Problem 1: A car drives around a horizontal, circular track at constant speed. Consider the following three forces that act on the car: (1) The upward normal force exerted on the car by the road, (2) the downward gravitational force on the car, (3) and the frictional force that is directed toward the center of the circular path.

Which of these forces does zero work on the car as the car moves along the circular path?
MultipleChoice :

1) 2
2) 1, 2, and 3
3) 2 and 3
4) 3
5) 1 and 3
6) 1 and 2
7) 1

Problem 2: A fuel tank is being lifted by a crane so that it moves upwards at a constant speed.

Part (a) Which force is doing *negative* work on the fuel tank as it is being lifted?
MultipleChoice :

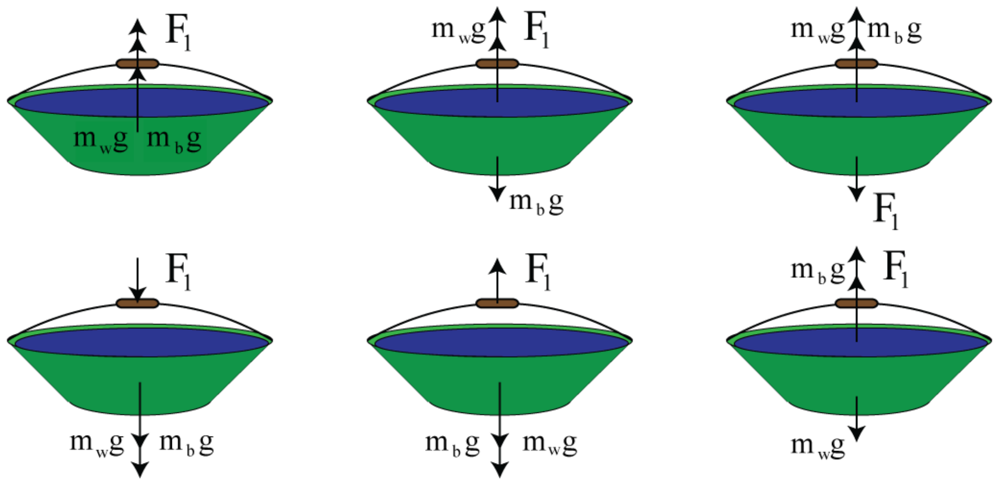
1) There is no work being done because the kinetic energy of the fuel tank is constant.
2) The force of the fuel tank acting on the rope.
3) The force of the rope acting on the fuel tank.
4) The force of gravity on the fuel tank due to the Earth.

Part (b) Which force is doing *positive* work on the fuel tank as it is being lifted?
MultipleChoice :

1) The force of the fuel tankacting on the rope.
2) The force of the rope acting on the fuel tank.
3) There is no work being done because the kinetic energy of the fuel tank is constant.
4) The force of the Earth acting on the fuel tank.

Problem 3: A farmer is using a rope and pulley to lift a bucket of water from the bottom of a well that is h_y = ***10.5*** m deep. The farmer uses a force F_1 = ***57*** N to pull the bucket of water directly upwards. The total mass of the bucket of water is $m_b + m_w$ = ***4.2*** kg.

Part (a) Select the correct free body diagram.
SchematicChoice :

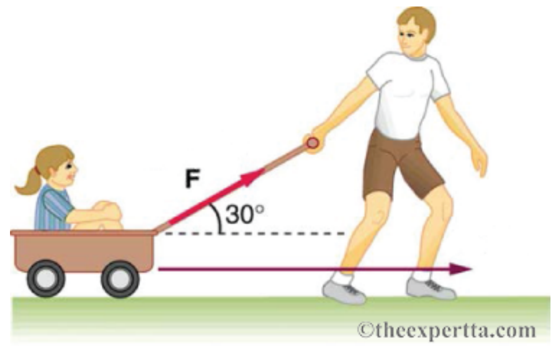


Part (b) Calculate how much work W_f in J the farmer does on the bucket of water (via the rope) to raise it to ground level.
Numeric : A numeric value is expected and not an expression.
W_f = ____

Part (c) Calculate how much work W_g in J gravity does on the bucket filled with water as the farmer lifts it up the well.
Numeric : A numeric value is expected and not an expression.
W_g = ____

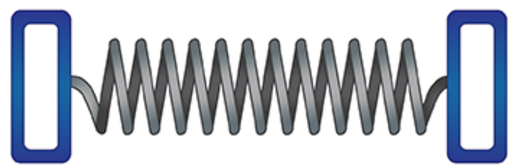
Part (d) Calculate the net work W_{net} in J done on the bucket of water by the two forces F_1 and F_g.
Numeric : A numeric value is expected and not an expression.
W_{net} = ____

Problem 4: A boy is pulling his sister in a wagon, as shown in the figure. He exerts a force of F = *55.5* N at an angle of 30°.

