

FACT: The amount of work done by a steady force is the amount of force multiplied by the distance an object moves parallel to that force: $W = F \times \cos(\theta)$. The units are N.m, which equal a Joule (J). Positive work is done by a force parallel to an object's displacement. Negative work is done by a force antiparallel to an object's displacement. Work is a scalar quantity so it can be positive or negative, but does not have a direction. The area under a force vs. displacement graph is work.

Q1. A friend's car is stuck on the ice. You push down on the car to provide more friction for the tires (by way of increasing the normal force), allowing the car's tires to propel it forward 5 meters onto the less slippery ground. How much work do you do? (0)

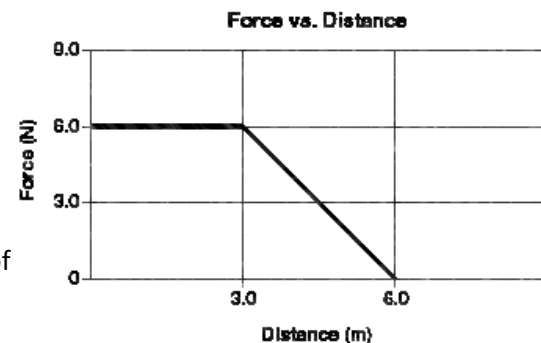
Q2. You push a crate up a ramp with a force of 10 N. Despite your pushing, the crate slides down the ramp 4 m. How much work did you do? (-40J)

Q3. How much work is done in lifting an 8-kg box from the floor to a height of 2m above the floor? (160J)

Q4. A 15-kg crate is moved along a horizontal floor by a warehouse worker who is pulling on it with a rope that makes a 30° angle with the horizontal. The tension in the rope is 69 N, and the crate slides a distance of 10 m. How much work is done on the crate by the worker? (600J)

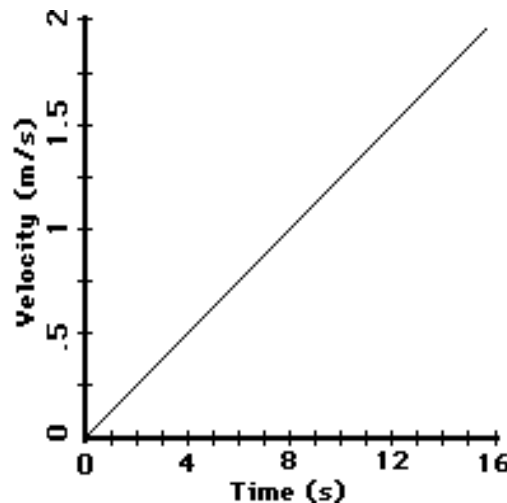
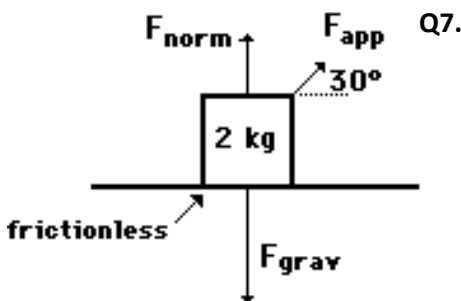
Q5. In The previous question (Q4), assume the coefficient of kinetic friction between the crate and the floor is 0.4. (a). How much work is done by the normal force? (b). How much work is done by the friction force? (0; -462J)

Q6. Examine the force vs. displacement graph for a block being pulled across a horizontal table. Determine the amount of work being done on the book. (27 J)



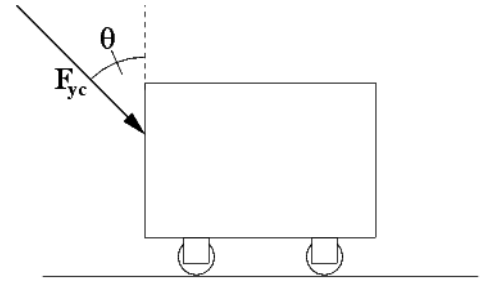
Q7. A student pulls a 2-kg backpack across the ice (assume frictionless) by applying a force at a 30.0 degree angle to the horizontal. The velocity-time graph for the motion is shown below. Perform a careful analysis of the situation and determine the magnitude of the applied force. Next determine the amount of work done by the student on the backpack.

