Energy Forms and Changes

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EM: "Energy Forms" might be interpreted as energy is created

Progress:
https://docs.google.com/spreadsheet/ccc?key=0Ajw3oS4YmCBqdDVrTnp1eXQ2cnhVYlBQbW5EMzQzYVE#gid=0

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Learning Goals

CO Standards:

8th Physical Science

- 2. There are different forms of energy, and those forms of energy can be changed from one form to another – but total energy is conserved

NP: Pretty general. I think if we hit all the TEKS, we'll have this one covered.

Stamatis: It might be good to define conservation in a way that I suspect will be the NGSS way: Conservation doesn't mean total energy of a closed system is constant.

Rather, the energy of any system is conserved--by this we mean that changes of energy inside the system, if they occur, will be balanced by energy coming into the system minus energy flowing out of the system. This is consistent with how we think of conservation of charge. Changes in charge inside a system are balanced by the charges that go in minus the charges that go out.

NP: I like the NGSS definition. It's a difficulty, I believe, with "what is the system?" One alternate idea is that if the energy is changing, you need to make your system larger (more inclusive of sources and sinks). Personally, I prefer the idea that if the energy is changing, you need to account for how much came in and how much went out, and from/to where.

TEKS:

112.18, Science, Grade 6, Physical Science

(8) Force, motion, and energy. The student knows force and motion are related to potential and kinetic energy. The student is expected to:

(A) compare and contrast potential and kinetic energy;

Force, motion, and energy. The student knows that the Law of Conservation of Energy states that energy can neither be created nor destroyed, it just changes form. The student is expected to:

(9) Force, motion, and energy. The student knows that the Law of Conservation of Energy states that energy can neither be created nor destroyed, it just changes form. The student is expected to:

(A) investigate methods of thermal energy transfer, including conduction, convection, and radiation;

NP: Should this be in a sim on general energy changes, or just about thermal? Or maybe tabs for different types of energy changes, including thermal?
-conduction, convection, radiation is its own sim

Stamatis: I would beg you never to have the term potential energy without qualifying what type of potential energy. So, gravitational energy (or even gravitational potential energy) is much better than potential energy. Also, it would be great to always have the possibility of thermal energy (maybe through a friction slider?)

NP: Agreed about PE. For thermal, it will depend on the particular system, but I like the idea of having a friction slider (or equivalent) that can let students see how changes in thermal depend on particulars of the system.

EM: Maybe all the TEKS below here could be in a section that is "what the sim will NOT include'.

-

(B) verify through investigations that thermal energy moves in a predictable pattern from warmer to cooler until all the substances attain the same temperature such as an ice cube melting; and

NP: This could be done in a sim on thermal energy transfer.

(C) demonstrate energy transformations such as energy in a flashlight battery changes from chemical energy to electrical energy to light energy.

NP: Not sure how one "demonstrates" this.

EM: Maybe some way to measure energy at each point, to show that there is 'energy' in the battery and 'energy' in the bulb. Not sure how to get across that one is 'chemical energy' and the other is 'electrical energy'.

Stamatis: Important decision for y'all about circuits: The following sim has the "correct" physics re: energy transfers in resistive circuits. Yet, that is not how the story goes in any curriculum that I know. http://www.oberlin.edu/physics/dstyer/CircuitSurveyor/

NP: Perhaps this will be more clear when we have a good energy representation (chunks?) that are color coded by energy form.

(7) Matter and energy. The student knows that some of Earth's energy resources are available on a nearly perpetual basis, while others can be renewed over a relatively short period of time. Some energy resources, once depleted, are essentially nonrenewable. The student is expected to:

(A)research and debate the advantages and disadvantages of using coal, oil, natural gas, nuclear power, biomass, wind, hydropower, geothermal, and solar resources;

NP: I think we'll avoid this one in the sim

112.16, Science, Grade 5, Physical Science

(6) Force, motion, and energy. The student knows that energy occurs in many forms and can be observed in cycles, patterns, and systems. The student is expected to:

(A) explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy;

NP: Textbooks list 5 types as "mechanical, thermal, electromagnetic, chemical, and nuclear". I think the 5 above are more salient to 5th grade, so maybe use those?

Stamatis: Sound is a form of energy is some elementary curricula. Also, mechanical is what exactly? (I know the canonical answer, but unlike the others, it has no single indicator.) Why not motion energy, spring energy (or elastic energy), thermal, chemical,

…)

NP: AAAS lists "motion, thermal, gravitational, elastic, chemical, electrical, and light" in the paragraph below. This leaves out sound. I think the TEKS are lumping motion, gravitational, and elastic into mechanical (indicated by either speed or position). I like the AAAS because the form directly references the indicator.

Sim learning goals:

- describe the different types of energy and give examples from everyday life
- Can change one form of energy into another (work on these)
- Can identify when the form of energy has changed
- "students can tell the energy story for real-life system" (Stamatis)
- Energy is conserved

Sim Design

Physical Model

Symbol	Variable name	Notes
Q	heat	calculate below
m	mass	calculate below
ρ	density	in table
κ	thermal conductivity	in table
V	volume	depends on shape
A	surface area	depends on shape
T	temperature	In deg C or K
T_{eq}	equilibrium temperature	calculate below
N_E	number of energy "chunks"	calculate below
p	chunks multiplier	set based on space available in sim

Equation	Description

$m = \rho V$	mass of object
$V_{cube} = width \times length \times height$	volume of cube (or rectangular shape)
$V_{cylinder} = \pi r^2 \times height$	volume of cylinder (*r* = *radius of bottom*)
$\Delta T = \frac{Q}{mc}$	change in temperature
$Q = mc\Delta T$	change in thermal energy.
$Q_{tot} = mcT$	If using K, the total thermal energy is mcT since *Q=0* at 0K.
$\frac{dQ}{dt} = -\kappa A \nabla T$	time rate of heat change by conduction
$\nabla T = \frac{T_{hot} - T_{cold}}{d}$	simplified version of temperature gradient, *d* is the distance between bodies
$T_{eq} = \frac{m_1 c_1 T_1 + m_2 c_2 T_2}{m_1 c_1 + m_2 c_2}$	equilibrium temperature for objects 1 and 2 brought into contact
$N_E = Q_{tot} \times p$	number of energy chunks in an object

For more see http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/spht.html

Values below from:
http://en.wikipedia.org/wiki/Heat_capacity#Table_of_specific_heat_capacities
http://hyperphysics.phy-astr.gsu.edu/hbase/tables/thrcn.html#c1

Important: We need to come up with a model for how quickly heat transfers between objects.

- We can use thermal conductivity, but I'm not sure how to do this with two objects in contact...and not sure we need to be completely physically accurate anyway on this.
- More important, when heater is off objects will return to room temperature. This means objects should be constantly exchanging energy with air, even while being heated/cooled and also when in contact. But this means the equilibrium temperature will be a little different from what you would calculate just based on object temperature.
- Energy lost to air will be much slower than between objects, so this is probably OK. Especially since only qualitative, probably won't be able to notice the effect unless you wait a long time.
- What they would see is two objects brought together, they would reach equilibrium fairly quickly, then both objects would start to approach room temperature. This is a bit complicated, but it is what students might expect to see.
- This also means energy chunks will be constantly floating off into the air. This is OK because the energy chunks in air will be about 100X fewer than in objects.
- KP: These seem like great issues to discuss with Mike -- he'll have great suggestions on

this I think.

- NP: Discussed with Mike. Preliminary model idea below.

Time-dependent Energy Transfer

- Mike says a way to do this is to make thermal conductivity *between* objects a tunable parameter. Tune to get reasonable behavior.
- Make simplification that objects have even temperature distribution immediately - i.e., ignore thermal conductivity within objects.
- Use $\frac{dQ}{dt} = -\kappa A \frac{T_{hot} - T_{cold}}{d}$
- Choose some distance *d* between objects.
- Choose κ for the interface between objects. Have three constants:
    - $\kappa_{object-object}$
    - $\kappa_{air-object}$
    - $\kappa_{water-object}$
- Must have $\kappa_{air-object}$ << $\kappa_{object-object}$ and $\kappa_{water-object}$, so that air does not conduct away heat quickly.
- Objects would be brick and lead.
- *A* is the area in contact.
- Objects constantly exchange energy with everything they touch. So if objects touching each other on one side, they also exchange energy with air on sides that are in air.

Objects to use

- We are going to have water no matter what
- Other two good objects probably Iron and Brick
    - Iron is pretty close to water
    - Brick is about ½ as much energy at same temperatures
    - Meant highest / lowest ratio is 3:1. We should be able to show this.
- Do we make amount of energy relative to 0K or to 0C?
    - If 0K = 0 chunks, then number of chunks only changes about 36%. Noticeable, but not huge. (note that we will only allow 273.1 K - 372.9 K).
    - If 0C = 0 chunks, then *apparent* change can be greater, but it's not really correct. I don't think we should do this.
        - KP: I agree I don't think having 0 chunks at 0C is right - it has great potential to cause issues.
        - NP agrees.
    - Example: if we make 1 chunk per 10 K, then water at 273K ~ 114 chunks. At 373K ~ 156 chunks. Brick at 273K ~ 46 chunks, at 373K ~ 63 chunks.
    - Will students notice this change?
    - Will they be confused that there is still so much energy at 0C? I tend to think this is OK, since realizing there is energy even in cold things is important.
    - KP: Could also compromise and do something like 1 chunk per 20K until 273K then change to 1 chunk per 10K - so somewhat exaggerating the 0C and up

range for visual - or you could have do something like in Neuron where the "baseline e's" are somewhat faded and the incoming and outgoing e's are more visible?

- NP: I like the idea of having "background" E's faded. Just need to make sure the faded aren't interpreted as "less". I think we should try a fixed number, e.g. 1 chunk per 10K and see how it looks first.
- KP: It's interesting that air has so much less energy stored in it … maybe we can show e in air without overload? Or showing e in air is really not showing it in the first place?
- NP: Yes, air is basically going to have no E's. So I think it is accurate to have E's float into air and then disappear off the screen. This shows that energy is going into the air, but also keeps the total energy in air realistic without having E's floating in air.

Constants

					Energy (J) at deg K		
Material	c **(J / g-K)**	κ **(W / m K)**	ρ **(g / cm^3)**	m **of 1 cm^3**	**273**	**296**	**373**
Water	4.186	0.6	1.000	1.000	1142.8	1239.1	1561.4
Iron	0.450	79.5	7.800	7.800	958.2	1039.0	1309.2
Gold	0.129	314	19.300	19.300	679.7	737.0	928.7
Granite	0.790	0.8 (?)	2.700	2.700	582.3	631.4	795.6
Glass	0.840	0.8	2.500	2.500	573.3	621.6	783.3
Concrete	0.880	0.8	2.200	2.200	528.5	573.1	722.1
Brick	0.840	0.6	2.000	2.000	458.6	497.3	626.6
Lead	0.129	34.7	11.300	11.300	398.0	431.5	543.7
Wood	1.700	0.1	0.670	0.670	310.9	337.1	424.8
Air	1.012	0.024	.001	.001	0.357	0.387	0.488