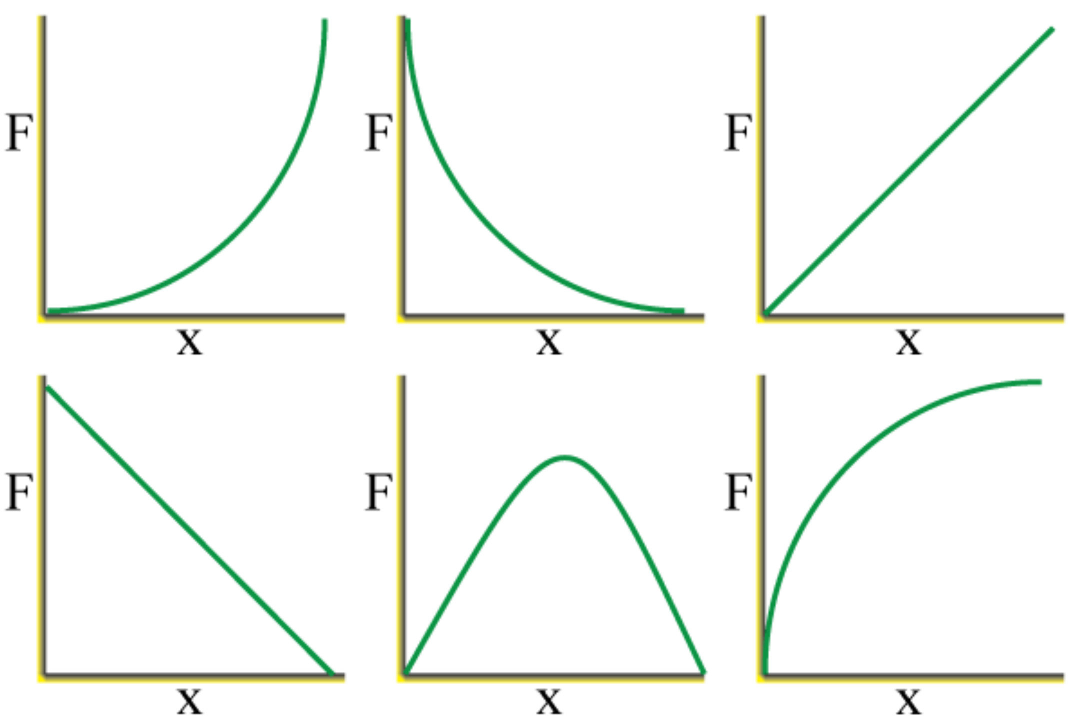


How much work does the boy do pulling his sister, in joules, if he pulls her *32* m?
Numeric : A numeric value is expected and not an expression.
W = ____

Problem 5: As a component of an exercise regiment to strengthen their pectoral muscles, a man stretches a spring which has a spring constant $k = 445$ N/m.



Part (a) If $x = 0$ corresponds to when the springs are at their relaxed state, which image best represents the magnitude of the force applied to the springs as a function of the stretch distance.
SchematicChoice :



Part (b) Write an equation for the work necessary to stretch the spring from the relaxed state to a distance x_1.
Expression :
W_1 = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, g, h, j, k, m, P, S, t, x_1, x_2

Part (c) Calculate the work, in joules, required to stretch the spring from its relaxed state to the position $x_1 = 54.7$ cm.
Numeric : A numeric value is expected and not an expression.
W_1 = ____ J

Part (d) Write an equation for the work necessary to stretch the spring from the position x_1 to position x_2.
Expression :
$W_{1\rightarrow 2}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, g, h, j, k, m, P, S, t, x_1, x_2

Part (e) Calculate the work, in joules, required to stretch the spring from $x_1 = 54.7$ cm to $x_2 = 81.8$ cm.
Numeric : A numeric value is expected and not an expression.
$W_{1\rightarrow 2}$ = ____ J

Problem 6: Consider an object with mass $m = 5.04$ kg on a frictionless table. The object moves along the positive x axis subject to a force which "repels" the object from the origin,

$$F = \frac{a}{x^2} + \frac{b}{x} \quad \text{for} \quad x > 0$$

where x is the position of the object relative to the origin.