$(F_{app} = 0.289N; W = 0.29 \times 16 \times \cos 30 = 4J)$

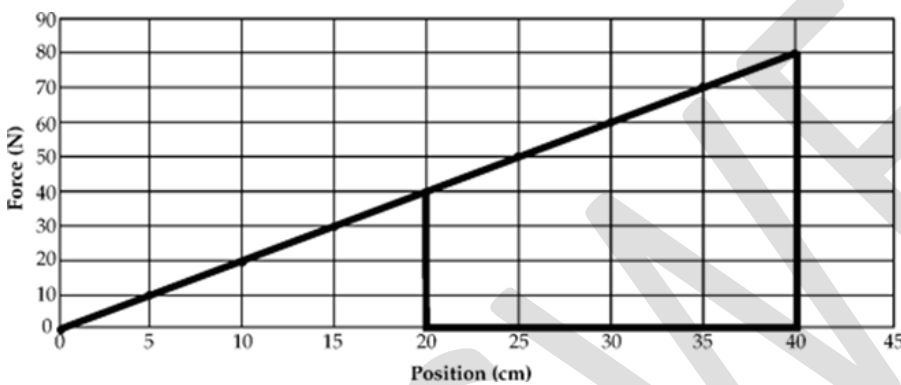


Q8. A box slides down an inclined plane 37° above the horizontal. The mass of the block, m , is 35 kg, the coefficient of kinetic friction is 0.3 and the length of the ramp, d , is 8 m. (a) How much work is done by gravity? (b) How much work is done by the normal force? (c) How much work is done by friction? (d) What is the total work done? (1690J; 0; -671J; 1019J)

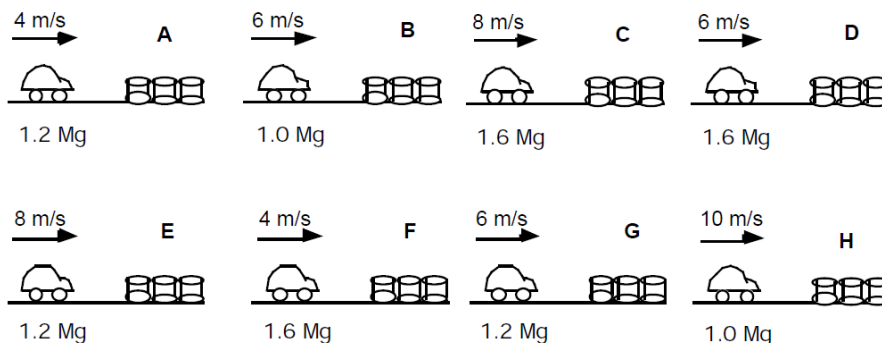
Q9: A person pushes a cart to the right with a force (F_{yc}) of 8 N at an angle of $\theta=40^\circ$ as shown in the diagram. The cart moves a horizontal distance of 10.0 m, what is the work done by the person on the cart? What is the work done by force normal? What is the work done by the force of gravity? (b) If the cart is moving at a constant velocity, determine the work done by the force of friction. (c) Lastly, calculate the net work on the cart. (51.4J, 0J, 0J, -51.4J, 0J)



Q10. A spring exerts a force as shown on the graph below. How much work is done as the spring stretches from 20 to 40 cm? (12J)



Q11. Given below are eight cars that are moving along horizontal roads at specified speeds. Also given are the masses of the cars. All of the cars are the same size and shape, but they are carrying loads with different masses. All of these cars are going to be stopped by plowing into barrel barriers. All of the cars are going to be stopped in the same distance. Rank these situations from greatest to least on the basis of the strength of the forces that will be needed to stop the cars in the same distance. (C,H,E,D,G,B,F,A)

