is the minimum work required of the hiker?
    c.) Can the actual work done be more than the answer to part b.)? Explain!!!

05. A 350-g mass is hung from a 32.50-cm long vertical spring causing its length to increase to 41.75 cm.
    a.) What is the spring constant of this spring?
    b.) What is the elastic potential energy of the system after the mass has stretched the spring?
    c.) What is the change in gravitational potential energy of the system after the mass has stretched the spring?
    d.) What is the change in total potential energy of the system after the mass has stretched the spring?
    For parts e.) through g.) assume someone pulls the mass down, stretching the spring an additional 9.25 cm and releases the mass. Answers to parts e.) through g.) are in relation to the original unstretched spring and refer to the instant the spring is released.
    e.) What is the elastic potential energy of the system after the mass has stretched the spring?
    f.) What is the change in gravitational potential energy of the system after the mass has stretched the spring?
    g.) What is the change in total potential energy of the system after the mass has stretched the spring?

ANSWERS: **01.** 8.30 cm **02.** 54.5 J **03.** a.) 7.84 J b.) 1.59 J c.) it's the same (7.84 J)
04. a.) 1.38×10^6 J b.) .) 1.38×10^6 J c.) Yes, if the hiker has an average acceleration during the trip.
05. a.) 37.1 N/m b.) 0.159 J c.) -0.317 J d.) -0.159 J e.) 0.635 J f.) -0.635 J g.) 0 J

Chapter 5
Work, Energy, Power, and Simple Machines
5.5 The Law of Conservation of Energy — Homework # 38

I

01. A box slides down a frictionless incline that is 15.0 m high. If it starts from rest at the top of the incline, what will be the speed of the box when it reaches the bottom?

02. Tarzan, running 5.85 m/s, grabs a vine hanging from a branch of a tall tree. How high can he swing?

03. A dart gun has a spring with a spring constant of 297.5 N/m. A 35.0-g dart depresses the spring 6.50 cm and is locked into place until the trigger releases it. The gun is pointed horizontally and the trigger is pulled. What will be the speed of the dart as it leaves the gun?

04. A ball is thrown straight up by a person standing in a foxhole such that it leaves the person's hand at 68.4 m/s just as the hand is level with the ground. How high will the ball go?

05. A rock is dropped from a cliff that is 238.7 m above the ground. With what speed will the rock hit the ground?

II

06. The bumper of a 1200-kg car has two springs, each with a spring constant of 8250 N/m. This car is pulling into a parking space and goes too far, running into the wall of a building. If the bumper depresses 7.25 cm as a result of the collision, how fast was the car going when it hit the wall? Ignore any losses of energy to dissipative forces.

07. An arrow is fired from a bow with a speed of 27.5 m/s at an unknown angle from the top of a 65.0-m high cliff. What will be its speed as it hits the ground below?

08. A ski is sliding along the snow-covered ground at 23.7 m/s when it encounters an incline. Ignore friction throughout the problem.
    a.) How high will the ski go?
    b.) If the incline is at angle of a 25.0°, how far along the incline will ski slide?

09. A 5.75-kg mass is hung from a vertical spring causing it to stretch 23.6 cm.
    a.) What is the elastic potential energy of the system?
    b.) What is the change in gravitational potential energy of the system?
    c.) What is the total change in potential energy of the system?

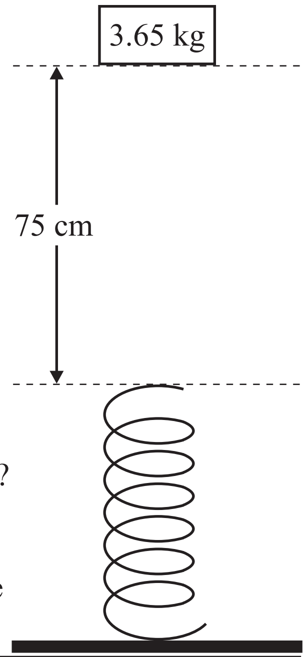
10. The high jump is a track event in which the *KE* of the athlete is converted to *GPE* without the aid of a pole. With what minimum speed must a high jumper leave the ground if he is to raise his center of mass 1.92 m and cross the bar with a horizontal velocity of 0.875 m/s?

11. A dart gun has a spring with a spring constant of 297.5 N/m. A 35.0-g dart depresses the spring 6.50 cm and is locked into place until the trigger releases it. The gun is pointed vertically up and the trigger is pulled. How high above the barrel of the gun will the dart go?

III

12. A 3.65-kg mass falls 75.0 cm before striking the top of a vertical spring with a stiffness constant of 975 N/m. How far will the spring compress? The 75.0-cm fall occurs before the mass depresses the spring. See diagram shown to the right.