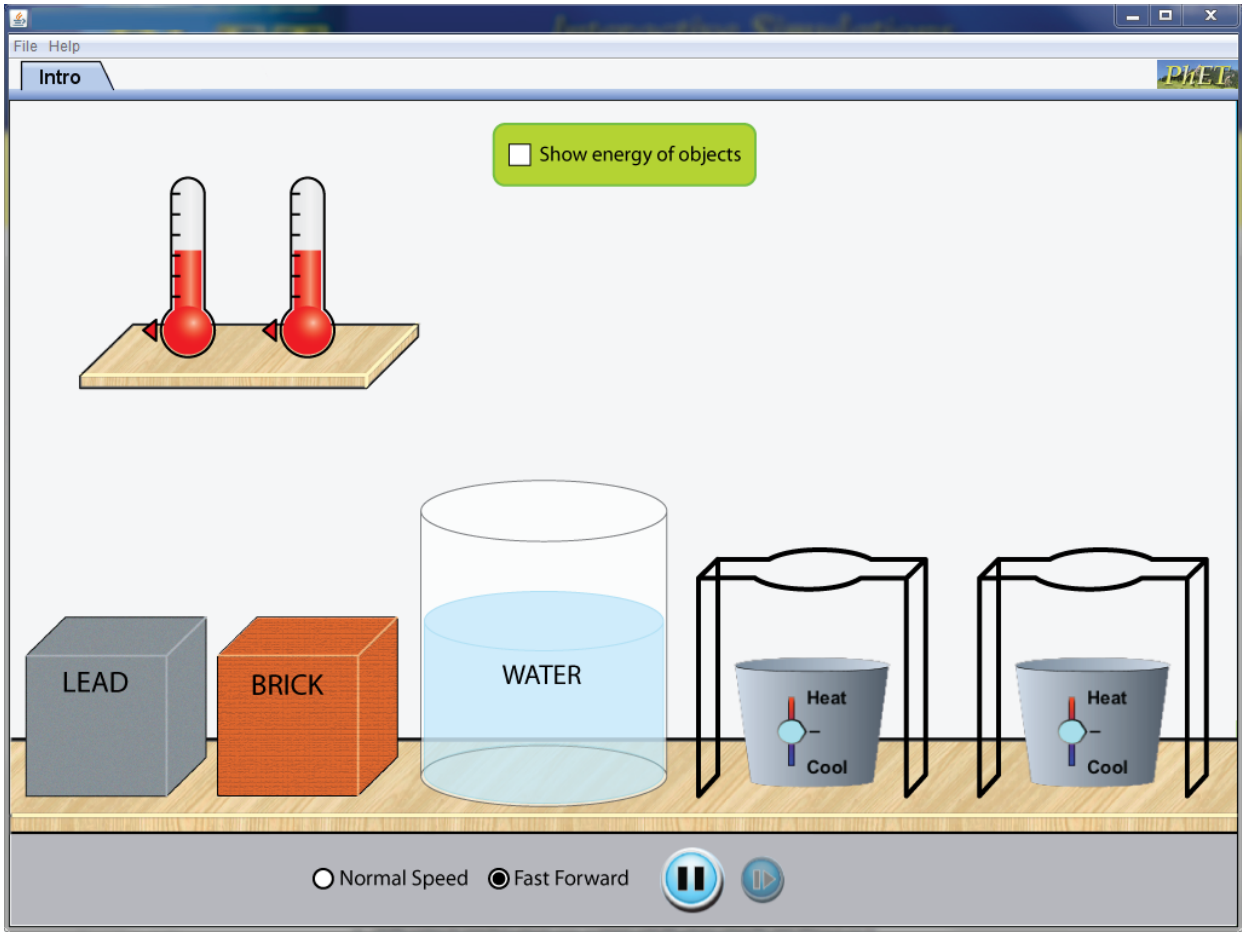
Meeting 9/27 Notes

- check for E's crossing paths

Tab 1 - Intro

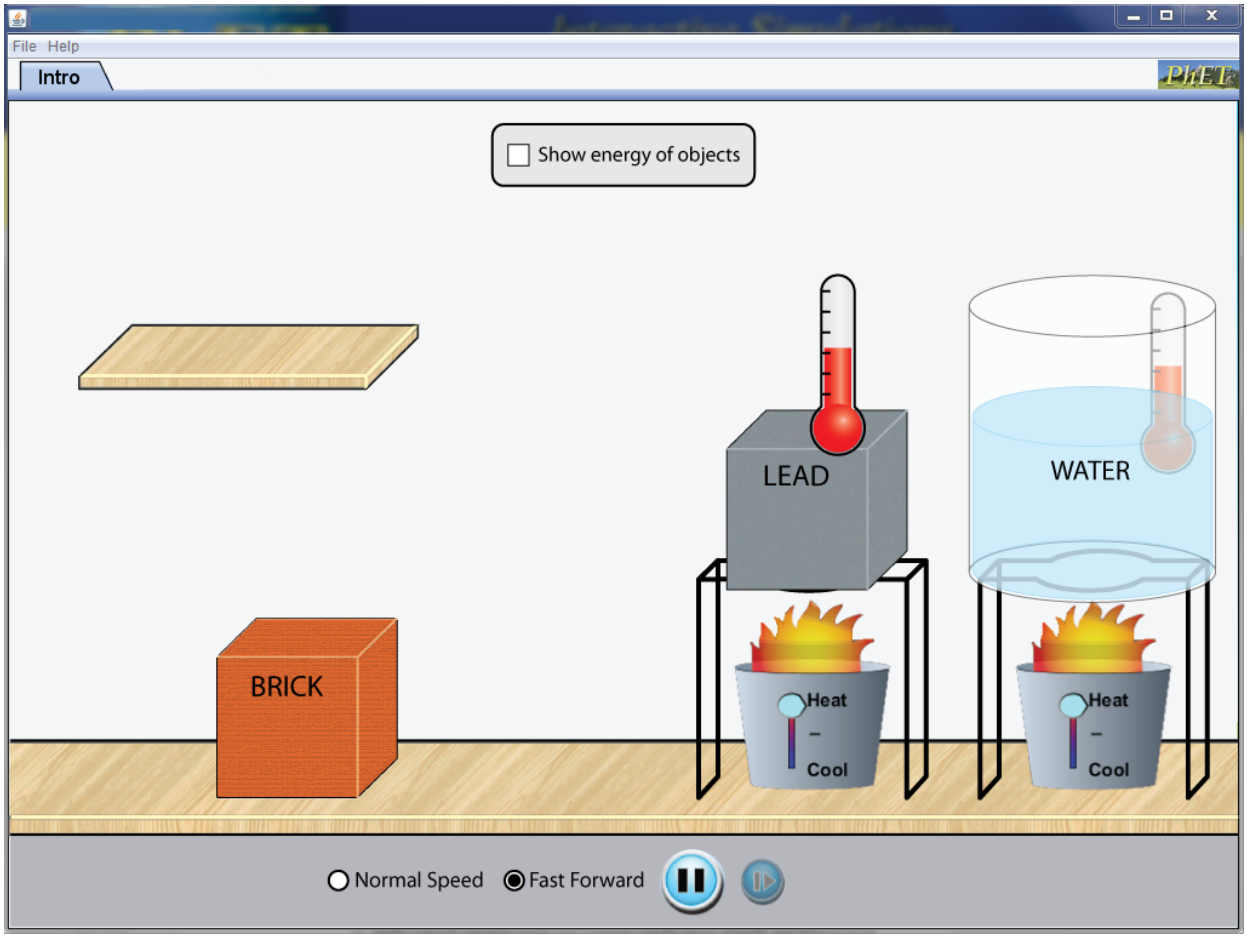
Start state

- Start with three "objects" (lead, brick, cup of water). All are at room temp (~26C).
- Bottom shelf is wood grain to look like a "fun lab"
- Two heaters with stands (borrowed from SOM Basics)
- Two thermometers sitting on a shelf (see below for description of use)
- Check box for "Show energy of objects" (see below)
- Radio buttons for "Normal speed" and "Fast forward"
    - Normal speed should still be faster than reality
    - Fast forward will make objects equal out in a couple seconds
- Play/pause/step buttons as usual
- Can move objects onto stands and heat/cool them
- Can place lead/brick in water and temperatures will equal out
    - Water level should rise when something is placed in it
    - Should be able to place two objects in water
- Can place lead on brick and temperature will equal out
- When heater is off, objects return to room temperature
- Limits on temperature
    - Upper limit: 99.9C (no water boiling)
    - Lower limit: 0.1C (no freezing)
    - When limit is reached, slider can not be moved in that direction anymore
    - *Reasoning*: we do not want to address phase energy in this sim, which is about basic energy forms and changes. We will address this learning goal in another related sim.
- Fast forward makes E's from air heat or cool very quickly (basically, like x1000)
- Normal, FFD vertically aligned

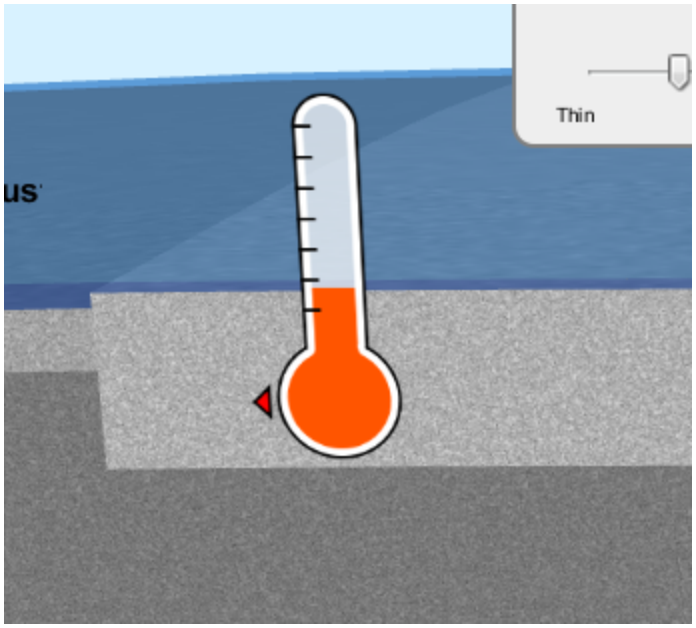


Thermometers

- Can be placed on top of solid objects, dunked into water.
- These are just qualitative (I don't think we need quantitative here.)
- Min temp = 0C, max = 100C
- Note that I have changed the termometer in the image above (small triangle to indicate measuring point).



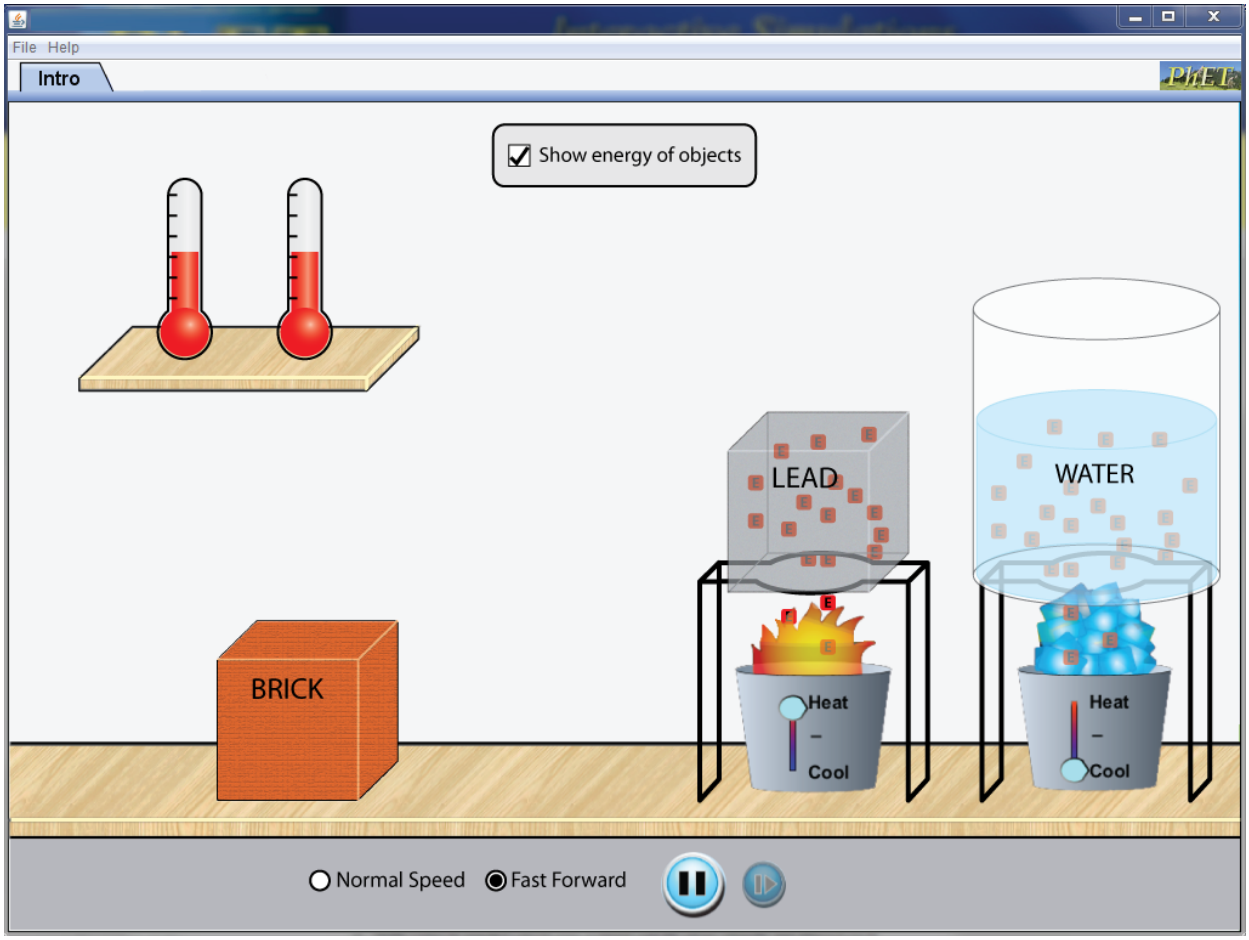
This design from Plate Tectonics might get around the ambiguity in “where is it measuring”.



Energy Representation

- Energy represented by squares with “E” in them (chunks)
    - E stands for “Energy” and as an extra indicator that this is a cartoonish rep
- Number of chunks proportional to amount of energy
- Objects start with energy equivalent to room temperature
    - Chunks are randomly distributed in object
    - Chunks stay in place, do not move around
- Objects become transparent so that chunks appear “inside”
- Heating objects
    - Chunks float up from heater to object
    - Chunks move to make room for new chunks
- Cooling objects
    - Chunks float down from object to cooler
    - Chunks move into gap and redistribute randomly
- No heating/cooling (heater off)
    - Objects should return to room temperature
    - If warmer than room temp: Chunks float out of objects into play area, then move off the screen (so no chunks left in the “air”)
    - If cooler than room temp: Chunks just appear. Don’t want to make chunks float in from somewhere mysterious.
- Heating/cooling with no object
    - No energy flows
    - *Only* showing *energy of objects*, so if no object, no energy shown

Energy chunks: filled squares with E (color coded fill)



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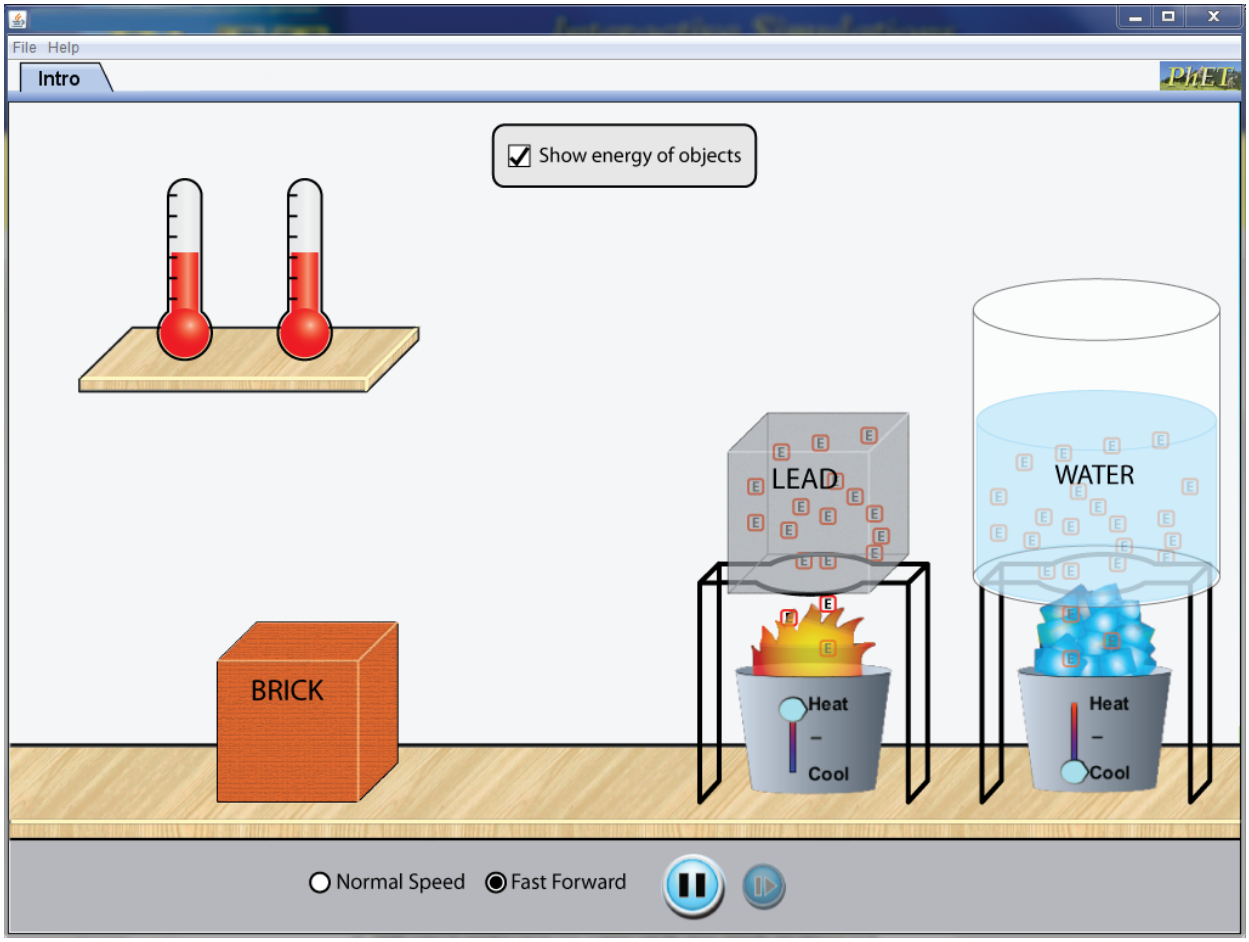
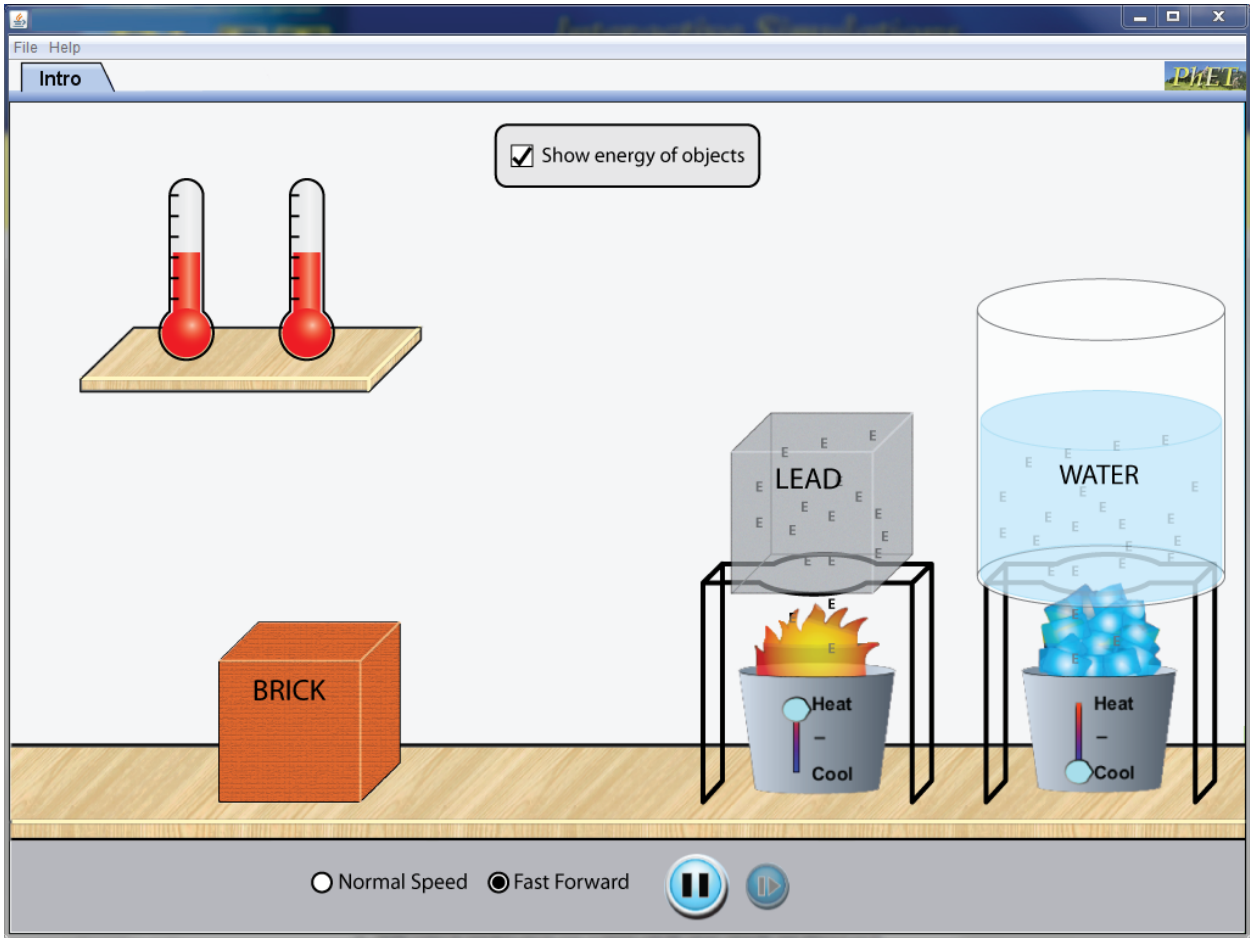
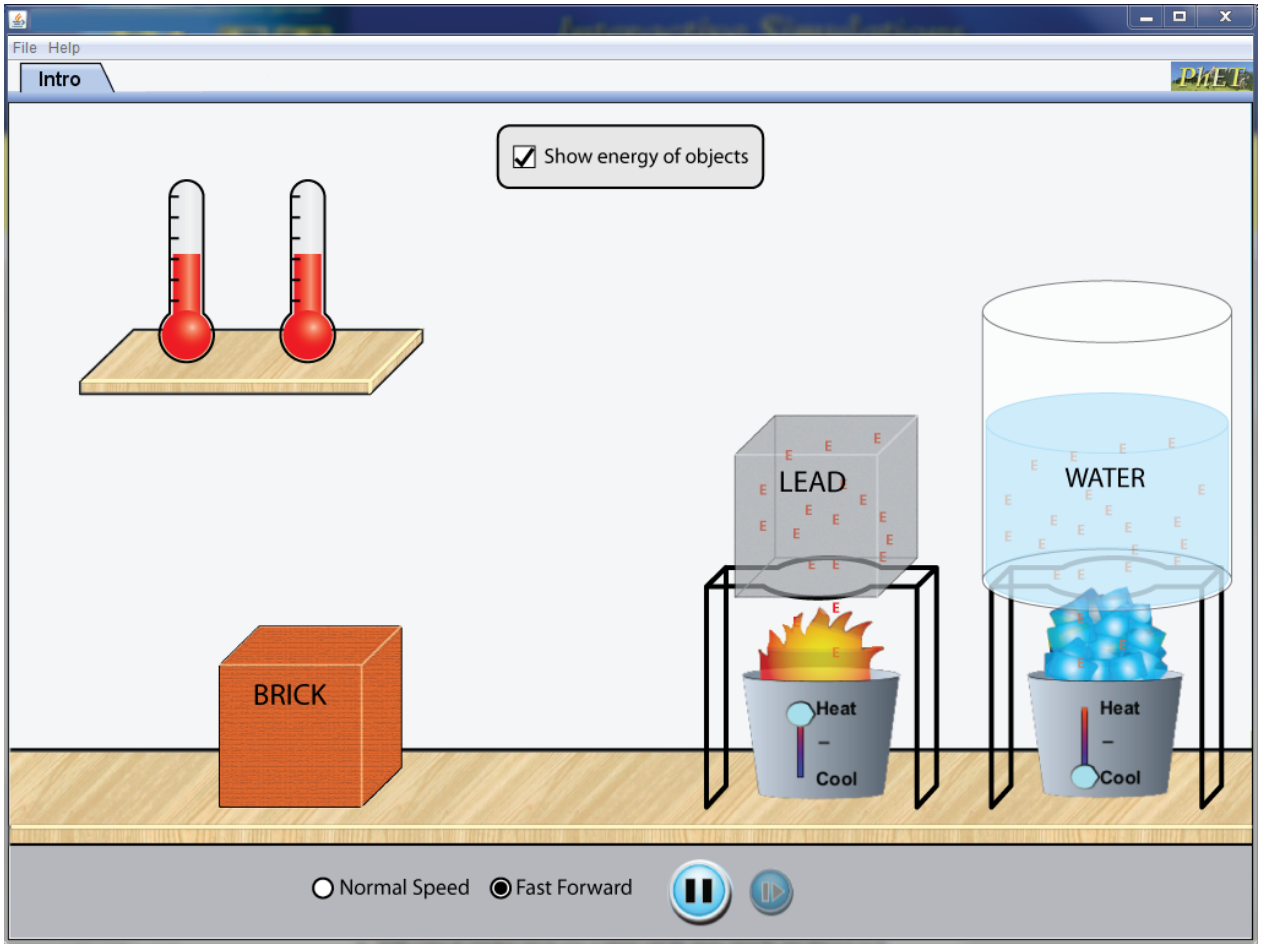
Empty squares with E (color coded outline)



