EA3 – Week 5
Energy Methods
Spring 2017
RQ

1. Work is
   A. force integrated over distance
   B. mass integrated over velocity
   C. force integrated over time

2. Conservative forces include
   D. force from friction
   E. force due to gravity
   F. force from deformation of a spring

3. Conservation of Energy
   G. includes kinetic energy
   H. cannot be used if friction is present
   I. is a “Great Truth”

4. Work done by a conservative force is
   A. converted into heat.
   B. Always zero.
   C. Independent of path.
   D. Infinite
Today’s Outline

• Energy Methods
  – Conservative forces
  – Conservation of energy
    \[ [\text{PE} + \text{KE}]_1 = [\text{PE} + \text{KE}]_2 + E_{\text{lost}} \]
  – Potential energy
    \[ V_{\text{gravity}} = mg \]
    \[ V_{\text{spring}} = 0.5kx^2 \]

• CQs
Energy

• Work: \( U = \int (F \cdot dr) \)
• Kinetic Energy: \( KE = 0.5mv^2 \)
• Conservative forces
  • No energy loss
  • Work is path independent!
  • \( \int F_{\text{conserv}} \cdot dr = -\int dV \)
  • \( U = V_1 - V_2 \) ... for conservative forces
• Conservation of energy:
  \[ [PE + KE]_1 = [PE + KE]_2 + E_{\text{lost}} \]
• \( V_{\text{gravity}} = mgy \)
• \( V_{\text{spring}} = 0.5kx^2 \)
CQ 1

Which interactions involve mainly conservative forces?

(A) A break shot in billiards (one ball scatters a bunch)
(B) Squash ball hitting a wall
(C) Football player colliding with another (and bouncing off)
(D) Football player colliding with another (and holding on)
(E) Tee-shot in golf
(F) Loop-the-loop in extreme skateboarding
CQ 2

The mechanical work that you do averages **positive** during which activities:

(A) You carry 10 heavy boxes off a truck down a ramp
(B) You do 10 chin-ups, starting and ending “down”
(C) You compress a damper by 3 inches
(D) You extend an initially-relaxed spring by 20 cm
(E) You hold a barbell at chest level for 60 seconds
(F) You ride a bicycle 10 miles along a level road
A bungee cord is properly adjusted over a tar pit for a particular jumper. Somehow the jumper winds up as -->

Which explanations are reasonable?

(A) The jumper ate a large meal and didn’t adjust the bungee
(B) The jumper didn’t just drop, but jumped upward.
(C) The jumper didn’t just drop, but jumped downward.
(D) Heat from the tar pit increased the k of the cord
(E) Heat from the tar pit decreased the k of the cord
(F) There is an attractive force due to the stickiness of the tar
You drop a superball from 5 feet off the Earth, onto the surface of the Earth, and it bounces repeatedly back to a height of ~5 feet. With each bounce the Earth recoils, gaining a little momentum toward the sun. Does this eventually pound the earth into the sun?

(A) Yes, in principle if this continued forever it would
(B) Gravity pulls the Earth back up between bounces
(C) Alternate bounces give the earth momentum of opposite signs
(D) Multiple bounces transfer no more momentum than one bounce
(E) The CM of the Earth-superball system is fixed
(F) The ball is so small that the momentum transferred to the earth never adds up to anything
Ring 1 is on the bottom half of a frictionless double-U pipe while ring 2 falls through the left end of the pipe.

1. What will happen if the collision of the two rings is perfectly elastic?
   - A. Both rings move together
   - B. Ring 2 stops, ring 1 moves
   - C. Ring 2 moves backward, ring 1 moves forward

2. Can Ring 2 push Ring 1 out from the right-hand end of the pipe?
   - D. Yes, as long as ring 2 gets enough potential energy
   - E. Never
   - F. Ring 2 will drop out there, too
A block is released from rest on an inclined plane (with friction), slides down the plane, compresses a spring and then rebounds back up the plane. Which are true?

