Energy methods – problem solving

Physics 211
Syracuse University, Physics 211 Spring 2017
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Announcements

- Office hours today: 5:10-6:50 – probably me + coaches
- Office hours moved from Friday to Thursday (5-7) to accommodate homework due date
- Homework due Friday
- ODS students: exam 2 will be returned tomorrow in recitation (sorry for the delay)
- Physics practice tomorrow will be an all-purpose help session: 7:30-9:30

Where we've been, where we're going

- Last time: we saw that "potential energy" is both a statement about nature and a bookkeeping trick to keep track of work
    - Potential energy only applies to conservative forces (gravity, springs)
    - Lets us account for the work done by these forces with no integrals required
    - Potential energy due to Earth's gravity: $U_g = mgy$
    - Potential energy in a spring: $U_e = \frac{1}{2}k(\Delta x)^2$

Power: rate of doing work

A bit of mathematics that will be useful to you:

"An object moves at a constant speed $\vec{v}$, subject to some force $\vec{F}$; at what rate does that force do work on the object?"

An example: an airplane flies at v=1000 m/s, and its engines exert F=300 kN of thrust. What is the rate at which the engines do work (power)?

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$$\text{Power} = \text{force} \cdot \text{velocity}$$
$$P = \vec{F} \cdot \vec{v} = 300 MW$$

- The engines output 300 MW of power: this is around 10 liters per second of fuel even at 100% efficiency!
- Some of that 300 MW of energy dissipated by drag heats up the airplane... (real numbers for a SR-71 Blackbird)

Problem-solving guide for problems involving energy

- Identify the various parts of the motion and what you need to know about them
  - Collisions/explosions: use conservation of momentum
  - Motion where you care only about begin/end states and not time: use work/energy methods
  - "Where does it land" projectile motion problems: can not use energy methods
- Draw a series of snapshots, showing what your "before" and "after" pictures look like (you may have more than two in some problems)
- Use force diagrams to calculate any forces you need to know
- Application of the work-energy theorem:

$$KE_{\text{initial}} + W_{\text{all}} = KE_{\text{final}}$$

OR

$$KE_{\text{initial}} + PE_{\text{initial}} + W_{\text{other}} = KE_{\text{final}} + PE_{\text{final}}$$

Sample problems

A mass m is hung from a spring of spring constant k and released. Which equation would let me find the distance d that it falls before it comes back up?

- A: $mgd - \frac{1}{2}kd^2 = 0$
- B: $\frac{1}{2}kx^2 = mgd + \frac{1}{2}mv^2$
- C: $0 = -mgd + \frac{1}{2}kd^2$
- D: $mgd + \frac{1}{2}kd^2 = 0$

Sample problems

A spring is used to launch a block up a ramp of total length L. The spring has spring constant k, the block has mass m, the ramp is inclined an angle θ, and it has a coefficient of kinetic friction μ_k. I compress the spring a distance x and let it go. How fast will the block be traveling when it reaches the top of the ramp?

Which equation would let me solve for this?

- A: $\frac{1}{2}kx^2 + \mu mgL\cos\theta = \frac{mgL}{\sin\theta} - \frac{1}{2}mv_f^2$
- B: $-\frac{1}{2}kx^2 + \mu mgL\sin\theta = \frac{mgL}{\sin\theta} + \frac{1}{2}mv_f^2$
- C: $\frac{1}{2}kx^2 - \mu mgL\sin\theta = mgL\cos\theta + \frac{1}{2}mv_f^2$
- D: $\frac{1}{2}kx^2 - \mu mgL\cos\theta = mgL\sin\theta + \frac{1}{2}mv_f^2$

Sample problems

A car coasts down a ramp and then up around a loop of radius r. How high must the ramp be for the car to make it around the loop? (See picture on document camera.)

How am I going to do this problem?

- A: Use conservation of momentum to relate the height of the ramp to the speed at the top of the loop, then use kinematics to determine if it will fall or not.
- B: Use conservation of energy to relate the height of the ramp to the speed at the top, then use kinematics to determine at what point it will fall in the loop.
- C: Use conservation of energy to relate the height of the ramp to the speed at the top, then use Newton's second law and our knowledge of rotational motion to determine the required speed.
- D: Use kinematics to relate the height of the ramp to the speed entering the loop, then use Newton's second law and our knowledge of rotational motion to determine the required speed.

Sample problems

A truck pulling a heavy load with mass $m = 4000$ kg wants to drive up a hill at a $30°$ grade.

If the truck's engine can produce 100 kW of power (134 hp), how fast can the truck go? (Neglect drag.)

A 1000 kg car has an engine that produces up to P=100 kW of power. If it accelerates as hard as it can, at what speed does its acceleration become limited by the engine?

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At low speeds: static friction limits acceleration
At high speeds: engine power limits acceleration

42. ‖ A 1000 kg elevator accelerates upward at 1.0 m/s^2 for 10 m, starting from rest.

a. How much work does gravity do on the elevator?

b. How much work does the tension in the elevator cable do on the elevator?

c. Use the work-kinetic energy theorem to find the kinetic energy of the elevator as it reaches 10 m.

d. What is the speed of the elevator as it reaches 10 m?

57. ‖ The spring shown in **FIGURE P11.57** is compressed 50 cm and used to launch a 100 kg physics student. The track is frictionless until it starts up the incline. The student's coefficient of kinetic friction on the 30° incline is 0.15.

a. What is the student's speed just after losing contact with the spring?

b. How far up the incline does the student go?

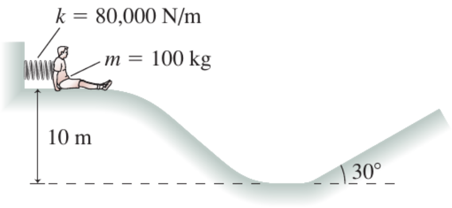

FIGURE P11.57

Sample problems

49. ‖ Truck brakes can fail if they get too hot. In some mountainous areas, ramps of loose gravel are constructed to stop runaway trucks that have lost their brakes. The combination of a slight upward slope and a large coefficient of rolling resistance as the truck tires sink into the gravel brings the truck safely to a halt. Suppose a gravel ramp slopes upward at 6.0° and the coefficient of rolling friction is 0.40. Use work and energy to find the length of a ramp that will stop a 15,000 kg truck that enters the ramp at 35 m/s ($\approx$75 mph).