Just E, black (no color coding).



Just E, letter color coding (red = thermal)



Tab 2 - Energy Systems

- Bridge from 1st to 3rd tab
- Have just a few objects here.
    - Can switch source (left), changer (middle), and sink (right) using arrow buttons at bottom.
    - The objects “slide” up to switch out when using the arrow buttons, as if on a big wheel.
- Can adjust something in source (e.g., faucet slider > rate of water > generator speed > heater temperature)
- Can show energy. The energy chunks will flow through the system and change color coding as they change energy form.
    - Need to figure out how they get from the faucet to water...and need to consider PE vs KE of water...are these all mechanical, or separate KE and PE?
- For sun, have slider to change time of day. So at noon, bright and lots of energy (bright bulb). At night, no sun, no energy to bulb.
- Not sure about 3rd case. Just came up with steam > generator > bulb, but there might be

something better.

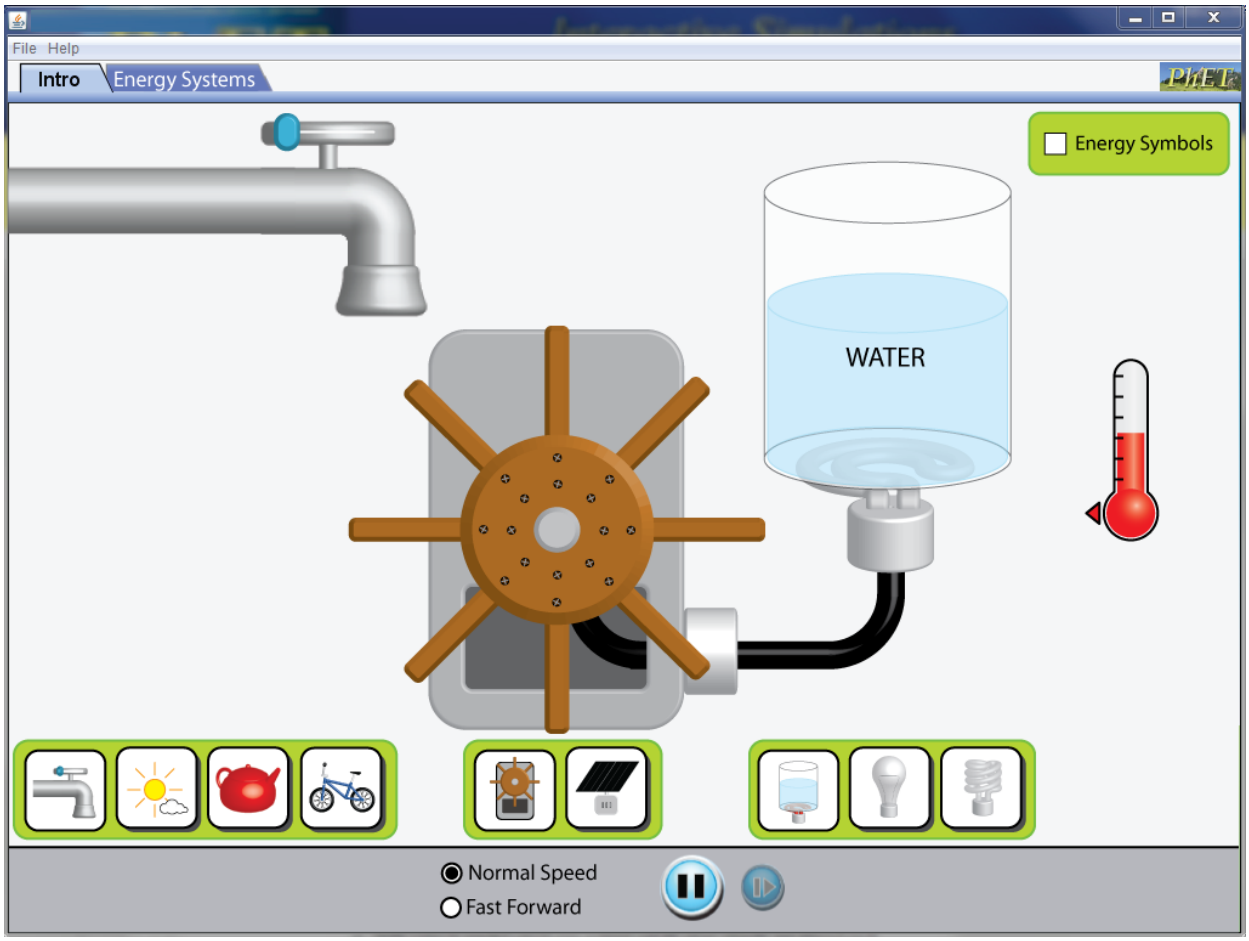
Ideas

- Have the theme “how to you heat up water?”
    - Have sun, fire, electric heater that you can use
    - Explore energy forms and mini-story

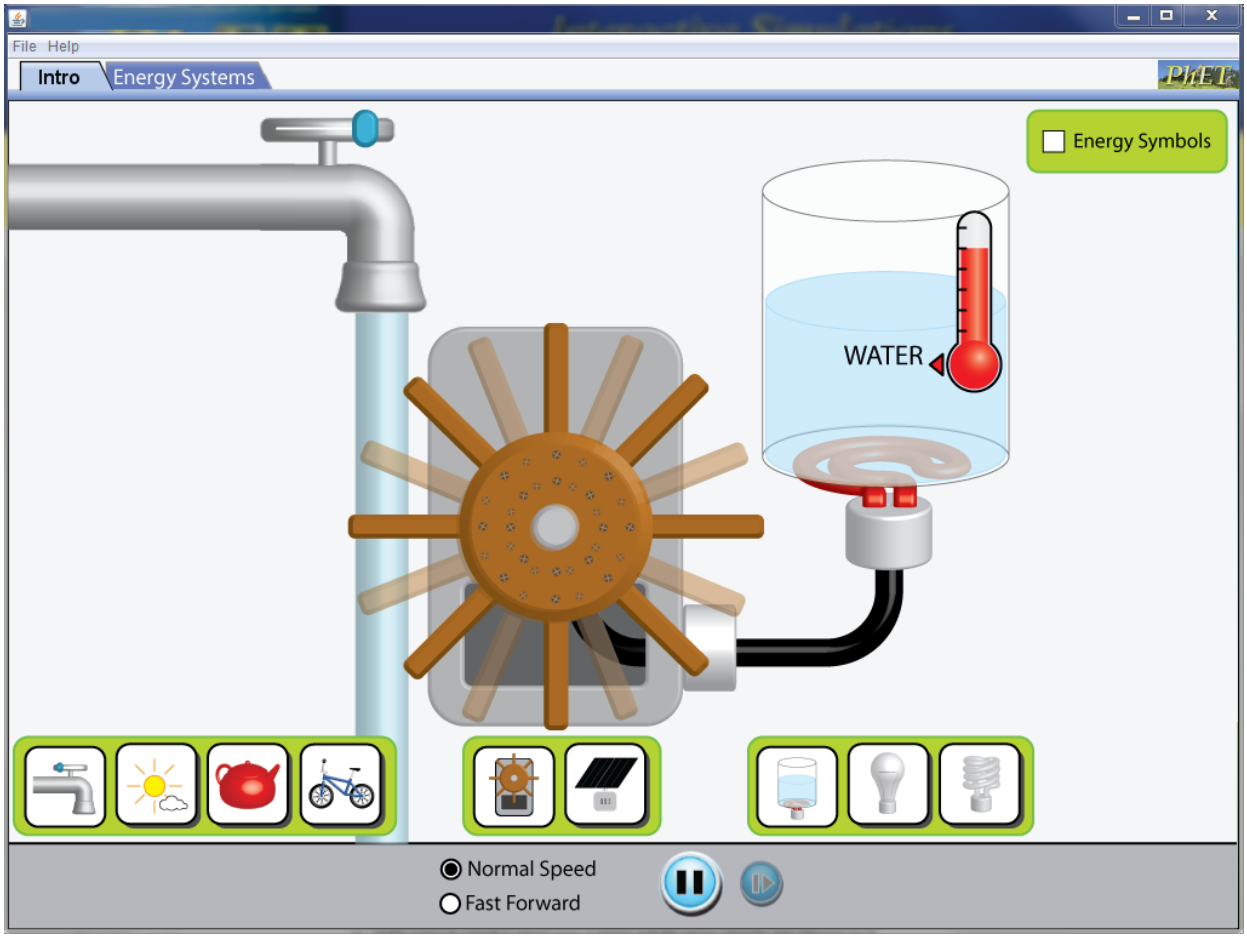
Start in this state, faucet, generator, water cup. This ties to 1st tab.

Request for transparent part of generator so you can see wire.

Mock up below uses buttons for to switch objects rather than spinners.

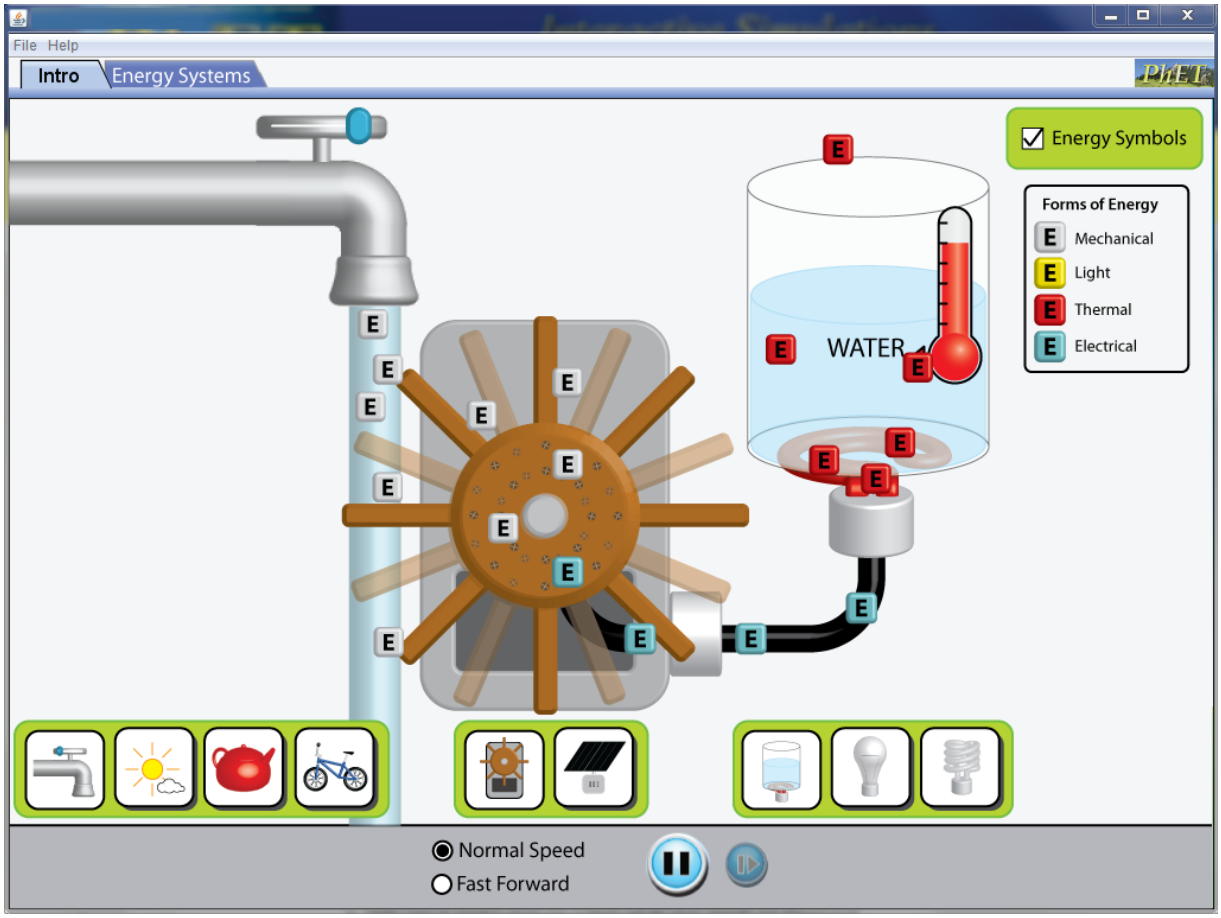


When water is running, it turns the generator and heats up the water.

