Power; reviewing work and energy

Physics 211
Syracuse University, Physics 211 Spring 2020
Walter Freeman

March 30, 2020

How are you all doing?

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How have your classes been going?

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How has *this* class been going?

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- Your questions
- A few demo problems on conservation of momentum and energy

- A new idea, in more depth: *power*
- An example of that idea

Your questions

What would you all like to talk about? (Homework, recitation problems, big ideas...)

While you're thinking: how useful are the recordings of recitation and homework solutions?

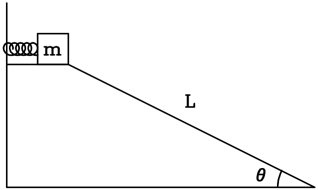
- **A:** Not useful
- **B:** Moderately useful
- **C:** Quite useful
- **D:** I've not watched any of them yet

Please give me feedback on them (what can I do better?) if you've watched any.

The work-energy theorem and conservation of energy

"When do I use the conservation of energy and when do I use the work-energy theorem?"

They are really the same: *potential energy* is a bookkeeping device for the work done by conservative forces.



Some students are sledding down the hill in front of the music building; it has a length L and is at a slope θ. To go faster, they build a sled-launcher, consisting of a spring of spring constant k. A student compresses it by a distance d and launches themselves down the hill.

How fast are they going at the bottom?

What's the work done by **the spring**?

- A: $W_{\text{elas}} = -\frac{1}{2}kd^2$
- B: $W_{\text{elas}} = +\frac{1}{2}kd^2$
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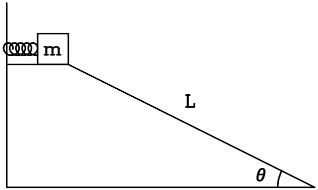

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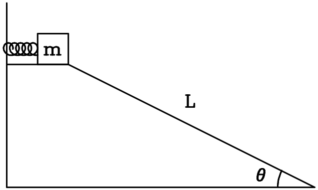

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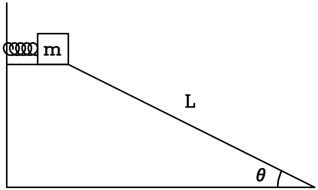

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What's the work done by **friction**?

- A: $W_{\text{grav}} = \mu(mg\cos\theta)$
- B: $W_{\text{grav}} = -\mu(mg\cos\theta)$
- C: $W_{\text{grav}} = -\mu(mg\cos\theta)(L\sin\theta)$
- D: $W_{\text{grav}} = mgL$

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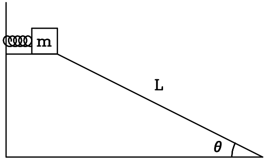

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Power

You encountered *power* before as the rate of doing work or transforming energy:

$$P = \frac{E}{\Delta t}$$

This is important in engineering, since many of our machines are constrained by the rate at which they can manipulate energy, or that they require energy:

- My laptop: 4W (minimum to run) - 25W (maximum cooling system can handle)
- A duck: 25-60W (sustained power from flight muscles)
- Human on a bike: 100-300W (sustained over an hour), five times that (peak)
- Horse: 750W (averaged over a working day), 10 kW (brief peak)
- Automobile engine: 75 kW (my car) - 400 kW (high-end sports car)
- Diesel-electric locomotive: 2500 kW
- Nuclear submarine: 30 MW
- Nuclear reactor: 1500 MW (electric), 3000 MW (heat)

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Starting with the work-energy theorem, as always:

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Power is the rate at which work is done – the *time derivative* of work. So we take time derivatives of both sides:

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Biking with air resistance

A cyclist and her bike have a mass of $m = 70kg$, and she can produce a sustained power of 120 W for a long time.

She can sustain a speed of 12 m/s. At this speed, the main friction force on her is the wind.

How big is that frictional force?

A: 700 N

B: 10 N

C: 1200 N

D: 100 N

Biking up a hill

A cyclist and her bike have a mass of $m = 70$ kg, and she can produce a sustained power of 120 W for a long time.

She then wants to ride up a hill, sloped at at an angle of about $\theta = 6^\circ = 0.1$ radian.

How fast can she go up the hill? *(This is a lot slower, so you can ignore air drag here.)*

Going down a steep hill, slowly

Suppose our $m = 70$ kg rider wants to go down a steep hill, angled at 10 degrees below the horizontal, at a safe speed of 4 m/s. *(At this speed, ignore air drag.)*

Brakes work by squeezing a rotating object with a large normal force, creating a lot of friction. This friction does negative work on the rotating wheel, converting its kinetic energy into heat.

What power will the brakes in her bicycle produce?

Brakes on a bike intended for off-road use. The rotor is designed to maximize airflow – to give the material a fighting chance of dissipating this much heat!

Another sample problem: work and energy

A basketball of mass m hangs from a cable of length L; it is pulled to the left at an angle θ and released.

A very strong wind blows from left to right, exerting a constant force F_w on the ball.

How fast will the ball be traveling when it is at its lowest point? What angle ϕ will the ball swing to on the other side?

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