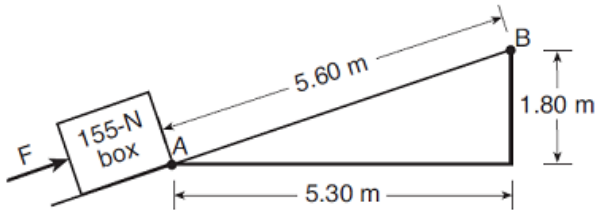


FACT: Equations for different forms of energy (unit = N.m or J). **Kinetic energy:** $KE = \frac{1}{2}mv^2$. Here, m is the mass of the object, and v is its speed. **Gravitational potential energy:** $PE_g = mgh$ (or U_g) Here, m is the mass of the object, g is the gravitational field, and h is the vertical height of the object above its lowest position. **Spring potential energy:** $PE = \frac{1}{2}kx^2$ (or U_e). Here, k is the spring constant ($\frac{N}{m}$), and x is the distance the spring is stretched or compressed from its equilibrium position. The term mechanical energy refers to the sum of a system's kinetic and potential energy.

FACT: Hooke's Law states that the more a spring is compressed (or stretched) the more force it applies to restore itself to equilibrium. This is expressed as $F_s = kx$.

Q12. A spring with a spring constant ($k = 4.0 \text{ N/m}$) is compressed by a force of 1.2 N . What is the total elastic potential energy stored in the compressed spring? ($x=0.3 \text{ m}$; $U_e = 0.18 \text{ J}$)

Q13. The diagram below represents a 155 N box on a ramp. Applied force F causes the box to slide from point A to point B. What is the total amount of gravitational energy gained by the box? (279 J)



FACT: A “conservative” force (e.g., gravity, spring) converts potential energy to other forms of mechanical energy when it does work. Thus, a conservative force does not change the mechanical energy of a system. So the sum of the potential and kinetic energy of the system is constant.

FACT: A “nonconservative” force (e.g., friction) can change the mechanical energy of a system. For example, the work done by friction on an object becomes microscopic internal energy, which raises the object's temperature and reduces the system's kinetic energy. The work done by a nonconservative can be expressed $W_{NC} = (\Delta KE) + (\Delta PE)$

FACT: The work done on an object by a net force equals the change in kinetic energy of the object: $W = KE_f - KE_i$. Therefore, doing positive work will result in an increase of kinetic energy. This relationship is called the work-energy theorem.

Q14. A tennis ball (mass = 0.06 kg) is hit straight upward with an initial speed of 50 m/s . How high would it go if air resistance is negligible? Solve this using the work-energy theorem. (125 m) Now try solving this using a UAM equation.

Q15. Refer back to **Q8** with the box sliding down an inclined plane 37° above the horizontal. If it starts from rest at the top, with what speed does it reach the bottom? (7.6 m/s)

FACT: Conservation of Energy- the internal energy of a system includes the kinetic energy of the objects that make up the system and the potential energy of the configuration of the objects that make up the system. This can be expressed showing the initial mechanical energy equals the final mechanical energy. $ME_i = ME_f \Rightarrow KE_i + PE_{gi} + PE_{ei} = KE_f + PE_{gf} + PE_{ef}$

Q16. A pool cue striking a stationary billiard ball (mass = 0.25 kg) gives the ball a speed of 2 m/s . If the average force of the cue on the ball was 200 N , over what distance did the force act? (0.25 cm)

Q17. A ball of mass 2 kg is gently pushed off the edge of a tabletop that is 5.0 m above the floor. Find the speed of the ball as it strikes the floor. (10 m/s)

Q18. An archer pulls an arrow of mass 0.10 kg attached to a bowstring back 30 cm by exerting a force that increases uniformly with distance from 0 N to 200 N . How much work does the archer do in pulling back the bowstring? ($k = 670 \text{ N/m}$; $W = 30 \text{ J}$)

Q19. In the above question, if the archer instead pulls back 60 cm, what will happen to the work done by the archer? (archer has to do 4 times the amount of work)

