Work Done by Constant Forces

PHYSICS 203, PROF. SONG, LU, & BEAN
JOHN JAY COLLEGE OF CRIMINAL JUSTICE, THE CUNY

Complete the textbook readings: 3-3, 7-2, 7-3

Recall the ***definition*** of work ***when forces are constant***: $W \equiv \vec{F} \cdot \vec{d}$
(refer to textbook section 3-3, "The Scalar Product")

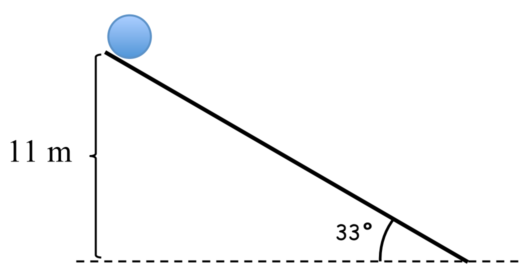
Recall the definition of Kinetic Energy: $KE \equiv \frac{1}{2}mv^2$
(where *v without an arrow on top* is the ***magnitude*** of velocity, i.e. speed)

Recall the Work-Kinetic Energy Theorem: $\sum W \equiv \Delta KE = KE_f - KE_i = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$

Recall that work can be negative ***or*** positive, but it is a ***scalar***, so ***its sign is not a direct indication of direction***. Work is negative ***when the force is opposite the direction of motion***. Work is positive ***when the force is in the direction of motion***. (Or the component of the force is in the direction of motion, or the component of the displacement is in the direction of the force. In other words, if the angle between the vectors is less than 90°. See textbook section 3-3.)

I. BOULDER ROLLS DOWN

An 85 kg boulder rolls down a ramp, as shown.



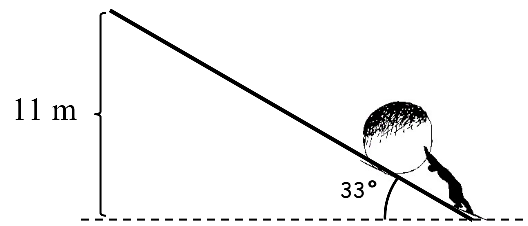
A. Calculate the work done by gravity on the boulder as it travels down the ramp. (Is this work negative or positive?)
B. The force of friction between the boulder and the ramp is 70***n***. Calculate the work done by friction on the boulder as it travels down the ramp. (Is this work negative or positive?)

Hint 1: what direction does friction point?
Hint 2: what is the displacement of the boulder?
Hint 3: it's not 11 m.

C. Calculate the work done by the normal force from the ramp as the boulder rolls down.
D. Calculate the ***net*** work done on the boulder as it rolls down.
E. Assume the boulder has an ***initial speed*** of 2 m/s at the top of the ramp. Use the W-KE theorem to calculate the final speed of the boulder when it reaches the bottom.

II. Boulder Rolls Up

Sisyphus is rolling the ***same*** boulder UP the ***same*** ramp—same mass, same force of friction, same height, same angle. (Don't know who Sisyphus is? Look him up.)



A. Calculate the work done by gravity on the boulder as Sisyphus pushes it all the way up the ramp. (Is this work negative or positive?)

B. Calculate the work done by friction on the boulder as Sisyphus pushes it all the way up the ramp. (Is this work negative or positive?)

C. Calculate the work done by the normal force from the ramp as Sisyphus pushes it all the way up the ramp. (Is this work negative or positive?)

D. Sisyphus pushes with a constant force of 700 ***n***. Calculate the work done by Sisyphus as he pushes it all the way up the ramp. (Is this work negative or positive?)

E. Calculate the ***net*** work done on the boulder as Sisyphus pushes it all the way up the ramp.

F. Assuming the bolder starts out from rest, calculate its final speed when it reaches the top of the ramp.

III. Return of the Piano Mover

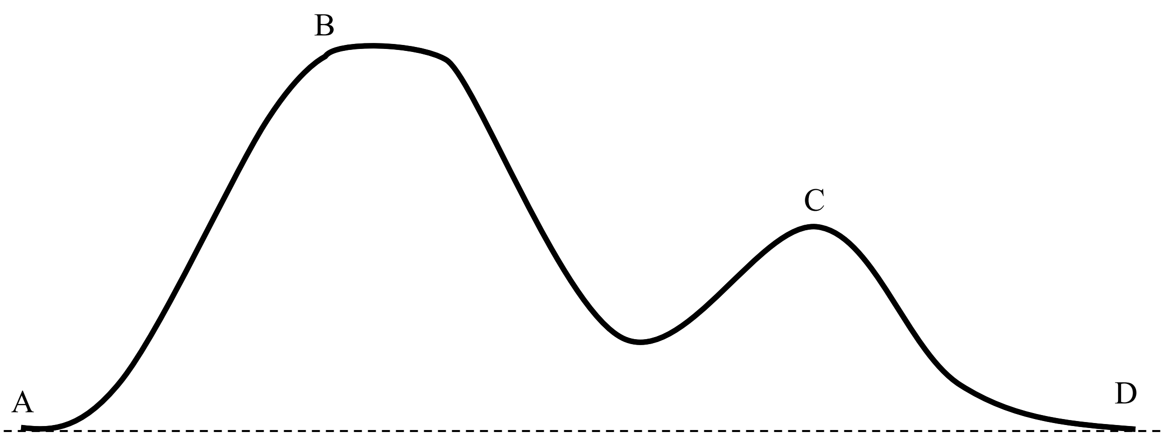
A mover is pushing a 200kg grand piano across a banquet hall. The mover pushes downward at an angle 15 degrees below the horizontal, with a force of 400N.