A. The KE of the block is zero at the moment it first contacts the spring
B. The PE of the block is most positive at the moment of release (at the top)
C. The KE of the block is largest when it first contacts the spring
D. The PE of the spring is greatest at the moment the rebounding block is leaving contact with it.
E. The greatest value of KE_{block} (at any time) is equal to the greatest value of PE_{spring} (at any time)
F. The block rebounds exactly to its initial height at release
CQ 7

Concept Question

Scifi’s "tractor beam" is a unilateral force, in which source A exerts a force on victim B, but B does not exert a force on A.

A. Not possible, as it violates Newton’s 3rd law
B. Momentum could not be conserved for the A+B system
C. Conservation of energy could not hold for the A+B system
D. The tractor force could not be a conservative force field for B
E. The interaction of A with B mediated by the tractor force could not be an elastic interaction
F. You're wrong, I know for a fact that the tractor beam is bilateral
Example Problem

Bullet initial velocity, $v$.
Box initially stationary.
Coefficient of friction, $\mu$.
Where does box stop moving, distance $D$?
Two blocks are connected with a rope as indicated in the figure. The system is released from rest and the friction coefficient between the object and the floor is $\mu_k = 0.25$. Assume the rope is inextensible and the pulley is weightless and frictionless.

Calculate the velocity of Block A after it has moved 2m.

A. First, analyze the blocks separately. Draw FBD of each block and be careful with the signs in the energy contributed to each block by the tension in the rope.

B. Now repeat the calculation by analyzing Blocks A & B together. Draw a single FBD of both blocks, including the rope that connects them. The tension in the rope does not contribute to your energy expressions since it is internal to the system.
Force & Velocity Sources and Transformers

Spring 2017
CQ 1 - What is it: a force source or a velocity source?

A 1/2 ton chain hoist hangs from a ceiling joist and can exert a great deal of vertical force to lift a heavy load. Sometimes they have only one speed (e.g. 2 inches per second), and sometimes they have several speeds selectable by a switch.

A) It’s a pretty good force source
B) It’s a pretty good velocity source
C) Neither one
CQ 2: Tensile Material Test Machine

A test machine is used to test material properties in tension. They are computer controlled with sensors for displacement and load.

What is best if you want to test at a constant displacement rate?

A) Hydraulic driven  
B) Screw-driven

What if you want to test at constant load?

C) Hydraulic  
D) Screw-driven
CQ 3 - What is it: a force source or a velocity source?

A rubber band exerts a retracting force whenever it is stretched, but it never exerts an expanding force.

A) It’s a pretty good force source
B) It’s a pretty good velocity source
C) Neither one
What is it: a force source or a velocity source?

A rocket engine produces 1.2 million pounds of thrust on the spacecraft, which accelerates as a result.

A) It’s a pretty good force source
B) It’s a pretty good velocity source
C) Neither one
CQ 5 - What is it: a force source or a velocity source?

During an earthquake, the ground (and anything on it) are caused to move up and down by as much as a few inches, at a frequency of several hertz.

A) It’s a pretty good force source
B) It’s a pretty good velocity source
C) Neither one
CQ 6 - What is it: a force source or a velocity source?

The Earth’s gravity acts on a passing asteroid, but fails to change its velocity or trajectory very much. In this system, gravity is

A) It’s a pretty good force source
B) It’s a pretty good velocity source
C) Neither one
The PowerStapl™ delivers three times as much force to the stapler as the operator applies to the handle. Equilibrium of this transformer (or you can think of this as the “force” part of its constitutive law) is:

A) $F_2 = 3F_1$, obviously
B) $F_2 = -3F_1$, due to our “object-centric” sign conventions
C) $F_1 = F_2$, because of Newton’s 3rd law
D) You can’t draw the arrows like that
E) $|V_1| > |V_2|$
F) $|V_2| > |V_1|$