Q20. In Q18, how fast is the arrow traveling when it is released by the archer? (24 m/s)

Q21. A large ball of Play-Doh with a mass of 40 grams is launched from a catapult with an initial speed of 5 m/s and an initial height of 1.0 meter. Assuming level ground, what is the final speed of the ball right before it strikes the ground? (6.7 m/s)

Q22. Given the force vs. displacement graph shown on right for a net force applied horizontally to an object of mass (2 kg) initially at rest on a frictionless surface, determine the objects speed after 2.0 m. (4.47 m/s)

Q23. The diagram on right shows a toy cart possessing 16 J of kinetic energy traveling on a frictionless, horizontal surface toward a horizontal spring. If the cart comes to a rest after compressing the spring a distance of 1.0 meter, what is the spring constant of the spring? (32 N/m)

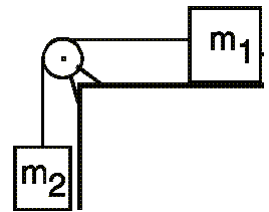
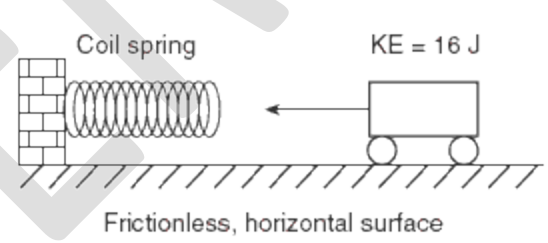
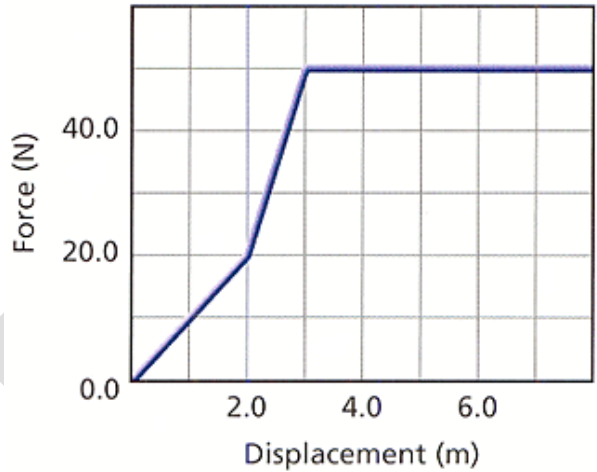
Q24. A car, initially traveling 30 m/s, slows uniformly as it skids to a stop after the brakes are applied. Sketch a graph showing the relationship between kinetic energy of the car as it is being brought to a stop and the work done by friction in stopping the car. (constant negative slope)

Q25. A 2 kg block starts at rest and is slides down a ramp from a height of 3 meters above the ground and reaches the ground with a kinetic energy of 50 J. Determine the total work done by friction on the block as it slides down the ramp and explain what has happened to some of the gravitational potential energy. (10 J; friction is nonconservative, so some of the U_g was converted into internal energy such as heat)

Q26. As a box is pushed 30 meters across a horizontal surface floor by a constant horizontal force of 25 N, the kinetic energy of the box increases by 300 J. How much total internal energy is produced during this process? (450 J)

Q27. Mass m_1 sits on a frictionless surface and is attached by a light string across a frictionless pulley to mass m_2 , as shown in the diagram. What happens to the gravitational potential energy and the kinetic energy of m_1 and m_2 when m_2 is released from rest? (U_g of m_1 is the same, KE increases; U_g of m_2 decreases; KE increases)

Q28. A box of mass m is attached to a spring with a spring constant k and sits on a frictionless horizontal surface as shown. The spring is compressed a distance x from its equilibrium position and released. Derive an equation for the speed of the box when the spring returns to its equilibrium position.