Problem 12



ANSWERS: **01.** 17.1 m/s **02.** 1.75 m **03.** 5.99 m/s **04.** 238.7 m **05.** 68.4 m/s **06.** 0.269 m/s **07.** 45.1 m/s **08.** a.) 28.7 m b.) 67.8 m **09.** a.) 6.65 J b.) -13.3 J c.) -6.65 J **10.** 6.20 m/s **11.** 1.76 m **12.** 27.4 cm

Chapter 5
Work, Energy, Power, and Simple Machines
5.6 Thermal Energy and Energy Conservation — Homework # 39

I

01. A 170.0-g hockey puck is given a push from a hockey stick such that it leaves contact with the stick traveling at 12.25 m/s and slides 84.6 m.
    a.) How much thermal energy is produced?
    b.) What is the coefficient of kinetic friction between the puck and the ice?

II

02. A 32.6-kg child, starting from rest, slides down 30.0°-slide that is 2.15 m high.
    a.) If thermal losses are ignored, what will the speed of the child be at the bottom?
    For parts b.) and c.), assume the speed of the child at the bottom of the incline was actually 5.00 m/s.
    b.) How much thermal energy was produced during the ride?
    c.) What is the coefficient of kinetic friction between the slide and the child's clothing?

03. A 39.5-kg crate, starting from rest, is pulled across a large room with a constant force of 70.0 N. For the first 8.00 m the floor is essentially frictionless. The next 9.00 m is carpeted creating a coefficient of friction of 0.28. What is the final speed of the crate?

04. Two identical railroad cars, each of mass 6400 kg, and traveling at identical speeds of 95.0 km/h are on the same track heading in opposite directions toward each other. They collide head on bringing both cars to rest. How much thermal energy is generated in this collision?

05. A ski, starting from rest, slides down a 12.5-m high slope that is angled at 60.0°. If the coefficient of kinetic friction between the ski and the snow is 0.07, how far will the ski slide across the level snow **AFTER** reaching the bottom of the slope __________?
    a.) if friction along the slope is ignored
    b.) if friction along the slope is included in calculations
    c.) Why are the answers to parts a.) and b.) so close in magnitude?

06. A crate falls off the back of a pickup truck, from a height of 1.05 m, when it is traveling 65.0 km/h. If the coefficient of kinetic friction between the crate and the road surface is 0.60, how far will the crate slide?

III

07. A 7.50-kg box is attached to a horizontal spring whose other end is attached to the wall as shown below. The box can slide along the floor where the coefficient of friction is 0.35. A force of 85.0 N is applied to the box so as to compress the spring 22.0 cm. If the force compressing the spring is removed, how far beyond the equilibrium position will the spring stretch on its first swing?

Problem 07

ANSWERS: **01.** a.) 12.8 J b.) 0.09 **02.** a.) 6.49 m/s b.) 279 J c.) 0.23 **03.** 3.30 m/s
04. 4.46×10^6 J **05.** a.) 179 m b.) 171 m **06.** 29.5 m **07.** 8.68 cm

Chapter 5
Work, Energy, Power, and Simple Machines

5.7 Power — Homework # 40

I

01. A motor with a rating of 25,000 W is used to wind the supporting cable of an elevator that has a mass of 1850 kg when empty.
    a.) How long will it take the empty elevator to go from the first to fifth floor which is 15.0 m above the ground?
    b.) How long will it take this elevator to go from the first to fifth floor with three people on board with masses of 45.0 kg, 62.5 kg, and 81.6 kg?

02. What is the average force exerted on a car from friction and air resistance if the car generates 12.5 hp when traveling at a constant 85.0 km/h?

03. Power companies send itemized bills each month to your home expressing the amount of electrical energy consumed by the household during the previous month. This energy is expressed as kilowatt-hours. How much energy is one kilowatt-hour expressed in metric units?

04. How much work can a 1.5 hp motor do in 20 minutes?

05. If a ½-hp garage door opener lifts a 7.00-foot-tall door in 12.0 s, what is the average force being applied against gravity and friction? (1 foot = 30.5 cm)

II

06. What power rating should a motor have if it is to pump 5.65 kg of water per minute to a height of 2.70 m?

07. A 1250-kg car slows down from 80.0 km/h to 60.0 km/h in 6.0 s when on a level stretch of road.
    a.) What power is needed to keep the car traveling at a constant 70.0 km/h on this level stretch of road?
    b.) What power is needed to keep the car traveling at a constant 70.0 km/h up a 15.0°-incline? Assume the same retarding forces as part a.).

08. What **AVERAGE** power was developed by the brakes of a 1350-kg car in bringing a car traveling 20.0 km/h to a halt over a distance of 60.0 m?