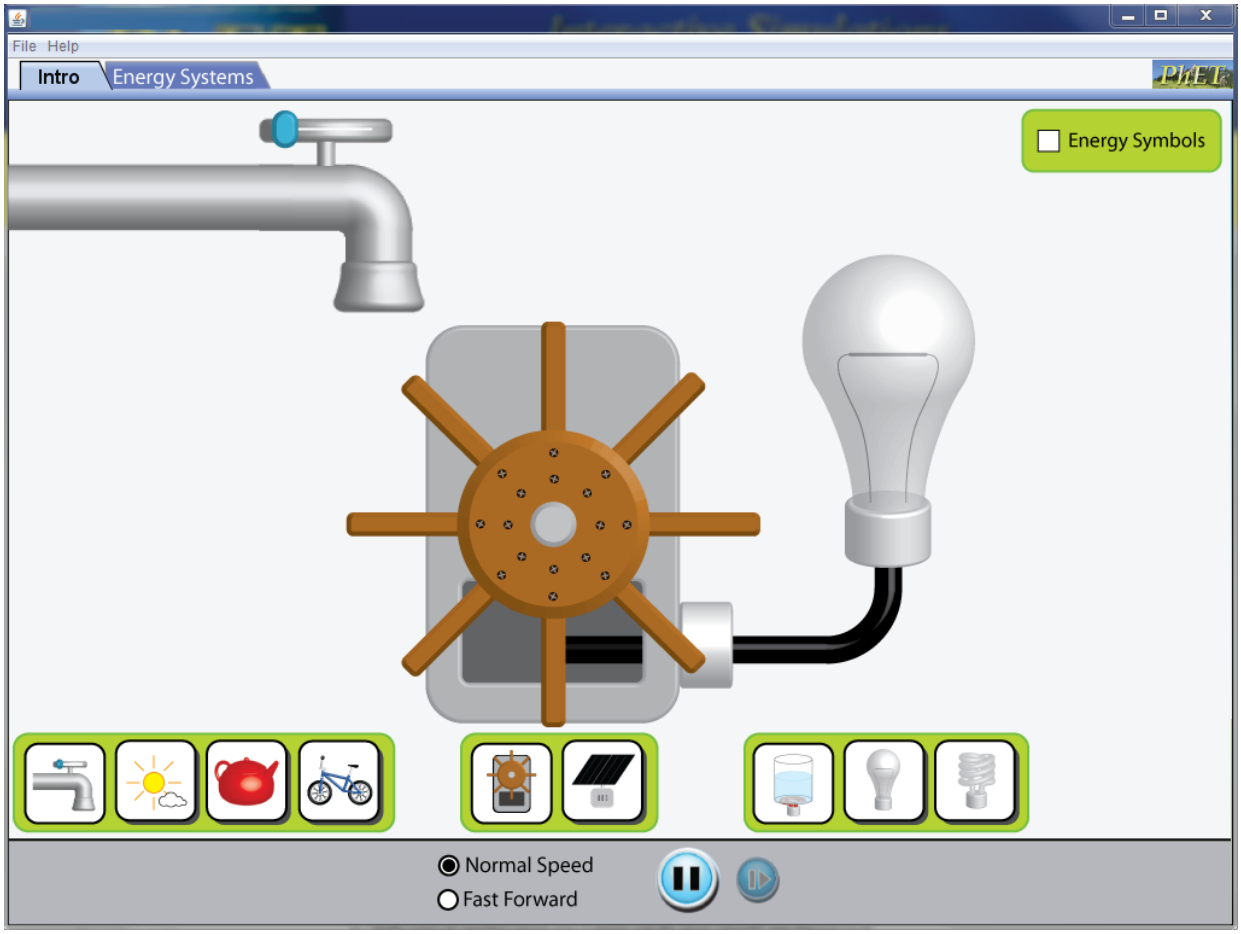


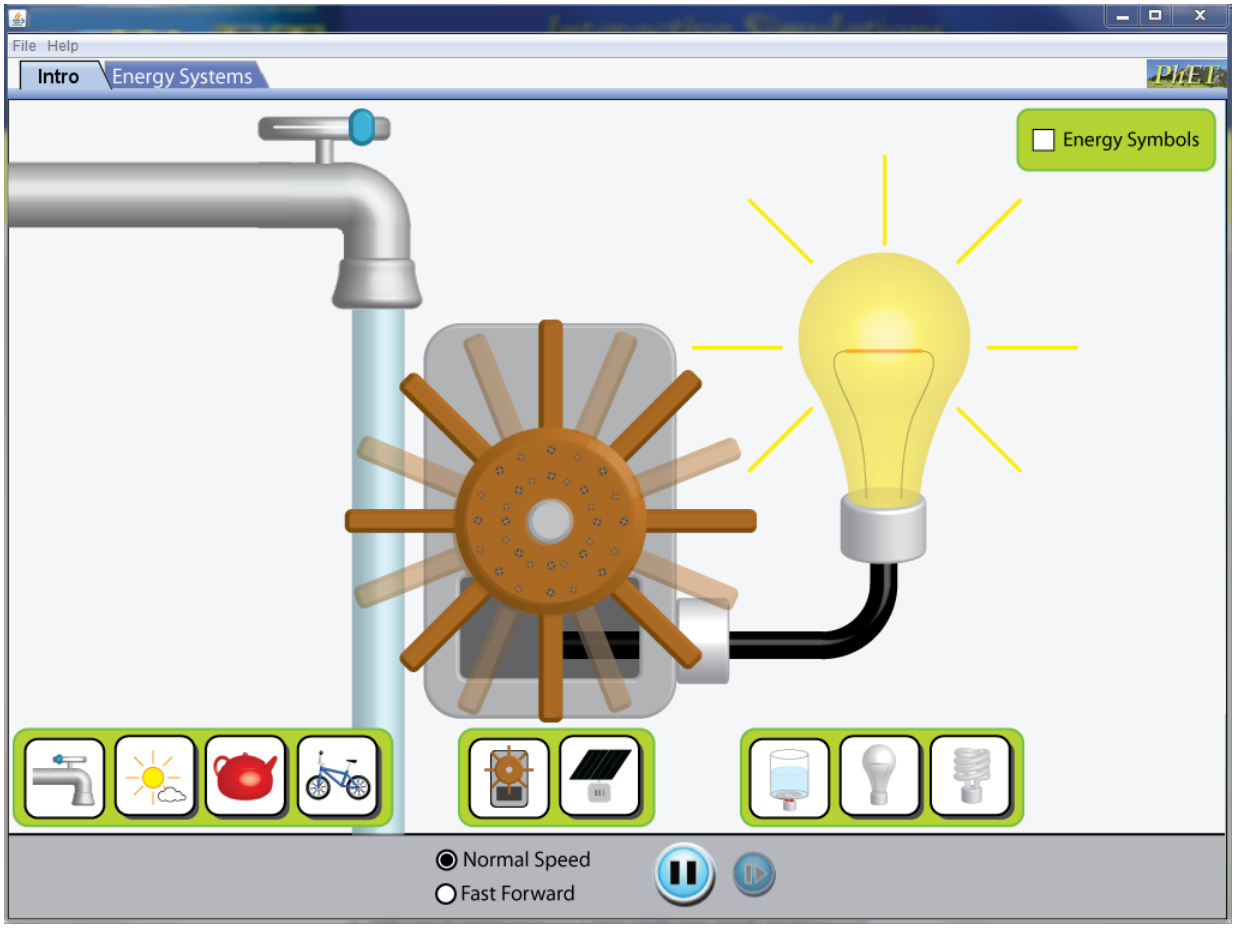
Showing energy chunks.

- “E’s” start as mechanical in water, flow into generator, then turn into electrical as then enter the wire. Then turn into thermal as they enter the water. Color will fade as energy form changes (e.g., from yellow to red).
- Legend appears when “Show energy” is checked.
- Is it OK to just have E’s floating on top? Should we make the generator transparent so you can see “inside” as mech E’s turn into electrical E’s?
- Need to decide what to do about electrical vs light energy. Some standards use “electromagnetic”, some treat electrical and light separately.
- Also note that I’ve left chemical energy out. There is no chemical energy in the objects used in this tab, and I thought it might be good to limit the number of forms in this tab, then include chemical in tab 3.

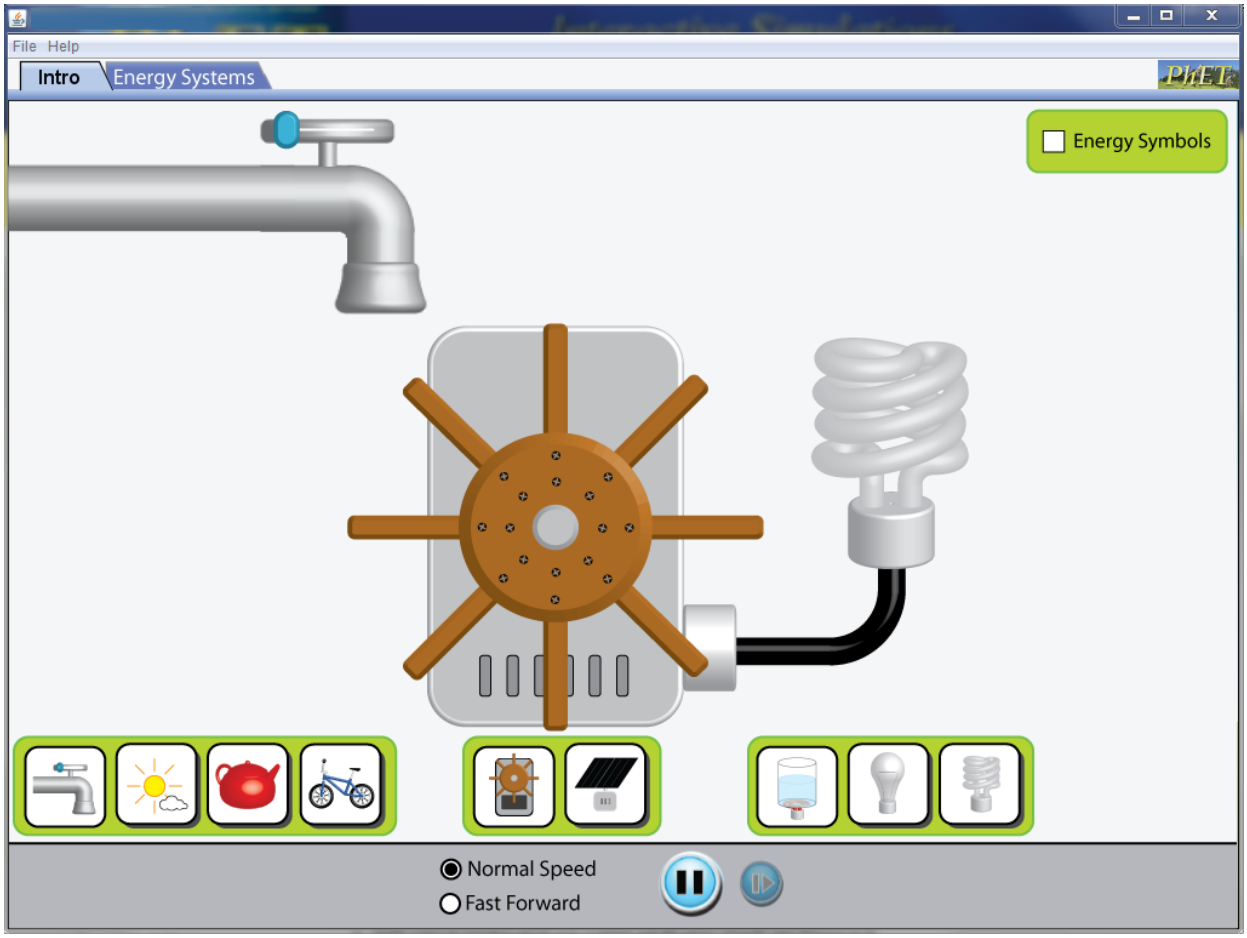


Can switch out the water cup for an incandescent bulb.


File Help
Intro
Energy Systems
PhET
Energy Symbols
Normal Speed
Fast Forward



Or a compact fluorescent.
Fluorescent bulb gives off less thermal than incandescent (it is more efficient for making light).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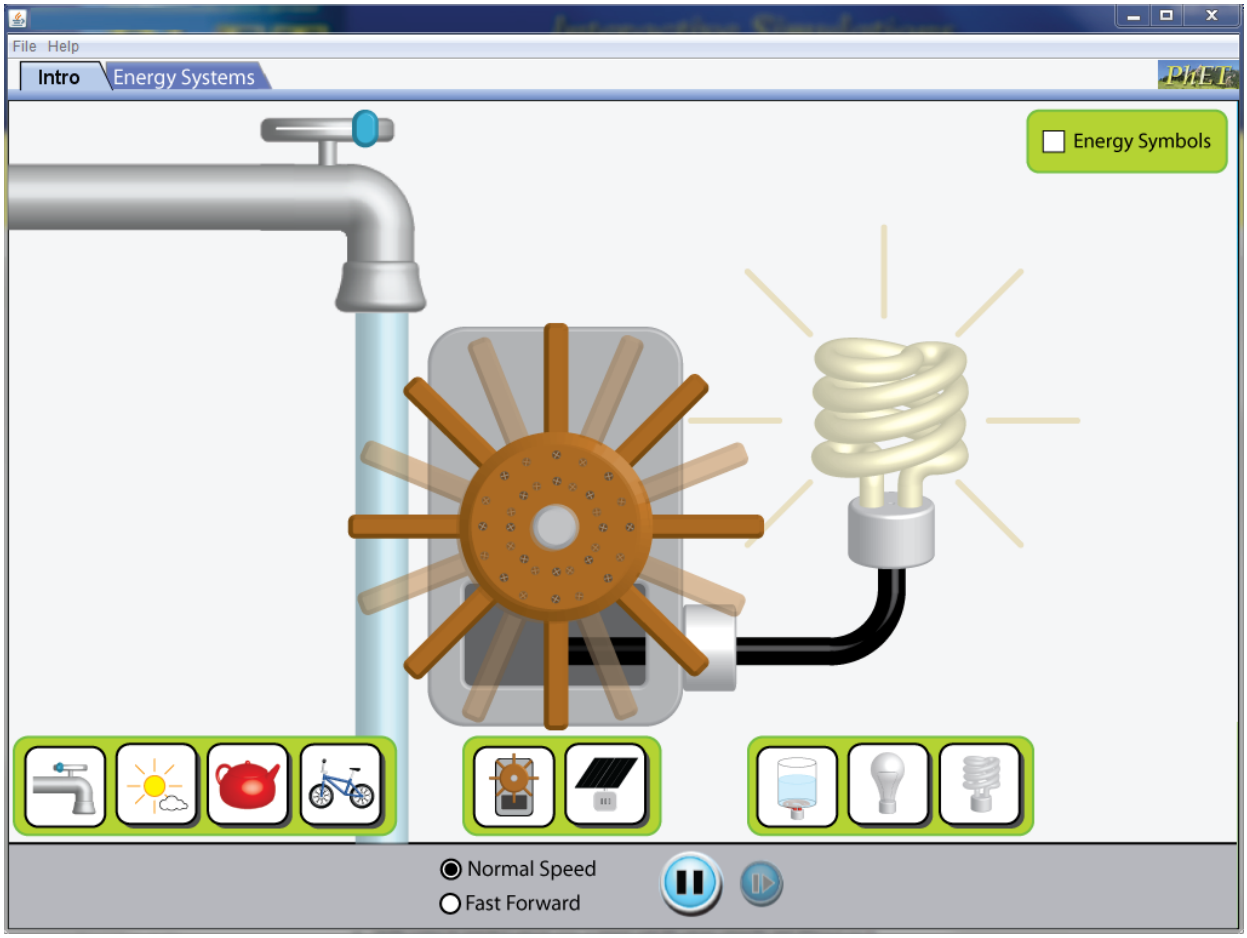
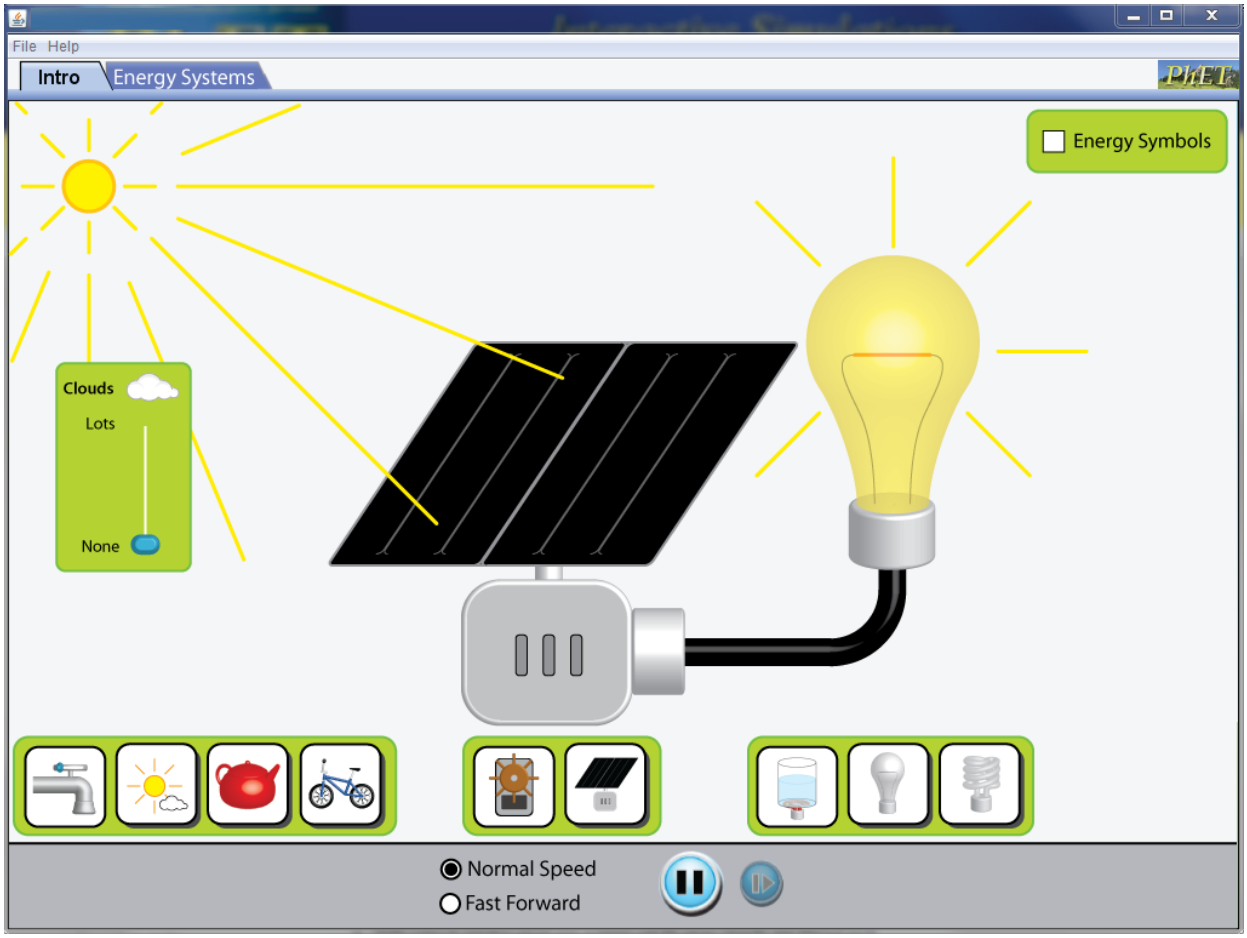
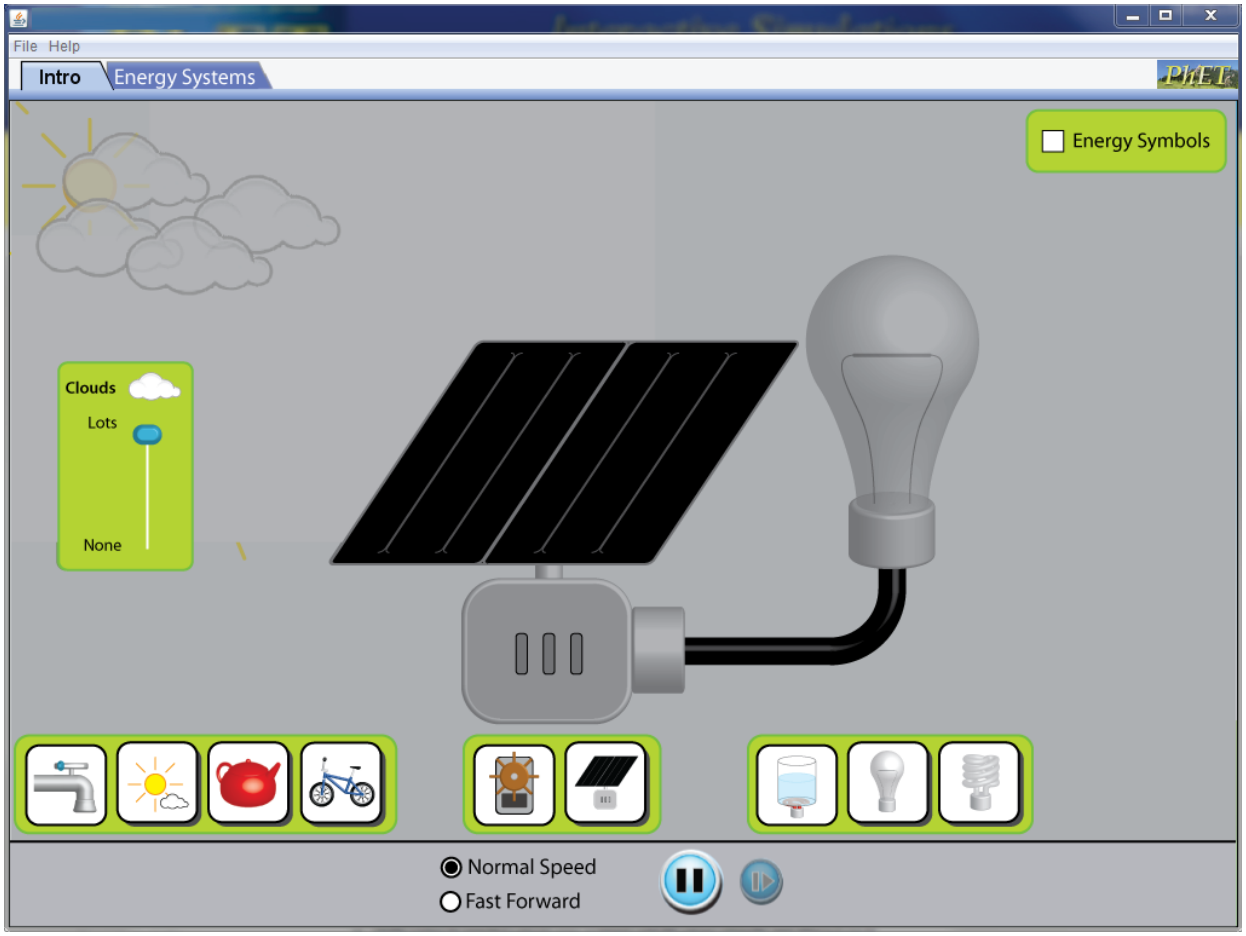