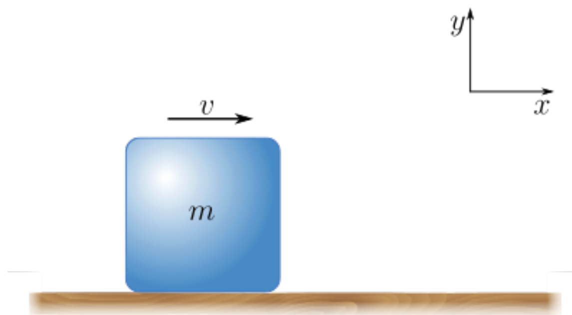
Part (a) Write an expression for the work done by the repulsive force on the object as it moves from an initial position x_1 to a final position x_2.
MultipleChoice :

1) $W = a\left(\frac{1}{x_2} - \frac{1}{x_1}\right) + b\ln(x_2/x_1)$
2) $W = a\left(\frac{1}{x_1} - \frac{1}{x_2}\right) - b\ln(x_2/x_1)$
3) $W = a\left(\frac{1}{x_1} - \frac{1}{x_2}\right) + b\ln(x_1/x_2)$
4) $W = a\left(\frac{1}{x_2^2} - \frac{1}{x_1^2}\right) - b\left(\frac{1}{x_2} - \frac{1}{x_1}\right)$
5) $W = a\left(\frac{1}{x_1^2} - \frac{1}{x_2^2}\right) - b\left(\frac{1}{x_1} - \frac{1}{x_2}\right)$
6) $W = a\left(\frac{1}{x_1} - \frac{1}{x_2}\right) + b\ln(x_2/x_1)$

Part (b) If the object starts at a position of $x_1 = 7.47$ m away from the origin, how much work, in joules, is required by an external force to bring it to a position of $x_2 = 1.31$ m away when $a = 18.7\ \mathrm{N \cdot m^2}$ and $b = 17.8\ \mathrm{N \cdot m}$?
Numeric : A numeric value is expected and not an expression.
W_{ext} = ____ J

Part (c) If the object starts at rest at a position $x_3 = 1.04$ m and is released, at what speed v, in meters per second, will the object be moving when it is at position $x_4 = 14.3$ m?
Numeric : A numeric value is expected and not an expression.
v = ____ m/s

Problem 7: A block of mass $m = 78.9$ kg slides along a horizontal surface. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.37$. The block has an initial speed of $v_0 = 30.1$ m/s in the positive x direction, as shown.



Part (a) Write an expression for the x-component of the frictional force the block experiences, F_f, in terms of the given variables and variables available in the palette.
Expression :
F_f = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, μ_k, θ, a, d, g, h, i, j, k, m, P, t, v_0

Part (b) What is the magnitude, in newtons, of the frictional force?
Numeric : A numeric value is expected and not an expression.
F_f = ____ N

Part (c) How far, in meters, will the block travel before coming to rest?
Numeric : A numeric value is expected and not an expression.
d = ____ m

Problem 8: The thrust created by one jet engine creates a force of $F = 87000$ N. It takes the plane (with a mass of $m = 7900$ kg) a distance of $d = 0.87$ km to take off.

Part (a) What is the take-off speed of the plane v_t in m/s?
Numeric : A numeric value is expected and not an expression.
v_t = ____

Part (b) How far in meters would you need to depress a giant spring k = 100,000 N/m in order to launch the plane at the same speed without help from the engine?
Numeric : A numeric value is expected and not an expression.
d_s = ____

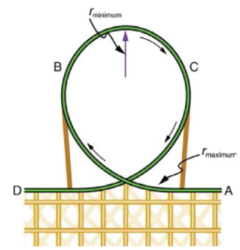
Problem 9:
Great Problems in Physics Series

Dr. Cindy Schwarz earned a BS in Mathematical Physics at the State University of New York at Binghamton. Five years later she was awarded her doctorate in experimental particle physics from Yale University for her research done on CP-Violation at Brookhaven National Laboratory.

I really like this problem because it shows the most sensible design for modern roller coasters. The shape that is ideal is called a clothoid and this problem uses an approximation to the shape. The clothoid is a curve that is characterized by its curvature being proportional to its length. This property makes it very useful as a transition curve when designing roller coasters. To approximate, the radius of curvature at the bottom of the loop is greater than the radius of curvature at the top of the loop. This assures a smaller (safer) acceleration at the bottom of the loop.

Read more about Dr. Schwarz and her research here.