09. A 1425-kg car is advertised to have 150 hp under the hood. What is the angle of the steepest hill it can climb at a constant 50.0 km/h if the force of friction and air resistance total 600 N?

10. What average power is created when a shotputter brings a 7.27-kg shot from rest to 12.3 m/s in 0.326 s?

11. A cyclist coasts down 7.20°-hill at a constant 6.95 m/s. The cyclist and his bicycle have a total mass of 82.6 kg.
    a.) What must be the cyclist's power output to go up the same hill at the same speed?
    b.) If the pedals rotate once every 0.475 s in a circle with a diameter of 30.0 cm what must be the average force applied to the pedals during each downward stroke to go up this hill at this speed? Ignore mechanical advantage.

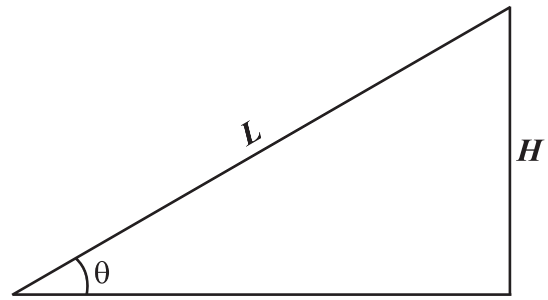
III

12. A small, above-ground pool with a diameter of 18.00 feet (1 foot = 30.5 cm) is filled to a height of 4.00 feet. How long would it theoretically take to circulate all of the water of the pool through a pump with a ½-hp rating and a ¾-inch (1 inch = 2.54 cm) diameter hose? Assume the average force on the water by the pump is 40.0 N.

ANSWERS: **01.** a.) 10.9 s b.) 12.0 s **02.** 397 N **03.** 3.60×10^6 J **04.** 1.35×10^6 J **05.** 2108 N
06. 2.49 W **07.** a.) 30.0 hp b.) 112 hp **08.** 1.29 hp **09.** 32.5° **10.** 2.25 hp
11. a.) 1410 W (1.88 hp) b.) 2233 N **12.** 3.00 hours

Chapter 5
Work, Energy, Power, and Simple Machines
5.8 Simple Machines — Homework # 41

Inclined Planes

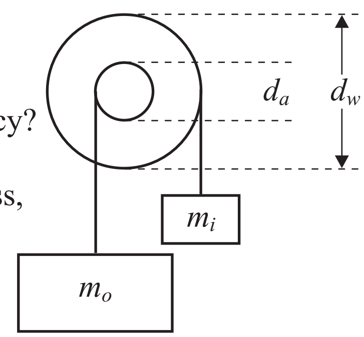


01. An inclined plane has a length 12.0 m and a height of 5.50 m.
    a.) What is the Ideal Mechanical Advantage (IMA) of this machine?
    b.) What is the minimum force needed to push a 720-kg box to the top?

02. An inclined plane has a length 17.5 m and a height of 4.25 m. A force of 255 N is required to push a 96.3-kg object to the top at a constant speed.
    a.) What is the IMA? b.) What is the AMA? c.) What is the percent efficiency?

03. What is the efficiency of a 20.0°-incline if a force of 65.0 N is required to push a 15.0-kg crate to the top?

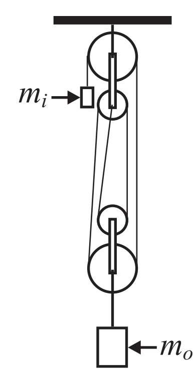
Wheel and Axle



04. A wheel and axle assembly is used at the top of a well to lift a bucket of water. The radius of the axle is 11.5 cm and the handle rotates in a circle with a radius of 48.0 cm. A force of 11.5 N must be applied to the handle to lift a 3.50-kg bucket of water.
    a.) What is the IMA b.) What is the AMA? c.) What is the percent efficiency?

05. A wheel and axle has an efficiency of 84.5%. One end of a string is tied to a 350-g mass, and the other end is wrapped around the axle. This object is lifted off the table-top at a **CONSTANT** speed when a minimum mass of 85.0 g, tied to a string wrapped around the wheel, is allowed to fall toward the table-top. If the diameter of the wheel is 12.5 cm, what is the diameter of the axle?

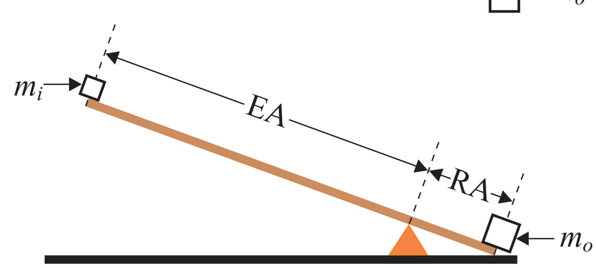
Pulleys



06. Consider the pulley system shown to the right. Assume m_i = 91.0 g and m_o = 300.0 g.
    a.) What is the IMA? b.) What is the AMA? c.) What is the percent efficiency?