Here we have sun, solar panel, incandescent bulb.

- Energy chunks will come from sun and go into panel, then bulb.
- Some energy from sun will not hit panel, and just floats away.
- Some energy from the bulb will be light, some will be thermal.
- **Note:** Could also have the solar panel heating water. All are interchangeable.

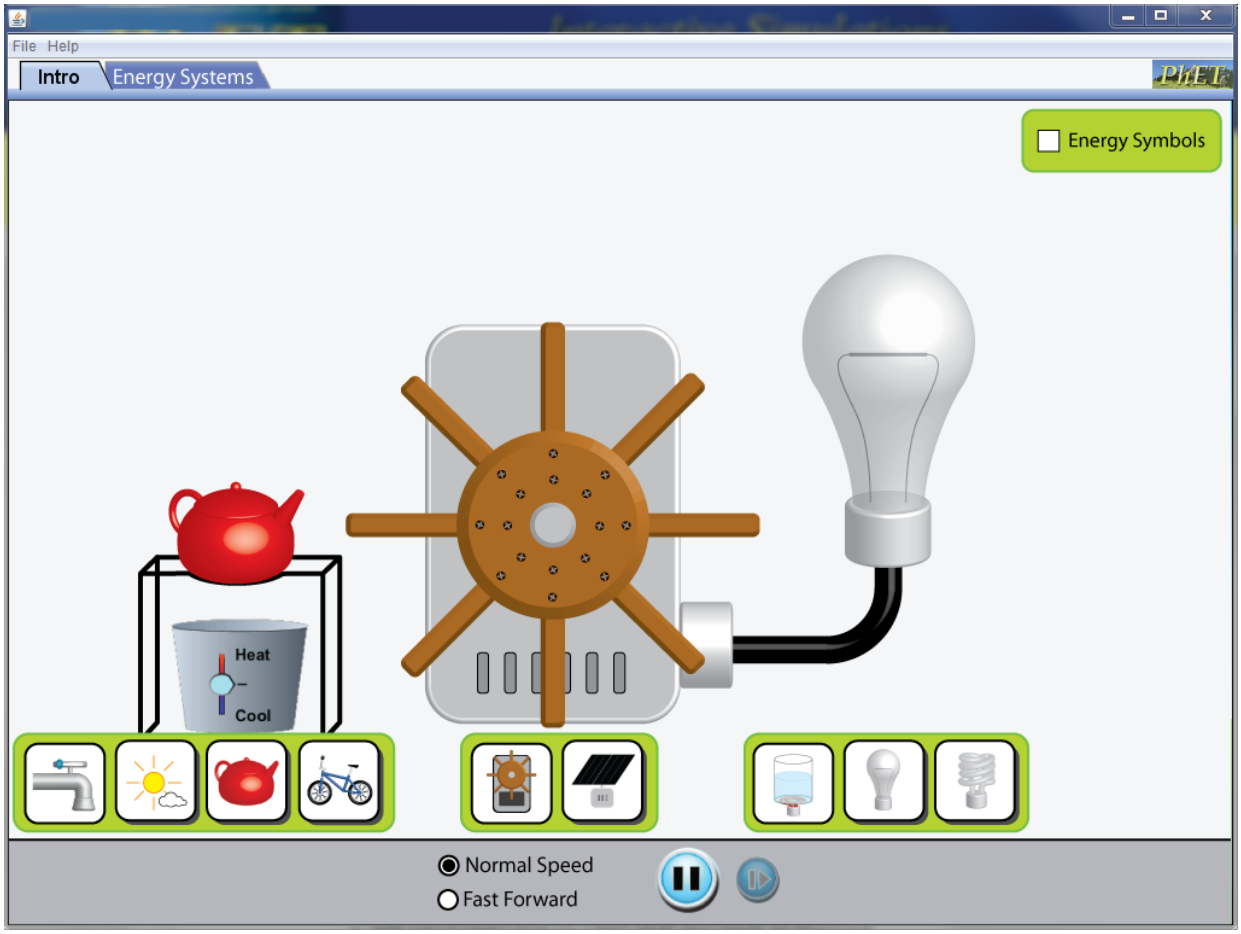


Increasing clouds decreases the sun rays, play area gets darker, and bulb dims.



Another option is teapot, generator, incandescent bulb.

- Increasing heat makes steam to turn generator. (see below)
- Some energy from steam goes into generator, some floats off.



Steam running the generator.

If user chooses a combination that won't work, no energy is transferred. For instance, faucet will not transfer energy to the solar panel. Sun will not turn the generator.

Bicycle

- Bicycle slides in with chain attached to generator.
    - (Need to decide whether to have generator paddles disappear.)
- Rear wheel turns chain.
- Riders legs move with crank to turn wheel.
- Can change bicycle speed with slider.
- More speed makes more energy.
- *Do we have energy (chemical?) from rider go into mechanical?*

To Discuss:

- Maybe have E's in generator, with transparency?
- Should E's appear instantaneously? Or some finite speed to energy flow? (not in water)
- In tea kettle, E's will leave in steam that doesn't hit wheel
- Possibly have presets as well as spinners?
- Do we differentiate PE and KE? Say PE at top of faucet and KE and bottom?

TL said:

1 I am not sure how the generator energy flow is going to look. I see that Kathy asked about that too. I thought perhaps the wire was going to somewhat visible in the generator, but that you seem to be asking if having somewhat transparent E's is ok. I am also a little confused about how the E's interact with the paddles of the generator. I'll watch for more drawings.

2 no real opinion yet

3 I see Kathy has commented that the tea kettle may not seem very realistic and yesterday Emily mentioned that students really gravitate to realistic situations. However, I am not sure what might be better.

4 I thought that was already in the design by using the florescent an incandescent bulbs?

5 I can see the advantage of presets, but I really like the tidy look that these drawings show.
6 I think differentiating between PE and KE might be nice, but I wonder if it is more essential to use "mechanical energy" vocabulary.

Tab 3 - Big Energy Stories

This will let students create and play out different “energy stories” (from Stamatis), where the students explain what happened to the energy, how it got from one thing to another and changed forms.

This is a **very** rough idea of what might make something interactive for larger systems. You can pull out sources, changers, and objects and plug them together. You can then use the tools to see what energy forms (mechanical, chemical, etc.) and changes (e.g., mechanical > electrical).

These are just some things I came up with quickly...would have to think more about what works together and makes sense. There should be multiple ways of plugging things together, and maybe objects that are more fun/interesting.

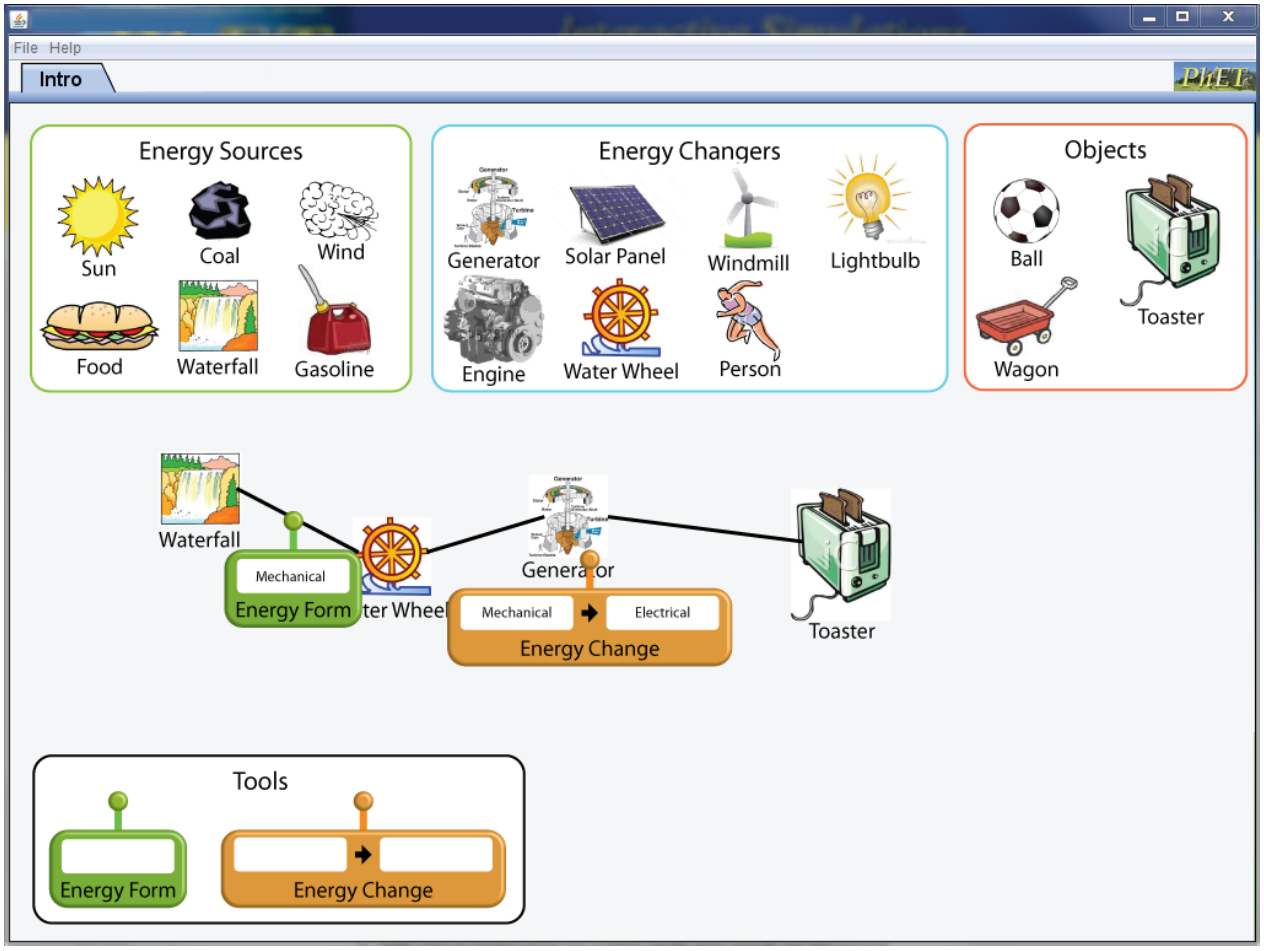
Also not sure if these meters are right. What happens if you put the “forms” meter on an object? Need to figure this out.

There could also be adjustments on the “sources”, like brightness of sun, or speed of water. Then could have a tool that measures energy “amount”? I’m open to other ideas.

Need to constrain, so that a waterfall can’t run a person.

Use color coding and SHAPE CODING for plugging pieces together. Make each take up a set amount of space, to constrain how many can fit on screen.

Look at google “app inventor”



Update 12/9/11:
I reworked the mockup below. I made the sources, converters, and users generic - but **note that in the sim they will use icons as in the drawing above.** I'm just using generic here so that we see how we're spanning the space, and can fill in with real objects later.