A. If he pushes the piano a horizontal distance of 20 meters across the floor, how much work did the mover do on the piano? (Is this work positive or negative?)

B. How much work does gravity do on the piano during the course of the 20 meter trip? Explain your reasoning.

IV. Roller Coaster

An 800kg rollercoaster car begins ***at rest*** at ***point A*** on the track below. An engine pulls it up to point B, at a height of 38m above the ground. When it reaches point B, the car is going 2 m/s. Assume that friction is negligible.



A. Calculate ***work done by gravity*** on the car as it ascends ***from A to B***.
B. Calculate work done by ***the normal force from the track*** as the car descends ***from B to D***.
C. Calculate the KE of the car at ***point A***.
D. Calculate the KE of the car at ***point B***.
E. Calculate the ***net work*** done on the car as it rises from point A to point B.
F. Calculate the work done by the engine as the car rises from point A to point B.

At point B, the engine is ***turned off***, and the car descends on its own (i.e. due solely to gravity) all the way back to point D. Points A and D are both at ground level.

G. Calculate the ***work done by gravity*** on the car as it descends ***from B to D***.
H. Calculate the work done by ***the normal force from the track*** as the car descends ***B to D***.
I. Calculate the final KE and final velocity of the car when it reaches point D.
J. When the car reaches point C, it is going 20.5 m/s. Find the elevation of point C above ground level.

GUIDE TO PROBLEM IV

A. Calculate the ***work done by gravity*** on the car as it ascends ***from A to B***.

- First ask yourself: is gravity doing negative work or positive?
- As the rollercoaster goes ***up*** from A to B, is gravity pushing with the motion or against it?
- Recall the second definition of work from the previous homework:
- $W \equiv F \times (the\ compoonent\ of\ d\ that\ is\ parallel\ to\ F)$
- What direction does gravity point?
- What is the displacement in this direction?
- If you paid close attention in lecture and/or did the textbook reading, you may even know an equation for work done by gravity.

B. Calculate the work done by ***normal force from the track*** as the car descends ***from B to D***.
   - First ask yourself: is normal force doing negative or positive work?
   - In other words, is normal force pushing ***with*** the direction of motion or ***against*** it?
   - This might seem confusing at first, because the direction of the normal force is constantly changing as the track bends.
   - Of course, the direction of velocity is also changing as the track bends.
   - At any given moment, what is the relationship between the direction of the normal force and the direction of velocity?
   - Another way you can think about it: is the normal force speeding the rollercoaster up, slowing it down, or doing neither one?

C. Calculate the KE of the car at ***point A***.
   - What is the rollercoaster's speed at this point? (It's given.)
   - What is the rollercoaster's mass?

D. Calculate the KE of the car when it reaches ***point B***.
   - Def of KE.

E. Calculate the ***net work*** done on the car as it rises from point A to point B.
   - You don't know the magnitude of all the forces, so you can't use the definition of W.
   - But you ***do*** know the change in KE. How can you use change in KE to find W?

F. Calculate the work done by the engine as the car rises from point A to point B.
   - You don't know the magnitude of the F_{engine}, so you can't use the definition of work.
   - But you do know the net work. What forces are influencing the car? How much work did each one do? (Hint: one of them did no work.)
   - Use your result from parts A, B, and E above.

The car descends on its own (i.e. due solely to gravity) all the way back to ground level at ***D***.

G. Calculate the ***work done by gravity*** on the car as it descends ***from B to D***.
   - Think about what you did in part A above.

H. Calculate the work done by ***normal force from the track*** as the car descends ***from B to D***.

I. Calculate the final KE and final velocity of the car when it reaches point D.
   - How many forces are acting on the rollercoaster as it travels from B to D?
   - How much work did each of these forces do?
   - Use the Work-KE Theorem.
   - Then use the definition of KE to find V.

J. When the car reaches point C, it is going 20.5 m/s. Find the elevation of point C above ground level.
   - Find KE at point C.
   - Find net work done on the car from point B to point C (or from point C to point D).
   - What two forces were acting on the car? Which is the only one that did any work?
   - If you know how much work gravity did, you can find the change in height.