Modern roller coasters have vertical loops like the one shown in the figure. The radius of curvature is smaller at the top than on the sides so that the downward centripetal acceleration at the top will be greater than the acceleration due to gravity, keeping the passengers pressed firmly into their seats.



Part (a) What is the speed, in meters per second, of the roller coaster at the top of the loop if the radius of curvature there is ***17*** m and the downward acceleration of the car is ***1.2***g? Note that g here is the acceleration due to gravity.
Numeric : A numeric value is expected and not an expression.
v = ____ m/s

Part (b) The beginning of this roller coaster is at the top of a high hill. If it started from rest at the top of this hill, how high, in meters, above the top of the loop is this initial starting point? You may assume there is no friction anywhere on the track.
Numeric : A numeric value is expected and not an expression.
h = ____ m

Part (c) If it actually starts ***5.5*** m higher than your answer to the previous part (yet still reaches the top of the loop with the same velocity), how much energy, in joules, did it lose to friction? Its mass is ***1600*** kg.
Numeric : A numeric value is expected and not an expression.
E_{lost} = ____ J

Problem 10: Suppose an elephant has a mass of ***3100*** kg.

How fast, in meters per second, does the elephant need to move to have the same kinetic energy as a *77*-kg sprinter running at *12.5* m/s?
Numeric : A numeric value is expected and not an expression.
v_e = ____

Problem 11: A block of mass 0.497 kg is released from rest at point A, and it slides down a curved slope to point B. The vertical height of point A is $h = 2.76$ m above point B, and the block arrives at point B with a speed $v_B = 4.79$ m/s.

How much work, in joules, was done by friction as the block slid from point A to point B?
Numeric : A numeric value is expected and not an expression.
W = ____ J

Problem 12: A *925*-kg van decelerates to rest from a speed of *75* km/h in a distance of *115* m. Assume the van is initially moving in the positive direction.

Part (a) If the brakes are applied consistently and are the only thing making the van come to a stop, calculate the force (in newtons, in a component along the direction of motion of the van) that the brakes apply on the van.
Numeric : A numeric value is expected and not an expression.
F_b = ____

Part (b) Suppose instead of braking that the van hits a concrete abutment at full speed and is brought to a stop in 2.00 m. Calculate the force, in newtons, exerted on the van in this case.
Numeric : A numeric value is expected and not an expression.
F_c = ____

Part (c) What is the ratio of the force on the van from the concrete to the braking force?
Numeric : A numeric value is expected and not an expression.
F_c/F_b = ____

Problem 13: A pitcher transfers a power of P = *230* W to a baseball of mass m = *0.085* kg for a period of t = *0.23* s.

What is the ball's speed in m/s when it leaves his hand?
Numeric : A numeric value is expected and not an expression.
v = ____

Problem 14: A car m = *2350* kg is traveling at a constant speed of v = *44* m/s. The car experiences a drag force (air resistance) with magnitude F_d = *490* N.

Part (a) Write an expression for the power the car must produce P_i to maintain its speed.
Expression :
P_i = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, F_d, g, h, j, k, m, P, S, t, v

Part (b) What is the power in horsepower (hp)?
Numeric : A numeric value is expected and not an expression.
P_1 = ____

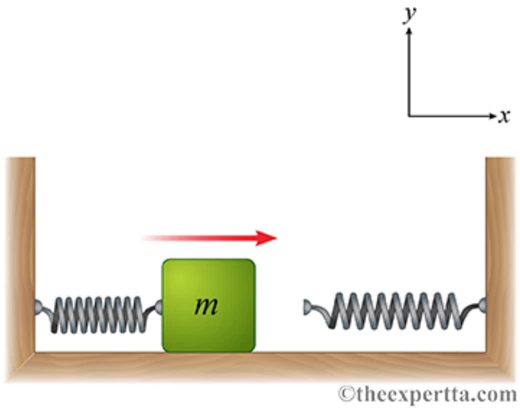
Part (c) The car encounters an incline which makes an angle of θ = *8* degrees with respect to the horizontal. The cruise control kicks in and increases the power to maintain the speed of the car. What is the new power (in hp) required to maintain a constant speed?
Numeric : A numeric value is expected and not an expression.
P_2 = ____

Problem 15: A hiker of mass *63* kg is going to climb to the top of Mount Tam, which has an elevation of 2,574 ft.