07. A pulley system with 6 pulleys is used to lift a 925 lb engine out of a car. The engine must be lifted 3.00 feet to get it out of the car. The system has a percent efficiency of 79.5%.
    a.) How far must a person pull the cable to lift the engine far enough to get it out of the car?
    b.) What force is needed to lift the engine out of the car?

Levers



08. A lever, as shown to the right has an Effort Arm (EA) of 1.800 m and a Resistance Arm (RA) of 0.450 m. Assume m_i has a weight of 3.00 lb and m_o has a weight of 10.5 lb.
    a.) What is the IMA?
    b.) What is the AMA?
    c.) Find the % efficiency.

ANSWERS: **01.** a.) 2.18x b.) 3234 N **02.** a.) 4.12x b.) 3.70x c.) 89.8% **03.** 77.3%
04. a.) 4.17x b.) 2.98x c.) 71.5% **05.** 2.57 cm **06.** a.) 4x b.) 3.30x c.) 82.4%
07. a.) 18.0 ft b.) 194 lb **08.** a.) 4.00x b.) 3.50x c.) 87.5%

Chapter 5
Work, Energy, Power, and Simple Machines
Conceptual Review Homework # 42

01. Can a centripetal force ever do work? Explain!!!
02. Determine the amount of work done by gravity on a 2000 kg satellite at an altitude of 3000 km in each orbit around the earth. (See Homework #26 in "Chapter 4-Circular Motion & Gravitation" for the table of "Planetary Data")
03. Can the normal force on an object ever do work? Explain!!!
04. A person is swimming upstream such that they are not moving with respect to the shore.
    a.) Is he doing any work? b.) If he stops swimming and floats, is work done on him?
05. Is the work done by kinetic friction forces always negative? Explain!!! Consider a magician pulling the tablecloth from underneath a set of china and glassware.
06. A person pushes as hard as he can against a wall for a considerable amount of time. The person has done no work, but is tired at the end. Explain!!!
07. Consider two springs with the same length. Spring 1 is stiffer (has a larger spring constant) than spring 2. On which spring is more work done if they are stretched __________? Explain!!!
    a.) the same distance b.) using the same force
08. Can ____________________ energy ever be negative? Explain!!!
    a.) kinetic b.) gravitational potential c.) elastic potential
09. Is the net work done on an object reference-frame dependant (depend on the reference frame)?
10. Is the change in kinetic energy reference-frame dependant? Explain!!!
11. How do the answers to 09 and 10 affect the work-energy theorem? Explain!!!
12. Is the change in gravitational potential energy reference-frame dependant? Explain!!!
13. Is the change in elastic potential energy reference-frame dependant? Explain!!!
14. Does the angle at which a projectile is launched from the top of a cliff affect the speed at which it hits the ground below? Explain!!!
15. If you compress a spring sitting upright on a table with your hand; then release it, can it leave the table? Explain!!!
16. In the 1972 summer Olympics, a United States pole vaulter was disqualified for using an illegal pole. It was a pole made of fiberglass. Is it true that fiberglass poles can lead to higher pole vaults because the additional potential energy of bending was converted to gravitational potential energy? Explain!!!
17. What happens to the gravitational energy of the water at the top of Niagra Falls after the water hits the river below? Explain!!!
18. Describe all of the energy transformations that take place when a child hops on a pogo stick.
19. Describe all of the energy transformations that take place in the path of a pendulum when friction is __________.
    a.) ignored b.) taken into account and explain why a grandfather clock has to be wound
20. If an object is released from the top of an incline, does the speed it reaches at the bottom depend on the angle of the incline when __________? Explain!!!
    a.) the incline is frictionless b.) the friction of the incline is considered
21. Why do experienced hikers step over a fallen log in their path rather than stepping on the log and down on the other side? Explain!!!
22. A car accelerates uniformly from rest.
    a.) From where does the kinetic energy of the car come?
    b.) What is the relation between the increase in kinetic energy and the friction force the road exerts on the tires?
23. Can a "superball" that is dropped rebound to height greater than its original height? Explain!!!
24. Which of the following factors affect the work you do in lifting a box from the floor to the table? Explain!!!
    a.) the angle at which you lift it (straight up vs. some other path) b.) time it takes
    c.) the height of the table d.) the weight of the box
25. Why are mountain roads cut in a zigzag fashion rather than straight up?
26. Can a simple machine have a mechanical advantage less than one? If so what would be its purpose?