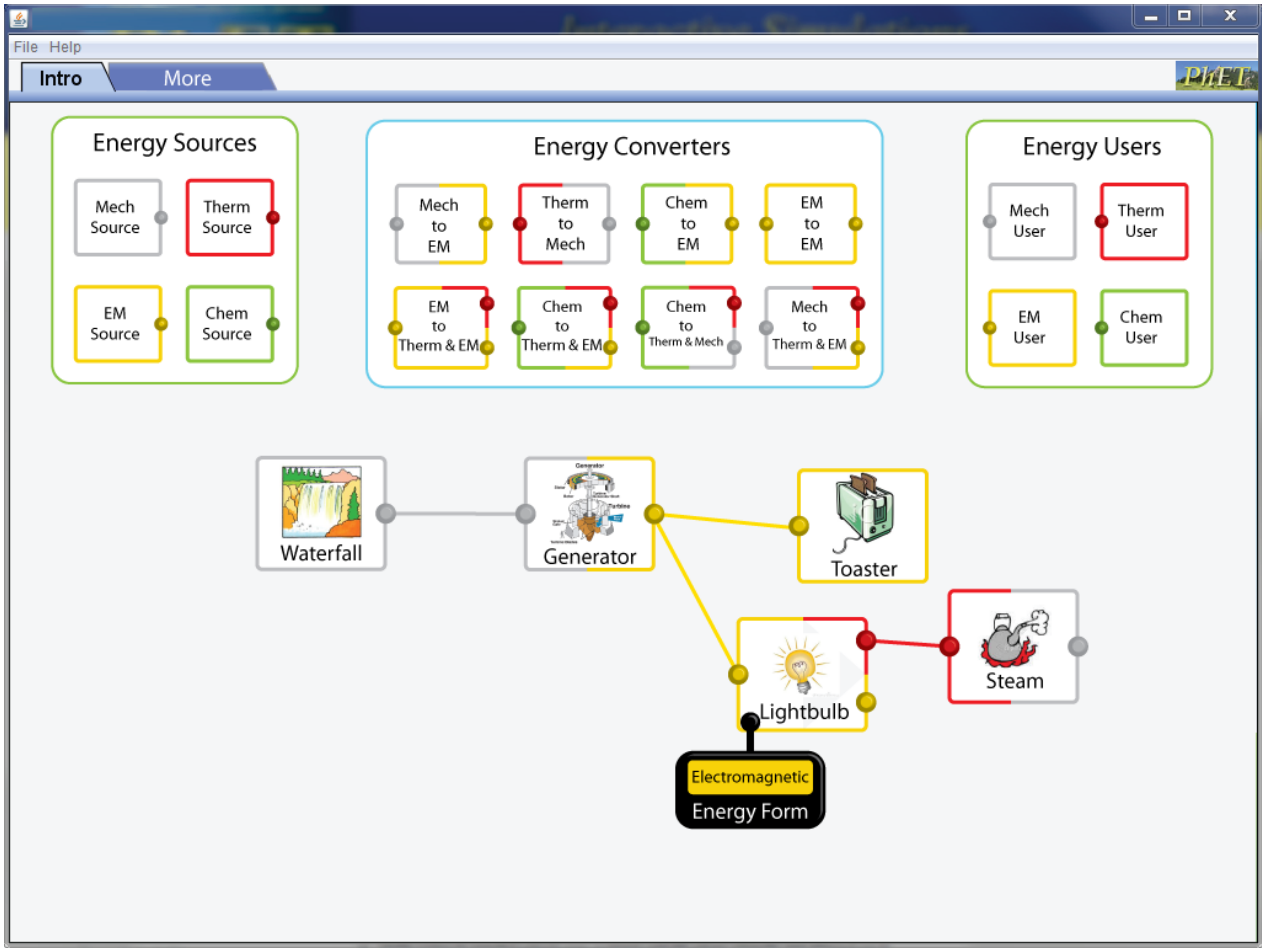
The color coding for forms (and for input / output types) will still be there as shown. The difference is that the words ("EM") will be replaced with icons (picture of the sun).

I also removed the "energy change" tool, since with the "left is in, right is out" converters you can measure before/after with one tool.

Questions:

- How to cue to plug things together? I think when you pull something out, you get a line from the *output* and some cue that you can drag the end.
- Would be useful to have 2 (or 3?) energy form tools?
- Could we use any other tools?
    - Energy amount maybe, but I think we should gloss over amounts (and efficiency, etc.)

    - KE vs PE?
- I'd like to have things animated, so for example:
    - Generator starts to turn when a source is plugged in.
    - Light bulb turns on.
    - etc....
- TEKS include **mechanical, light, thermal, electrical, and sound energy** (rather than mech, therm, chem, EM, and nuclear). I kind of like the TEKS better, at least for 5th grade.
- I left out nuclear. Christine said they don't get to this until 8th, so I thought best to just leave it out for simplicity and generality across grades.
- Should we have just single converters (e.g., mech to em) in the first tab, and multi-converters (e.g., EM to Therm & EM) in the "more" tab?
- Is "converters" an OK term? I thought changers might be better for 5th, but it's kind of a weird word.
- Is "users" an OK term? Can also call them "energy sinks", but that's definitely beyond 5th.
- I think Converters / Users is a good distinction, but some converters are also users (could think of a light bulb as an EM user...and a toaster turns EM into heat...). Need to think about this categorization.
- Should you be able to plug into multiple outputs (like generator > toaster & light bulb)? It makes sense that you should, but maybe a useful constraint to only have one input for every output? (If we have multiple, how to cue that you can plug in multiple?)



Sim Design Discussions

Start very simple, putting objects in water to see the temperature change. TEKS talk about putting objects in water, and AAAS benchmarks talk about “temperature as an indicator of therm energy”.

The idea here is that you can put brick or lead over the stove and change it’s temperature. Then put it in the water, and see the temperatures equilibrate.

Can use the thermometer to measure temperature. Or choose “Show temperature” to see temp shown as color (probably from blue to red). Or choose “Show energy”, which will show energy (probably as “chunks”, color coded by energy form).

- Should the water boil when heated above 100 deg?
- Should the water freeze when cooled below 0 deg?
    - SPU says yes, but we decided no because phase energy not a learning goal of ***this sim*** - can include this in a more advanced spin off sim

- Should there be a “pssss” sound when hot object is dropped into water?
    - SPU says yes, and probably yes. But need to worry that this is associated with water vaporizing, and we won’t be hearing objects above 99.9C
- Energy representations
    - Idea right now is chunks the move around.
        - Number of chunks = amount of energy?
    - Could also have arrows that show flow between objects?

EM: i like arrows rather than chunks

NP: EM now sees that we’re going with chunks

    - A total energy bar chart, to be more quantitative?
    - Have a total energy probe? Lattice of vibrating particles? (Ask Emily about this -chemical and physical change?)

EM: total energy of what? the water and the object? how would you indicate that, as opposed to total energy of everything on the screen?

EM: Can you put the blocks inside the water?

- Should we alllow change in mass?
    - Maybe for a slightly different sim - this would get more at heat capacity I think. Maybe higher leve, HS sim?

EM: Mass change gets complicated

- Should we have other materials?
    - Ice cube?
    - Two bricks?
    - Anything else common besides water, brick, lead?
    - Need to choose materials that will have energy that can be represented. That is, not too many nor too few E’s over the range from .1-99.9C.
- Are thermometers sufficient for showing temperature? Do we need “Show temperature”?

NP: Yes.

Energy representation discussion

- Small hexagons (or some other shape?) represent energy “chunks”

EM: This worries me. They may interpret this as a microscopic view of the material...it would be a big mess for students to confuse atom/molecule representations with energy representations. I like arrows!

NP: Replaced with colored square with “E” inside (color denotes energy form, here red = thermal)

- Red with yellow outline for thermal
- Number = amount of energy (?)

EM: Width or length of arrow = amount of energy? OK, i see the long conversation about this down below...so chunks it is. But please no perfect circles or spheres!

- Float up from heater into objects
- Solid objects turn transparent so that you can see the energy “inside” (what about the air/atmosphere?)
- If objects are cooled, the chunks float back into the heater

- Maybe “Show energy cartoon”, or “Show energy model”, or “Show energy dots” ??
- “Show energy in objects” ?
- Do energy chunks move?
    - Vibrate, pulsate?
    - Move around?
    - Probably best to have them move in, evenly distribute, then stay in place.
    - Randomly distributed (not lattice because looks like a lattice)
    - Little “E’s”? For Energy? Translatable?
    - What number of chunks for lowest to highest possible temperature?
- Stop cooling when hit 0.1C.
- Stop heating when hit 99.9C.
- Objects need to equilibrate to room temperature when heater is off.
    - Energy floats out of objects and off screen.
    - If heater is on, but no object, no energy moves.
- Have an energy window?
- Use “Normal” and “Fast fwd”.
- Pick objects that aren’t vastly different in temperature change rate, but not too close
- Pick objects that are familiar
- Make sure max number of E’s fit (note different materials different

Discussion with SPU folks

Rachel 2/13/12

Noah, thank you for including me! This is very exciting! I'm cc'ing Stamatis, who I know you've been talking to, and also Sam, who is surely a valuable presence since she knows all about both sims and the Energy Project work. Last but not least I'm including Hunter Close, who had a big role in developing the energy representations we use in the Energy Project.

One of your questions about the Energy Transfer screen is "how to show energy." Based on our Energy Project work I want to advocate for showing the energy as chunks of something that travel among objects in the scenario -- for example, blobs that flow out of the fire and into the lead block. The form of the blob can reflect the form of the energy. In our own work we often use letters (like C for Chemical and T for Thermal), but in a sim it could be symbols instead, or shapes, or colors.

I love that you're thinking of ways to let students build complex physical processes and track the energy as the process takes place. In the Energy Stories screen, the number-one thing that jumps out at me in what you're imagining so far is that energy is shown as being mainly *between* objects. It rides in a little gondola from one object to another, and sometimes it changes its clothes inside the gondola, is what I'm imagining. But the energy itself isn't shown, and the fact that energy can accumulate in objects is not part of the representation. We really treasure

representations in which energy has a clear location; we think it greatly facilitates detailed tracking of energy transfers and transformations in physical processes. Could we go there?

I want to respect that you might have your own goals and plans for this sim; I expect that you have plenty of experience dealing with opinionated people who think you should build the sim their way, and will treat my opinions accordingly. If you think our ideas are potentially improving the product, I'd love to work with you further.

Rachel

Noah P 2/13/12

Hi Rachel (and Sam, Stamatis, Hunter),

Thanks for the detailed feedback. This is definitely helpful. The design is still very much in flux, and we're looking for any and all ideas. Since you all are energy experts your input is especially valuable and will affect our design decisions.

Representing energy as "stuff" that moves and changes is one of the challenges we've been facing, and I like the idea of having it shown as chunks. This is what I was thinking would happen when you turn on "Show Energy" in tab 1.

I also take your points about the Energy Story tab – again, I think finding a good way to represent energy being "in" the objects as well as flowing between them is important. Probably best would be to use the same chunks representation, and probably use color coding for the energy forms. Changes in form could be represented as fading from one color to another. What do you think?

Looking forward to working with you all on this further.

-Noah

Stamatis 2/13/12

Noah,

I added some comments in the google doc. I like Rachel's suggestions and your ideas below.

In addition, I suspect that energy tracking will be an important idea in the Next Gen Science

Standards (Suspect being the operative word), which strengthens the argument for representing energy chunks, as we do. But buy fireproof underwear because you will be called to task about it. (Just wanted to be clear with you.)

--Stamatis

Noah P 2/14/12

Stamatis,

Thanks for the advice – I will buy several pairs.

To be clear – I'm assuming this is because the substance metaphor for energy is considered a "misconception"? I know it's been criticized in the literature (Chi, for example I think). I'm also assuming you folks use it because it's a productive resource, and it's probably how we actually think about energy even if we don't want to admit it.

That said, one of the issues we have with sims is acceptance by teachers. If they don't like the way we present some ideas, they won't use it even if we are sure it is pedagogically advantageous.

So question: what is your sense that middle school teachers are open to the "chunks" model/metaphor of energy?

-Noah

Hunter2/14/12

Yes, I think the problem is that it is considered a "misconception."

My sense as an instructor of these teachers is that they are open to it.

I know it can be a hot-button issue, but every sim pretends at least a little bit, right? There are no little blue balls in a queue in an electric circuit. The complex-valued wave function does not have a phase-dependent color of the rainbow. Etc. etc.

I think the more obviously pretend-y the energy chunks look, the more people will understand that it is to help people understand, and not to present an un-styled, serious grown up model that is exactly true. Though, I agree with Noah that many of these things are like "how we actually think about energy even if we don't want to admit it."

Noah 2/14/12

Thanks Hunter. I agree that the more cartoon-y we make it, the more obvious it will be what we are trying to do. The biggest complaints we get are when things look real, but are "wrong".

I'm most concerned with what teachers think, so good to know this is unlikely to be a problem.

(I am interested in what researchers think theoretically, but that's a different conversation. Someone could always do a "chunks vs no-chunks study" if they were so inclined.)

-Noah

Stamatis 2/14/12

I would not characterize a substance metaphor as a misconception. I think the argument of some is that it may *lead* to an energy-matter conflation misconception. But as Hunter said, any representation (and sim) has that danger.

On the other hand, the way in which field theorists think about energy is very much along the lines of a substance metaphor. There are energy densities, energy-momentum currents, etc. So, I feel perfectly validated as a grown-up physicist in defending the metaphor.

And teachers are completely open to it.

--Stamatis

Noah 2/14/12

Excellent – I think we're on the same page.

By the way, I just added a couple more images to the first tab design. One of them has my first stab at an energy representation – would LOVE your feedback on that.

-Noah P

Hunter 2/14/12

Should the water boil when heated above 100 deg?

YES. SOME WATER SHOULD ESCAPE AND IT SHOULD TAKE ENERGY WITH IT, IN THE FORM OF "PHASE ENERGY." ;) ALSO, THE USER SHOULD HAVE THE OPTION OF TURNING ON AN OPTION OF WORK DONE ON THE ATMOSPHERE DUE TO THE EXPANSION OF THE WATER WHEN IT VAPORIZES, IN THAT CASE, SOME OF THE ENERGY SHOULD GO INTO THE AIR AS GRAVITATIONAL ENERGY (SINCE THE AIR IS EFFECTIVELY LIFTED BY THE EXPANSION.

THINKING AGAIN, MAYBE THE USER SHOULD HAVE THE OPTION OF TURNING ON DIFFERENT COMBINATIONS OF FORMS UNTIL THE SIM SHOWS ALL OF THE ENERGY ONLY CHANGING FORM AND NONE APPEARING OR DISAPPEARING. THEN MAYBE THERE IS A CHALLENGE TO IT - PICK THE MINIMUM FORMS YOU NEED IN ORDER FOR THE ENERGY TO REMAIN CONSERVED. THIS MIGHT BE TOO COMPLICATED, AND IT ALSO MIGHT NOT BE A GOOD IDEA. :)

Should the water freeze when cooled below 0 deg?

YES. IN THAT CASE, PHASE ENERGY WILL NEED TO EXIST ALREADY IN THE LIQUID WATER AND TRANSFORM INTO THERMAL ENERGY OF THE ENVIRONMENT AS THE WATER FREEZES. DURING THE PHASE CHANGE (EITHER VAPORIZATION OR CONDENSING), THE NUMBER OF THERMAL ENERGY UNITS IN THE WATER SHOULD REMAIN CONSTANT. HERE IT MIGHT ALSO HELP TO BE ABLE TO TURN ON AND TURN OFF PHASE ENERGY IN THE LIQUID WATER - ENERGY THAT SOMETIMES YOU MIGHT RATHER NOT BE AWARE OF, LIKE DURING EVAPORATION. BUT DURING FREEZING OR MELTING, YOU NEED IT FOR THE STORY TO WORK, I.E. FOR THE CHUNKS TO BE CONSERVED.

Should there be a “pssss” sound when hot object is dropped into water?

SURE, WHY NOT?

Energy representations
Idea right now is chunks the move around.
Number of chunks = amount of energy?

YES. WITH OPTION TO HAVE MORE CHUNKS OR FEWER CHUNKS. MAYBE A SLIDER FOR THAT.

Could also have arrows that show flow between objects?

YES.

A total energy bar chart, to be more quantitative?

YES.

Have a total energy probe? Lattice of vibrating particles? (Ask Emily about this -chemical and physical change?)

I DIDN'T UNDERSTAND THIS ONE WELL ENOUGH TO COMMENT. BUT MAYBE MY POSITION ON PHASE ENERGY SPEAKS TO WHATEVER IS MEANT BY "CHEMICAL AND PHYSICAL CHANGE."

Should we alllow change in mass?

YES, IF IT IS NEEDED TO ACCOMODATE EVAPORATION.

Maybe for a slightly different sim - this would get more at heat capacity I think. Maybe higher leve, HS sim?
Shoudl we have other materials?

SURE. IT WOULD BE GOOD TO SHOW THE ENERGY INPUT BEING THE SAME BUT THE TEMPERATURE CHANGE BEING DIFFERENT.

Ice cube?

SURE.

Two bricks?
Anything else common besides water, brick, lead?

NOTHING COMES TO MIND.

Are thermometers sufficient for showing temperature? Do we need “Show temperature”?

WHY NOT BE EXPLICIT - THE WORD TEMPERATURE IS A SIGN THAT IS COORDINATED WITH THE ICONIC THERMOMETER SIGN. COULD HELP DISENTANGLE ENERGY AND TEMPERATURE.

Noah 2/14/12

>Thanks Hunter. I like all of these ideas. Keep in mind, this sim is for
>middle school students. Not sure phase energy or work done on
>atmosphere is appropriate for this level - but it might be good for a
>college level sim that builds off of this one.