Part (a) If the hiker starts climbing at an elevation of ***575*** ft, what will their change in gravitational potential energy be, in joules, once they reach the top? Assume the zero of gravitational potential energy is at sea level.
Numeric : A numeric value is expected and not an expression.
ΔV_g = ____

Part (b) Repeat the above calculation for the change in gravitational potential energy, but assume the gravitational potential is zero at the top of the mountain.
Numeric : A numeric value is expected and not an expression.
ΔV_g = ____

Problem 16: A block of mass m = ***0.35*** kg is set against a spring with a spring constant of k_1 = ***502*** N/m which has been compressed by a distance of 0.1 m. Some distance in front of it, along a frictionless surface, is another spring with a spring constant of k_2 = ***114*** N/m. The block is not connected to the first spring and may slide freely.



Part (a) How far d_2, in meters, will the second spring compress when the block runs into it?
Numeric : A numeric value is expected and not an expression.
d_2 = ____

Part (b) How fast v, in meters per second, will the block be moving when it strikes the second spring?
Numeric : A numeric value is expected and not an expression.
v = ____

Part (c) Now assume friction is present on the surface in between the ends of the springs at their equilibrium lengths, and the coefficient of kinetic friction is $\mu_k = 0.5$. If the distance between the springs is x = 1 m, how far d_2, in meters, will the second spring now compress?
Numeric : A numeric value is expected and not an expression.
d_2 = ____

Problem 17: Answer the following question concerning non-conservative forces.

From the given list please select all forces that are classified as non-conservative forces.
MultipleSelect :

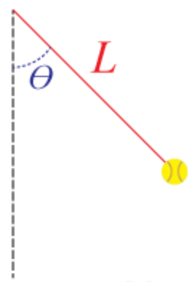
1) Elastic spring force.
2) Electrostatic force.
3) The force created between one car bumping into another, where the bumpers of both cars are dented.
4) Kinetic friction.
5) Drag force (air resistance).
6) Gravitational force.

Problem 18: A hydroelectric power facility (see figure) converts the gravitational potential energy of water behind a dam to electric energy.

Part (a) What is the gravitational potential energy relative to the generators of a lake of volume 50.0 km^3 (mass = 5.00×10^{13} kg) , given that the lake has an average height of ***38.5*** m above the generators?
Numeric : A numeric value is expected and not an expression.
ΔU_g = ____

Part (b) A 9 megaton fusion bomb (which is around 1000 times bigger than the WWII-era nuclear bombs) contains 3.8×10^{16} J of energy. What fraction of this energy is contained in the potential energy of the entire lake?
Numeric : A numeric value is expected and not an expression.
$U_{g,lake}/E_{bomb}$ = ____

Problem 19: A 0.25 kg ball is suspended from a light ***1.2*** m string as shown. The string makes an angle of ***34***° with the vertical. Let *U* = 0 when the ball is at its lowest point (θ = 0).



Part (a) What is the gravitational potential energy, in joules, of the ball before it is released?
Numeric : A numeric value is expected and not an expression.
U = ____

Part (b) What will be the speed of the ball, in meters per second, when it reaches the bottom?
Numeric : A numeric value is expected and not an expression.
v = ____

Problem 20: A mysterious force has been discovered in nature that acts on all particles in the three-dimensional space. You determine that the force is always pointed away from a definite point in space, which we can call the force center. The magnitude of the force has the following functionality: $F = Ae^{-br}$, where r is the distance from the force center to any other point.

Part (a) Write an expression for the potential energy U_D of a particle when it is at a distance D from the force center, assuming the potential energy to be zero when the particle is at in?nity.
SchematicChoice :

$U_D = \frac{A}{b}e^{-bD}$ $U_D = -Ae^{-bD}$ $U_D = \frac{A}{b}e^{-br}$

$U_D = Ae^{-bD}$ $U_D = \frac{A}{b}(e^{-bD} - 1)$ $U_D = -\frac{A}{b}e^{-bD}$

Part (b) If D is measured in meters, then what must the units be for the proportionality constant A in order that the energy be in Joules?
Expression :
units = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, **γ**, **θ**, **A**, **b**, **d**, **D**, **e**, **g**, **h**, **kg**, **m**, **n**, **s**, **v**

Part (c) If D is measured in meters, then what must the units be for the constant b in order that the energy be in Joules?
Expression :
units = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, **γ**, **θ**, **A**, **b**, **d**, **D**, **e**, **g**, **h**, **kg**, **m**, **n**, **s**, **v**

Part (d) If the particle is a distance ***0.91*** m from the force center and the constants are A = ***15*** and b = ***8***, then what is the potential energy of that particle?
Numeric : A numeric value is expected and not an expression.
PE = ____