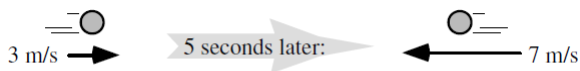
$$V = \sqrt{\frac{k}{m}}x$$

Q29. Sophia accidentally drops her 1.5-kg dolly down a large slide at the park that rises 6 meters above the ground. Dolly slides down while 3 J of negative work from friction are exerted on poor dolly. Once dolly reaches the bottom of the slide, she flies off horizontally from 1.0 meter above the ground. How far from the base of the slide does dolly land? ($V_f = V_{0x} = 9.80 \text{ m/s}$ found using conservation of energy; find $t = 0.45 \text{ s}$ noting $v_{0y} = 0$; find range = 4.4 m; so poor dolly lands 4.4 meters from the base of the slide!)

Q30. A bungee jumper of mass 60 kg steps off a 40-m high cliff. It takes approximately 40 N to stretch the cord 1 meter. How close does the jumper get to the ground? (10 m)

Q31. A boulder (mass=40 kg) is dropped off a 50-m high cliff. On the way down air resistance has an average drag force of 100 N on the boulder. Find the speed with which the object crashes into the ground. (27 m/s)

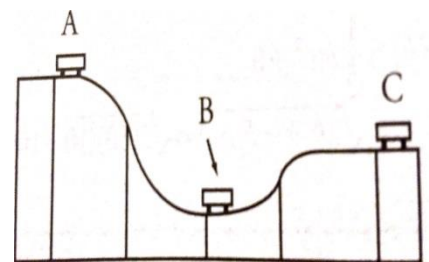
Q32. A 2-kg object accelerates uniformly as a net force acts on it. During the 5 seconds this force acts, the object changes its velocity from 3 m/s east to 7 m/s west as shown in the diagram below. Determine the net work done on the object. Draw the velocity as a function of time graph and use this graph to determine the displacement of the object. (40J)



FACT: Solving problems using an energy approach is almost always an easier method than using UAM and kinematics. Think about it. Most often, you do not need to know the time, the mass, no need for constant acceleration, and you do not need to know the path the object takes.

Q33. [Video Analysis] Visit the Unit 3 webpage on www.PedersenScience.com and scroll down to the problem set for this unit. You will find an accompanying video of a 54.5-kg person jumping on a trampoline. Watch the video twice before answering the following questions. (a) What is the girl's potential energy when she is just about to leave the trampoline in reference to the ground? (381.5 J) (b) What is the girl's potential energy when she reaches her maximum height above the trampoline in reference to the ground (654 J)? (c) Using these two potential energies, what is her velocity as she leaves the trampoline? (3.2 m/s)(d) Using this information and the fact that mechanical energy is conserved, calculate the spring constant (k) for the trampoline. (1550 N/m)

Q34. A roller coaster is at rest on the top of a 30 m hill (point A). The car starts to roll down the hill and reaches point B, which is 10 m above the ground, then rolls up the track to point C, which is 20 m above the ground. (a) A student assumes no energy is lost, and solves for how fast the car is moving at point C using energy arguments. What answer did he get? (14.1 m/s). (b) If the final speed of at C is actually measured with a sonar gun and is found to be 2.0 m/s, what percentage of the energy was not conserved? (~32.5 % not conserved) What happened to the energy? (converted into heat and sound)



FACT: Power is the rate at which work gets done. It is expressed as $\text{Power} = \frac{\text{Work}}{\text{time}}$ with units of J/s, which is renamed as the watt. The watt is symbolized as W (not to be confused with W for work), therefore, $1\text{W} = 1 \text{ J/s}$. One horsepower (hp) is defined as 746 watts. Please note that you will not need to calculate horsepower, as this is an antiquated term used in the United States (e.g., inches, miles, etc.).