>
>I could imagine having energy leave the water with vapor as it boils.
>I'd want it to be quantitatively correct, but only shown qualitatively.
>Same with freezing. I'd like to avoid anything that doesn't address the
>main learning goals about forms of energy and *simple* energy transfer
>(by simple, I mean between the few basic objects shown in the sim).
>
>If it is simpler to just avoid boiling and freezing, we can do that.
>But it would be nice to include them if there is a simplified way to
>represent what happens at the phase transition.
>
>-Noah

Eleanor 2/14/12

Work done on the atmosphere probably not appropriate for middle school.
However, I think phase energy is. Phase energy is no more complicated than thermal energy -- in fact, I think the inclusion of phase energy in the model makes thermal energy easier to understand. Otherwise, how do you explain a glass of ice water staying the same temperature as the ice melts? Makes no sense.

Energy of phase change is taught in middle school physical science, I think; calling it "phase energy" is not standard, but I think it should be.

-Eleanor

Stamatis 2/14/12

In NGSS, there will be major emphasis on microscopic (atomic?) description of phenomena. So, the choice of name for phase energy will be quite consequential. I think we are all agreed that we should not call it thermal energy.

--Stamatis

Eleanor 2/15/12

The physical science textbook I had when I taught 9th grade used "latent heat of fusion" and "latent heat of vaporization." Yuck.

Noah 2/15/12

Cold fusion in 9th grade? Cool!

So...maybe including phase energy is a good idea, since it is an energy change that comes up in MS. I wonder if there is a way we could connect it to more concrete ideas, like "freezing energy" and "boiling energy"?

Part of my concern probably stems from the fact that many students we work with in Dallas are English language learners, so they already struggle with basic vocabulary. The more we can tie abstract terms to concrete the better, I think.

-Noah

Hunter 2/15/12

Phase of matter, state of matter, other names? - it's unfortunate that this sounds so abstract.

So you COULD say that a liquid has energy just in virtue of being a liquid (in relation to a solid), but then you end up saying confusing things like "liquid energy."

I think "freezing energy" and "boiling energy" make it sound like the energy is associated with the process or change rather than with the state - and I think we need students to understand that it is associated with the state. So, I have no brilliant solution, just observations of the various problems with each solution.

Stamatis (response to NP above) 2/15/12

I like this!

--Stamatis

Correspondence with EM:

EM: I looked over the second tab. I have some questions and thoughts:

- would each of the three scenarios essentially be like a new tab. So once selected, the whole screen is different?

NP: Basically yes. The “scenario” selection panel, energy check box, thermometer, and energy form tool would stay the same. The scenario itself would change.

- It looks to me like what you can do on the second tab (for the first scenario) is a) turn water on/off b) measure temperature, c) check energy form, d) turn on/off the little energy E's and e) change the scenario. Am I missing anything? Can you move the turbine thing or the water at all? If not, it might be useful to highlight stronger the other things you can do…maybe make the water faucet tab more prominent, and the thermometer and energy form meter thing more prominent. This may not be a problem for students, but I think what I would want to do initially would be to move the turbine and/or the water.

NP: That's exactly what I had in mind. I could see how someone might want to move the turbine…maybe it would be OK to make it moveable left/right, so you can move it out of the water stream. Then you would see that energy only transfers to the turbine if it is "in" the water? I agree that the Energy Form tool could be more prominent…although really, I want students to play with the system first, then start measuring things. I think a color other than black would be better for the energy tool – I just didn't want it to be confused with the color coding for the energy forms. It could also have a tip that looks more like crosshairs.

- I like the third scenario, and it could also start a great discussion about where the energy to heat might come from.

NP: Yup, that was the idea. And scaffolding toward possible sca=enarios in the 3rd tab.

- Silly question: will the burner part of the heater change color? Oh, wait…it does! Cool.

NP: Yup (don't ask how long it took me to draw that burner in Illustrator). I think a little glow might be nice too.

- Sillier question: where will you show the energy E's on the turbine…?

NP: Good question, actually. I think they will float into the paddle wheel from the water as mechanical, then change to electrical as it floats down to the wire. Then it will change to thermal as it flows out of the heater into the water.

- I don't quite have a good picture in my head of what the other scenarios will look like. Like…can you turn the sun on and off, or make it brighter or dimmer?

NP: There will be a "night/day" slider that lets you change the brightness of the sun. Maybe it will fade the sun or something, but yes you will be able to dim the sun.
In the 3rd scenario, we need to be careful. I think it is OK to have "more heating = more steam".

In general, I love that this sim is for middle school, but could also be useful for undergraduate students. When I taught general chemistry, students were always really into anything related to energy (from a real world use perspective) and when I TA'd physical chemistry, most of the

students did their final projects on energy use related topics. Now we just need to figure out how to get the little E's to work from a chemistry perspective, and we can be off making some great chemistry/energy sims.

NP: Interesting – I'm curious what you mean by "get the little E's to work from a chemistry perspective". We should discuss this point more.

For Teacher Tips when Published

- Constraint: No phase changes, i.e. can't boil or freeze water, can't melt blocks.

Meeting Notes

8/10/2012

Off center solar panel look OK? If so, update icon?
- Ans: Looks okay, don't worry about icon.

Should the be some delay in the heater element heating up? Right now it is directly proportionate to incoming energy.
- Ans: Yes, there should be delay.

Delay for light bulbs?
- Ans: Yes.

Highlight on wheel - how handle?
- NP will send new artwork.

How many watts should it take to light the CF bulb and the incandescent bulb?

Basically, it would be good to have watt values and efficiencies for everything.

- Make teapot a little bigger, Noah will send a larger one later.
- Have a bit of warmup delay for burner and bulbs.
- Energy chunks fade from one to the other when they transform.
- Will add solar energy, make electrical energy blue.

Various meetings between 6/21/2012 and end of July 2012

Is fix for E's wandering through other containers adequate (basically just put the E on top of the Z order).
- A: Okay, but it would be better if it didn't drop in the top the way it does, since this sort of looks like it goes through the bottom of the block on top (for a two-block stack).

Make half of the slider track disappear on the burner when overheated, have a 5 second "timeout".

E's on wire should disappear when switching the energy converter.

Spec question: Should 2nd tab the bridge to 3rd? Is that what spec should say? (Currently says "Bridge from 1st to 2nd tab").
2nd tab: Should name be "Mini-Energy Stories" (section name) or Energy Systems (shown in picture)?
- A: Energy Systems

2nd tab: Thinking about use cases where the user changes one of the reels while energy is being generated.
- Okay to freeze when the reel changes? That would prevent e's from flowing out the end of the electric cable.
-- A: Yes, this is fine.
- Okay to turn off faucet? I.e. is it okay if the faucet doesn't retain its state when swapped out?
-- A: Yes, this is fine.

Should the reel wrap around, or hit a limit? I am assuming a limit so far (like Balancing Act).
- Limit is fine.

No reset all on 2nd tab. Want one?
- Yes.

Thermometer on 2nd tab: Shall I limit where it can be placed so that users don't stick it on the sun, or in the running water, or the teapot steam, etc?
- Just have it permanently fixed to the beaker.

I made the clock control panels look the same on both tabs, though they are different in spec. Cool?
- Make consistent.

For the control panel that controls visibility of energy chunks on the 2nd tab, is it safe to assume:

- Wording should be the same as for the 1st tab.
-- A: Yes.
- There should NOT be an energy chunk in the control panel, since there are different colors.
-- A: Yes

Move control for chunks to be top right, legend just below.

Use the color on 1st tab for background of Energy Symbols control.

Question about sticky thermometer: What should behavior be when dropped into beaker?
- See below.

Chunks move faster when dropped in water so that user doesn't really see them move.

Tweak temp difference threshold for air to best value for interviews.

Fix clipping for beaker on top of blocks.

Magic thermometer - inside the beaker. Measures block first, beaker 2nd, air last. Burner is the same.

When a chunk comes out of the air into a thermal container, or goes out of the thermal container into the air, it should not pass through (or behind) any of the other thermal containers.

Chunks moving between thermal energy containers when there are differences, and exchanges with air. Address oddities.

Thermometer triangle matches the color of the thing being measured. Make a version with and one without, make both available for interviews.

Make the burners block motion of the blocks and beaker so things can't be dragged in front of them.

Tool tips for the speed controls are popping up in the wrong places.

6/21/2012

Clipping look good?

How is the behavior of energy chunks when heating/cooling with nothing on burner?
- Mostly looks good.
- Should wander in more from the sides (not necessarily from directly above) when burner is

cooling.

Do we need greater randomization of positions of chunks in the blocks?
- No, team thinks it looks reasonably good.

Holding off interaction with air until temperatures within a certain range.
- Team approved.

Infrared view (goggles or something)?
- Not too keen on this, since it shows temperature, not energy.

- Sticky thermometer - sticks to the thing that it is in contact with.

- Chunks have to come from outside the blocks when they are immersed in the beaker (could just do this all the time).

- Change captions - Normal and Fast Forward.

6/14/2012

Thermometer size
- Team says now good.

Cursor change when slider moves out from under it.

A little faster on the stove animation.

E's in the air - A little more range for wandering.

Add back lines for the cubes.

Stage I - Try clipping out the water E's somehow when the blocks are in the water.
Stage II - Squish the energy around the blocks, so that they are never in front or behind.

Developer control for inter-heat exchange constants.

6/7/2012

Energy chunks heating the air - does it look okay?
- Ans: Prototype where E wanders up, then disappears is OK.

- Blocks should cool down in air over time, ejecting E's, having one after a long time would be

fine.

- Caption: "Energy Symbols".

Should the energy chunks emerge fully formed from the bucket?
- Fine the way it is on current version.

- Make the chunk density match the one that has the brick with one value at 0 C and 2 at room temperature. There will be a lot in water.

- For 3D look for the E's in the object, try space filling, then some reasonable z-order layering but no size perspective.

- Animate the flame/ice going out rather than just disappearing.

Need to discuss how much to tweak specific heat values to get things looking good.
- Add a unique set of transfer constants for brick versus iron.

Okay to have only 1 E chunk removed to get to 0 C?
- Yes.

Demo the limits and get feedback.
- Team liked and approved.

Demo: Linear from 0 K with correct specific heat values.
- No good due to expected issues - not enough transfer of heat.

Demo: Brick has 1 at 0 K, 2 at room temp, correct specific heats.
- The design team is OK with this.

Issue: Block on block on burner - limit is hit, then unhit. Hysteresis? Other ideas?
- Team feels that the current behavior is OK.

Does the E need to be translated?
- No, use the graphic, put graphic in control box for clarity.

Notes 10/25
- What to do with biker and solar panel?
    - disable slider?
    - ride off screen? could be distracting
    - have thermals come off of wheel - about 1/10 with generator, same amount with solar panel but no mechanical
- Issue with energy still flowing after generator stops?

- internal flywheel?
- keep because energy needs to be conserved (not destroyed)

Resources

AAAS Benchmarks (Energy)

http://www.project2061.org/publications/bsl/online/index.php?chapter=4#E2

It is useful to think about energy *indicators*. As described below:

Energy appears in different forms and can be transformed within a system. Motion energy is associated with the speed of an object. Thermal energy is associated with the temperature of an object. Gravitational energy is associated with the height of an object above a reference point. Elastic energy is associated with the stretching or compressing of an elastic object. Chemical energy is associated with the composition of a substance. Electrical energy is associated with an electric current in a circuit. Light energy is associated with the frequency of electromagnetic waves.
(from http://www.project2061.org/publications/bsl/online/index.php?chapter=4#E2)

The Energy Project (SPU)
http://www.spu.edu/depts/physics/EnergyProject.htm

Motion, Forces, and Enegy (Prentice Hall)
Key ideas (see summary p. 127)

- 5 forms of energy
  - mechanical
  - heat
  - chemical
  - electromagnetic
  - nuclear
- Kinetic and Potential
  - stretched rubber band has potential (snapping rubber band has kinetic)
  - kinetic is “energy of motion”
    - KE = ½ mv^2
    - moving car has KE
    - doing work on object changes KE
  - potential is “energy of position”
    - PE_gravity = weight * height
    - PE is *stored* energy
    - doing work changes PE

- Energy Conversions
    - KE-PE conversions
        - dropped stone has PE that turns into KE
        - swinging pendulum
    - Other conversions
        - solar (electromagnetic) into electricity
        - solar (EM) into chemical (plants)
        - motor turns EM into mechanical
        - waterfall (generator) turns mechanical into electrical
        - engine turns chemical into mechanical
        - stereo turns electromagnetic into sound (mechanical)
        - operation of hair dryer uses many conversions
            - chemical (coal) > heat (water) > mechanical (steam turns turbine) > electric (generator) > heat (hair dryer)
- Conservation of Energy
    - “energy can be neither created nor destroyed by ordinary means”
    - in light bulb, “heat released is energy that did not become light”
- Physics and Energy

Study Guide

Summarizing Key Concepts

5–1 Nature of Energy

- Energy is the ability to do work.
- Energy appears in many forms: mechanical, heat, chemical, electromagnetic, and nuclear.

5–2 Kinetic and Potential Energy

- Energy that an object has due to its motion is called kinetic energy.
- Kinetic energy equals one half the product of the mass times the square of the velocity.
- Energy that an object has due to its shape or position is called potential energy.
- Potential energy that an object has due to its height above the Earth's surface and its weight is called gravitational potential energy.

5–3 Energy Conversions

- Energy can change from one form to another. Changes in the form of energy are called energy conversions.
- The most common energy conversions occur between kinetic energy and potential energy. But all forms of energy can be converted to another form.

5–4 Conservation of Energy

- The law of conservation of energy states that energy can neither be created nor destroyed by ordinary means.

5–5 Physics and Energy

- Energy is involved in every physical activity or process.
- An increase in speed or velocity is accompanied by an increase in kinetic energy.
- An object that has kinetic energy also has momentum.
- A force doing work on an object to change its motion is giving energy to the object.
- Power is the rate at which energy is used.
- The conservation of work can be understood because energy is conserved.

Reviewing Key Terms

Define each term in a complete sentence.

5–1 Nature of Energy

energy
mechanical energy
heat energy
chemical energy
electromagnetic energy
nuclear energy

5–2 Kinetic and Potential Energy

kinetic energy
potential energy
gravitational potential energy

5–3 Energy Conversions

energy conversion

5–4 Conservation of Energy

Law of Conservation of Energy

Guide for Reading

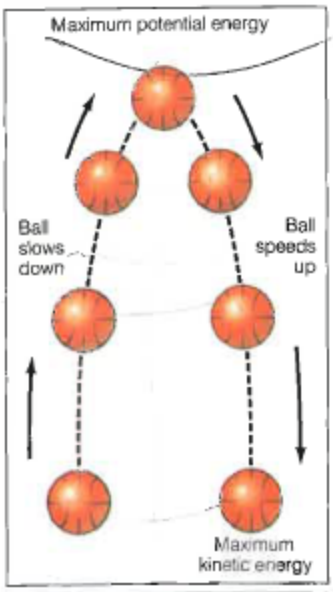
Focus on these questions as you read.

- *What is an energy conversion?*
- *What are some common examples of energy conversions?*

5–3 Energy Conversions

When you think of useful energy, you may think of the energy involved in moving a car or the energy you get from the food you eat. But in both these examples, the useful energy was obtained by first converting energy from one form to another. The mechanical energy of the car came from burning the chemical energy of fuel. Your energy also comes from chemical energy—the chemical energy stored in the food you eat. Energy can be transferred from one object to another and energy can be changed from one form to another. Changes in the forms of energy are called **energy conversions.**

Figure 5–12 *As a basketball player throws the ball in the air, various energy conversions take place. What are these conversions?*

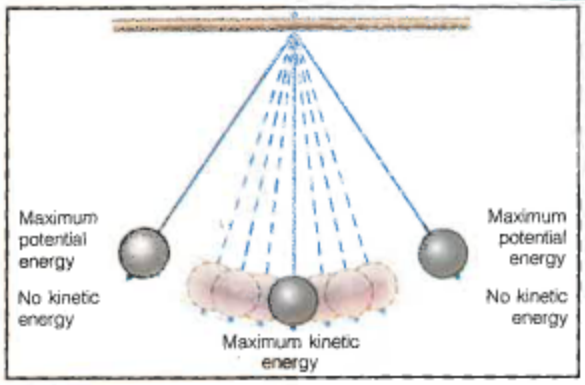


Kinetic–Potential Energy Conversions

One of the most common energy conversions involves the changing of potential energy to kinetic energy or kinetic energy to potential energy. A stone held high in the air has potential energy. As it falls, it loses potential energy because its height decreases. At the same time its kinetic energy increases because its velocity increases. Thus potential energy is converted into kinetic energy. Similarly, the potential energy stored in a bent bow can be converted into the kinetic energy of the arrow.

Conversions between kinetic energy and potential energy are taking place around you every day. Think of tossing a ball up into the air. When you throw the ball up, you give it kinetic energy. As the ball rises, it slows down. As its velocity decreases, its kinetic energy is reduced. But at the same time its height above the Earth is increasing. Thus its potential energy is increasing. At the top of its path, the ball has slowed down to zero velocity so it has zero kinetic energy. All of its kinetic energy from the beginning of its flight has been converted to potential energy.

Then the ball begins to fall. As it gets closer to the Earth's surface, its potential energy decreases. But it is speeding up at the same time. Thus its kinetic energy is increasing. When you catch it, it has its maximum velocity and kinetic energy. The potential energy of the ball has changed into kinetic energy.



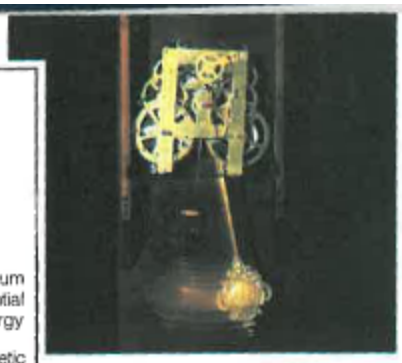


Figure 5–13 *A continuous conversion between kinetic energy and potential energy takes place in a pendulum. Potential energy is greatest at the two highest points in the swing and zero at the bottom. Where is kinetic energy greatest?*

Other Conversions

Although conversions between kinetic energy and potential energy are common, they are not the only changes in energy that take place. **All forms of energy can be converted to other forms.** For example, the sun's energy is not used merely as heat energy or light energy. It is converted to other forms of energy as well. Solar products convert the energy of sunlight directly into electricity. Green plants use the energy of the sun to trigger a process in which sugars and starches are made. These substances store the energy as chemical energy. In this process, electromagnetic energy is converted to chemical energy.

In an electric motor, electromagnetic energy is converted to mechanical energy. In a battery, chemical energy is converted to electromagnetic energy. The mechanical energy of a waterfall is converted to electromagnetic energy in a generator. Solar cells convert the sun's energy directly into electrical energy. In a heat engine (such as an automobile engine), fuel is burned to convert chemical energy into heat energy. The heat energy is then changed to mechanical energy. In a microphone-loudspeaker system, the microphone converts mechanical energy in the form of sound into electromagnetic energy in the form of electricity. The electromagnetic energy goes to the loudspeaker that then converts the electric signal back into sound.

ACTIVITY THINKING

A Day at the Amusement Park

Use the illustration of a roller coaster ride to answer the questions that follow:

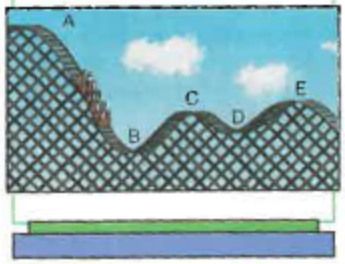
1. At what point does the car have the greatest potential energy?

2. At what position does the car have the greatest kinetic energy?

3. At what position does the car have the least potential energy?

4. At which point, C or E, does the car have more potential energy?

5. Describe the kinetic–potential energy conversions that occur on the roller coaster.



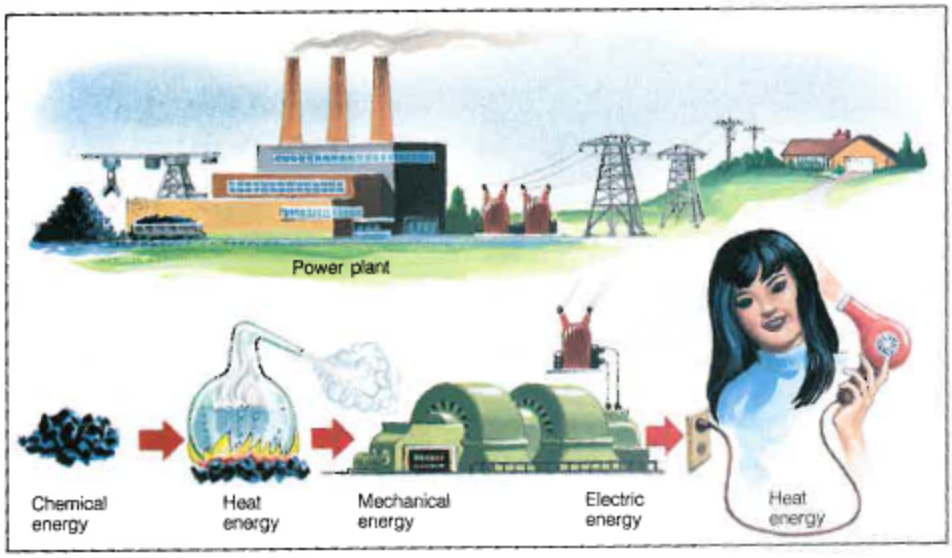


Figure 5–14 *A series of energy conversions is needed to produce the heat energy of the hair dryer. Trace the conversions.*

ACTIVITY DOING

Mixing It Up

1. Fill two mixing bowls with cold water. Record the temperature of the water in each bowl.

2. Run an electric or hand mixer in one bowl for a few minutes.

3. Take the temperature of the water in each bowl again. You must read the thermometer with great precision.

How did you expect the temperatures to compare after you used the mixer?

How do the final temperatures actually compare? Why?

Often a whole series of energy conversions is needed to do a particular job. The operation of a hair dryer is a good example of this. See Figure 5–14. The electromagnetic energy used by the dryer is generated from some fuel source, such as gas. The chemical energy of the fuel is released by burning it. The fuel provides heat energy, which in turn is changed to mechanical energy. This mechanical energy is used to make a generator do the work of providing the dryer with electromagnetic energy in the form of electricity. When you turn the dryer on, the electricity is changed back to heat energy.

Figure 5–15 *This cute little animal is enjoying an afternoon snack totally unaware that the complex process of energy conversion is taking place. Describe the energy conversions.*

Laboratory Investigation

Relating Mass, Velocity, and Kinetic Energy

Problem

How does a change in mass affect the velocity of an object if its kinetic energy is constant?

Materials *(per group)*

- rubber band
- 3 thumbtacks
- 12 washers glued together in groups of 2, 4, and 6
- wooden board, 15 cm x 100 cm
- meterstick

Procedure

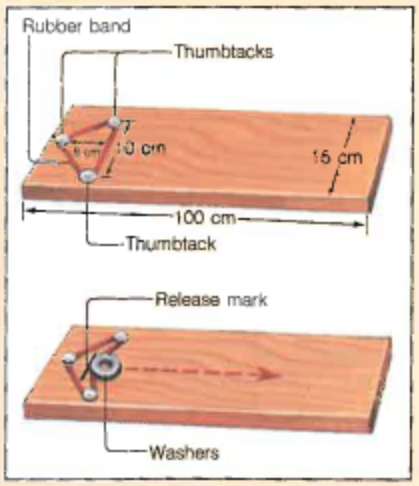
1. Place three thumbtacks at one end of the wooden board, as shown in the figure.
2. Stretch the rubber band over the three thumbtacks to form a triangle.
3. In front of the rubber band, place two washers that have been stuck together.
4. Pull the washers and the rubber band back about 2 cm, as in the figure. Release the rubber band. The washers should slide about 70 to 80 cm along the board.
5. Practice step 4 until you can make the double washer travel 70 to 80 cm each time.
6. Mark the point to which you pulled the rubber band back to obtain a distance of 70 to 80 cm. This will be your launching point for the entire experiment.
7. Launch the double washer three times. In a data table, record the distance in centimeters for each trial. Remember to use the same launching point each time.
8. Repeat step 7 for a stack of 4 washers.
9. Repeat step 7 for a stack of 6 washers.

Observations

Calculate the average distance traveled by 2 washers, 4 washers, and 6 washers.

Analysis and Conclusions

1. What is the relationship between the mass, or number of washers, and the average distance traveled?
2. What kind of energy was in the washers when you held them at the launching point? How do you know?
3. After the washers were launched, what kind of energy did they have?
4. You launched all the washers from the same position. Was the energy the same for each launch?
5. Assume that the farther the washers slid, the greater their initial velocity. Did the heavier group of washers move faster or slower than the lighter group?
6. If the kinetic energy is the same for each set of washers, what happens to the velocity as the mass increases?



From Christine Denison:

I can't speak too much for the 6th grade TEKS, but a sim over exploring the difference between **mechanical, sound, electrical and thermal energy** would be super helpful in 5th grade and could even

be scaled down to be used with 3rd and 4th (I have our 3rd and 4th grade teachers using the sims as demos all the time)! Usually this standard focus on how energy changes from one form to another. For instance, a light bulb transforms what type of energy into what type of energy?

Energy resources are also a HUGE theme all throughout middle school and elementary school in Texas. I would definitely love to help you all figure out how to create a sim around this TEKS. The only energy form that students don't learn about until 6th grade is nuclear power, but all the rest that you listed are covered! Teaching the advantages and disadvantages of energy resources seems tricky through a sim, but if students could somehow compare and contrast them, or even just explore how each of them works to produce electricity that would be great.

Metadata

Description
Explore how heating and cooling iron, brick, and water adds or removes energy. See how energy is transferred between objects. Build your own system, with energy sources, changers, and users. Track and visualize how energy flows and changes through your system.

Main Topics
- Energy
- Conservation of energy
- Energy systems
- Energy forms
- Energy changes
- Thermal energy

Key words:
Energy, conservation of energy, energy transfer, energy forms, energy changes, energy systems, chemical energy, mechanical energy, thermal energy, electrical energy, energy conversion, energy efficiency, heat capacity, solar energy, heat conduction, heat dissipation, thermal equilibrium, temperature

Sample Learning Goals
- Predict how energy will flow when objects are heated or cooled, or for objects in contact that have different temperatures.
- Describe the different types of energy and give examples from everyday life.
- Describe how energy can change from one form of energy into another.
- Explain conservation of energy in real-life systems.
- Design a system with energy sources, changers, and users and describe how energy flows

and changes one form of energy into another.

- Tell the energy story for real-life systems.

Related Simulations

- Energy Skate Park: Basics
- Generator
- States of Matter
- Greenhouse Effect

Credits

Design Team
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Emily Moore
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Thanks
Stamatis Vokos
Sam McKagan
Rachel Scherr
Hunter Close
Eleanor Close

Ideas for TIPS

- On the thermometers, the 2nd tick from the top is 100C, the 2nd tick from the bottom is 0C *(show image of thermometer)*
- The water will boil at 100C, but it will not freeze. This is because the water is being cooled with ice, and since the ice is at 0C, it will never actually make the water freeze.
- Each E represents a certain amount of energy. Energy is actually distributed through the whole object, and energy transfers between objects continuously. However, the Es might make it look like energy is only in a few places, and transfers in chunks. In interviews, most students said they thought the energy was everywhere, and transferred constantly, and that the Es were just a way of representing energy. However, it may be useful to address this issue with students.
- Objects constantly cool back down to room temperature. This is why you will occasionally see an E floating off of an object into the air.
- You can address energy efficiency with the biker, the teapot, and the incandescent bulb. Each of these objects loses some energy as thermal. The thermal energy released represents a loss in efficiency. Note that *energy is still conserved*.

Interviews Summary

First 2 interviews.

See the top matter for a bug and suggestion, and below for a summary. Overall, sim worked very well.

- Major bug with the thermometers. If you click one without dragging, it disappears. If you click another, it disappears and the other one reappears. (I never noticed this because I always drag, which always works.)

- Suggestion: Both students clicked the thermometers, they just didn't drag them right away. In addition to fixing the thermometer bug, I suggest we make the thermometer "pop" to the side when clicked, like tools do in some other sims, to cue students that they can be dragged.

On the popping thermometers – I'd like to try this in the interviews tomorrow, which means John will need to try to get it working before 4pm. We therefore can't wait to discuss at design meeting. Here are my suggestions for John:

- Top priority: fix disappearing thermometer – must do, please work on a.s.a.p.

- Second priority: make thermometer "pop" to the side when clicked – can discuss as status meeting, then have rest of day until 4pm to get working

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Summary

6th grade girl and 7th grade boy. Both students got to everything in the sim and didn't have any trouble using it. They started by moving objects around in tab 1, dropping iron and brick in the water, and putting things on the stands and heating / cooling them. They took some time to turn on the Es or pull out the thermometers (3-4 min for the girl, 5-6 min for the boy), but they did get to them, and did a lot of sense making after that (like talking about energy moving between the objects, the different amounts of energy they could hold).

I think the delay for students using thermometers partly had to do with them disappearing – the students both clicked, the thermometer disappeared, and then they moved on to something else.

Neither student went to the 2nd tab on their own – eventually, I asked them "did you notice the tabs at the top". They both said yes, but they didn't know if they should click on them (this is something I've heard students say before). Once they went to the 2nd tab, they turned on the water, talked about different types of energy turning into other types, tried just about every different configuration there is. They both explained all the energy changes in several systems,

noticed that the incandescent created thermal while the fluorescent didn't, used the Feed Me to keep the girl going, and just about everything else they could do. They both commented that the water wouldn't make the solar panel work, and so on.

The girl turned Es on and off several times while the sim was running, and the behavior of pre-populating didn't appear to bother her (she just stayed with the flow, didn't comment on anything looking weird). The boy didn't turn the Es on and off, just on, so I didn't get a read on whether the pre-populating looked weird to him.

Both students figured out that you could play "keep away" with an E coming down by making it chase the brick. Fortunately, they both did this for just a few seconds and then moved on, so it wasn't a distraction.

Overall everything seemed to work very well. The only thing is that I had hoped they turned on the Es and used the thermometers a little sooner, but as I said they did get to them and everything went smoothly after that.

Second 2 interviews:

The first student (male, 7th) was very engaged. He never clicked on Fast Forward or Reset All, but otherwise explored everything in the sim. The second student (female, 6th) was not very engaged at first. She asked right away "what am I supposed to do", and asked several other times "is this what I'm supposed to be doing" or "what should I do now?". She seemed to be in "performance mode", at one point saying that she had learned about energy in school but didn't remember much about it. She talked very quietly, kept saying "I don't know" when I asked questions, and in general seemed very shy and reluctant to say what she was thinking. However, I saw her do a good deal of exploring with the sim.

Both students started by moving objects around in tab 1, and commented that they didn't see anything happening. But, within a minute or two they grabbed the thermometers (which don't disappear now). First student turned on the Es within a couple minutes, second student student didn't (eventually I pointed them out to her). Once they had the thermometer and Es, they did a lot of sense making.

The 2nd tab worked very well for both students, similar to the first two interviews, so I won't go into much detail. The second student didn't turn on the Es, but once I pointed them out, she used them to describe how energy changes types as it moved through the system.

I asked both students about their interpretation of the Es. When I asked "what do you think the Es are", they both just said "energy". I asked more specifically about when energy was moving, if it was all the time or just when an E went across. The first student said all the time, constantly, and mentioned the fact that the temperature changed constantly. He said that if you were going

to show it correctly, there should be a lot more Es going across all the time. The second student was less sure and said she didn't know – maybe all the time, but not sure.

I also asked about where the energy was, everywhere or just where the Es are. First student said everywhere, that the Es were just "blobs" that told you how much energy was there, but that there must be more everywhere else throughout the object. The second student, again, was not sure, but seemed to indicate she thought there was something more than just the Es. (Overall, the second student did not want to say much except "I don't know".)

Here is a list of potential issues that arose. I just discussed with John ways to address them, also listed below, so please let me know if you have comments.

- Students still took some time to turn on Es. It was only a couple minutes, and they did find them, so I think it is OK. But:
  - I'm thinking about ways to make the control for Es more attractive (but not too attractive). Maybe a different style of button. (The second student actually hovered the mouse over the Es checkbox, but didn't click it.)
- The second student thought there was chemical E in the bulb.
  - New bulb images should fix this.
- The first student turned on the heaters only briefly at first – he commented several times that they should stay on. Eventually he just held them on continuously, but at first he only held them on for a faction of a second.
  - We could make the heater control stay in place, but there are issues with this. Partly, we don't want heating on all the time for the same reasons we don't in SOM (students losing track of the heater being on, for instance). In addition, putting the control back to zero could be problematic. We could make the control snap to zero when it gets close, but I have a feeling students won't move the slider near zero, and it will always be heating or cooling. Since this was the only student that commented on this, and he eventually just held the control in place, I think we can leave it as is.
- Because the first student just moved the heater control briefly, he didn't see Es come out of the heater right away, and didn't think anything was happening. (After a minute or so, he held it on longer and did see Es come out.)
  - My thought was to have an E come out right away the first time a user turns on the heat or cold, but this turns out to be difficult to code. What John is doing is making it so that an E comes out when the heater is first turned on, but not cold (for technical reasons, this is relatively easy). I think this will work, because all the students turned on heat before cold, so they will see the E come out right away.
- If a thermometer is in the middle of the water cup and you drop an object in, the thermometer that was in the water starts reading the temperature of the dropped object. This means you lose a reading of the water temperature. The first students saw this and thought the water temperature jumped. I recall that all of the students put the thermometer in the middle of the water, not on the side. Then when they dropped an object in, the thermometer jumped to the temperature of the object. Also, if two thermometers are in the water, it is hard to tell them apart.

- My proposal is that if the thermometer is in the middle of the water, when an object is dropped in the thermometer moves to the right side, so it is still reading just the water. This is sort of like the controls moving over in FAMB when you stack 3 objects. John said this wouldn't be too hard to implement.