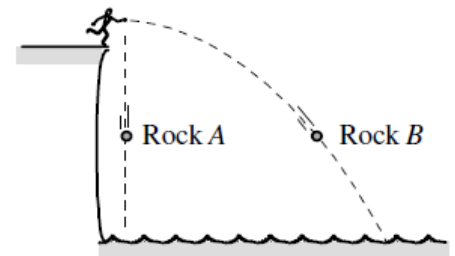
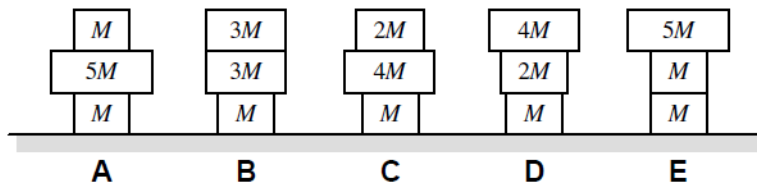
Q35. A mover pushes a large crate ($m = 75 \text{ kg}$) from the inside of the truck to the back end, which is a distance of 6 m. The mover exerts a steady push of 300 N. If he moves the crate this distance in 20 s, what is his power output during this time? (90 W).

Q36. Mary holds a 5 kg mirror against the wall 1.5 m above the ground for 20 s while Johnny nails it in place. What is Mary's power output during this time period (0 W).

FACT: If $P = \frac{W}{t}$ and $W = Fx \cos\theta$, then $P = \frac{Fx}{t}$ (please note I have left out the "cos θ " to simplify the relationship). Recall that $v = \frac{\Delta x}{t}$, so $P = Fv$. If there was an angle then $P = F \cos(\theta) v$.

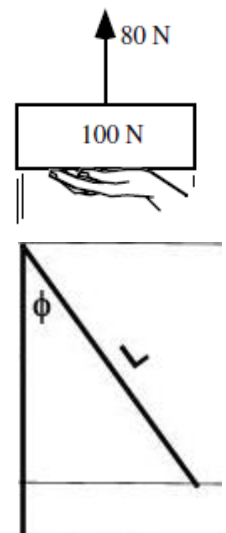
Q37. A 70-kg cyclist develops 210 watts of power while pedaling at a constant velocity of 7 meters per second east. What average force is exerted eastward on the bicycle to maintain this constant speed? (30 N)

Q38. Shown below are five stacks, each containing three blocks. The masses of the blocks are given in the diagram in terms of M , the mass of the smallest block. Each block has the same height and has its center of mass at the center of the block. Originally, all the blocks were flat on the ground. Derive equations in terms of M , g , h that will allow you to rank (greatest to least) the amount of work required to assemble the blocks. ($E > D > B > C > A$).



Q39. Rock A is dropped from the top of a cliff at the same instant that an identical Rock B is thrown horizontally away from the cliff. (a) Draw sketches of the $v(t)$ and $a(t)$ graphs for each both rocks. Use a coordinate system in which up is the positive vertical direction and the positive horizontal direction is away from the cliff with the origin at the point the balls were released. (b) Is the kinetic energy of the dropped Rock A at the start of the motion greater than, less than, or the same as the kinetic energy of the thrown Rock B? (c) Is the kinetic energy of the dropped Rock A halfway down greater than, less than, or the same as the kinetic energy of thrown Rock B halfway down? (b) Rock A has less initial kinetic energy since Rock A has zero initial velocity and thus zero kinetic energy. (c) Rock A has less kinetic energy since Rock A and Rock B have the same vertical velocity but Rock B also has a horizontal velocity, and a greater speed, thus it a larger kinetic energy.

Q40. A 100-N box is initially moving upward at 4 m/s. A woman is applying a vertical force of 80 N with her hand to the box as shown on the right. Sketch a graph of the velocity and kinetic energy of the box as a function of time for the first 2 seconds.



(The net force is constant and directed downward, so the velocity decreases at a constant rate. Kinetic energy is proportional to the velocity squared, so it decreases quadratically)

Q41. A pendulum of mass M swings on a light string of length L as hown in the diagram to the right. If the mass is released from rest at an angle of ϕ (ϕ), as shown, derive an expression for the maximum speed of the pendulum as a function of ϕ , L , and any required fundamental constants. $V = \sqrt{2gL(1 - \cos\phi)}$