Episode 217: Conservation of energy

The Principle of Conservation of Energy lies behind much of the physics studied at this level. Although we are concerned with conservation of mechanical energy in this episode it is useful to extend the principle to its wider context in order to give the students a full appreciation of the overarching nature of the principle when they meet it in different guises.

Summary

Discussion: Examples of energy conservation. (5 minutes)

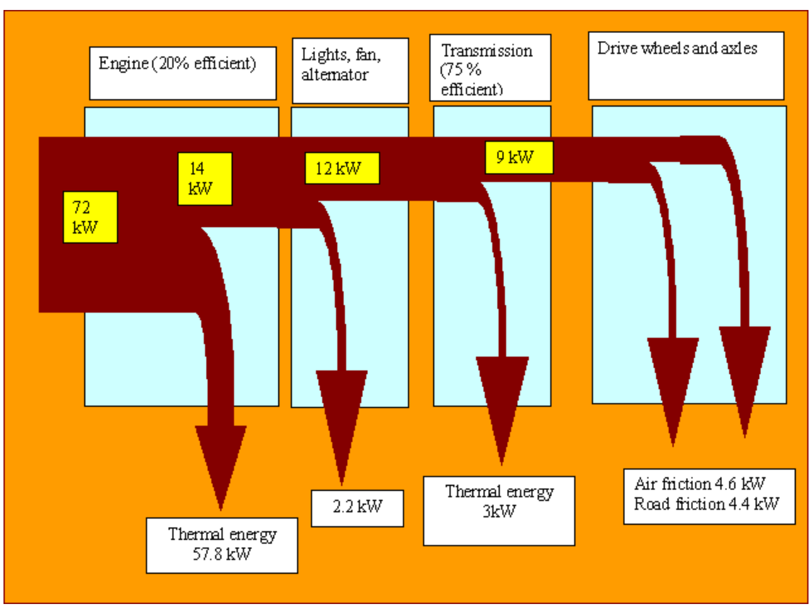
Demonstration: Energy transfers. (10 minutes)

Student questions: Including calculations. (15 minutes)

Discussion:

Examples of energy conservation

Introduce different forms of energy and discuss the interchanges. Concentrate on kinetic, gravitational potential and thermal energy. A Sankey diagram can be used to show where the energy goes when it is 'lost', such as the example shown here of energy changes per second (measured in Watts) in a motor vehicle.



TAP 217-1: Sankey diagram for a motor vehicle

Note that some students may think that the conservation of energy is an idealised notion, and that in practical situations, energy is not conserved. This is an incorrect idea. Energy is always conserved; in practical situations, some energy may be transferred as heat energy when we do not want it to be; however, correct accounting will show that the total amount of energy is still constant.

Demonstration:

Energy transfers

In transport systems, it is vital to minimise energy losses. This demonstration draws attention to these energy losses.

An alternative approach would be to ask a group of students to prepare this as a presentation, which they could then make to the class.

TAP 217-2: Free transport?

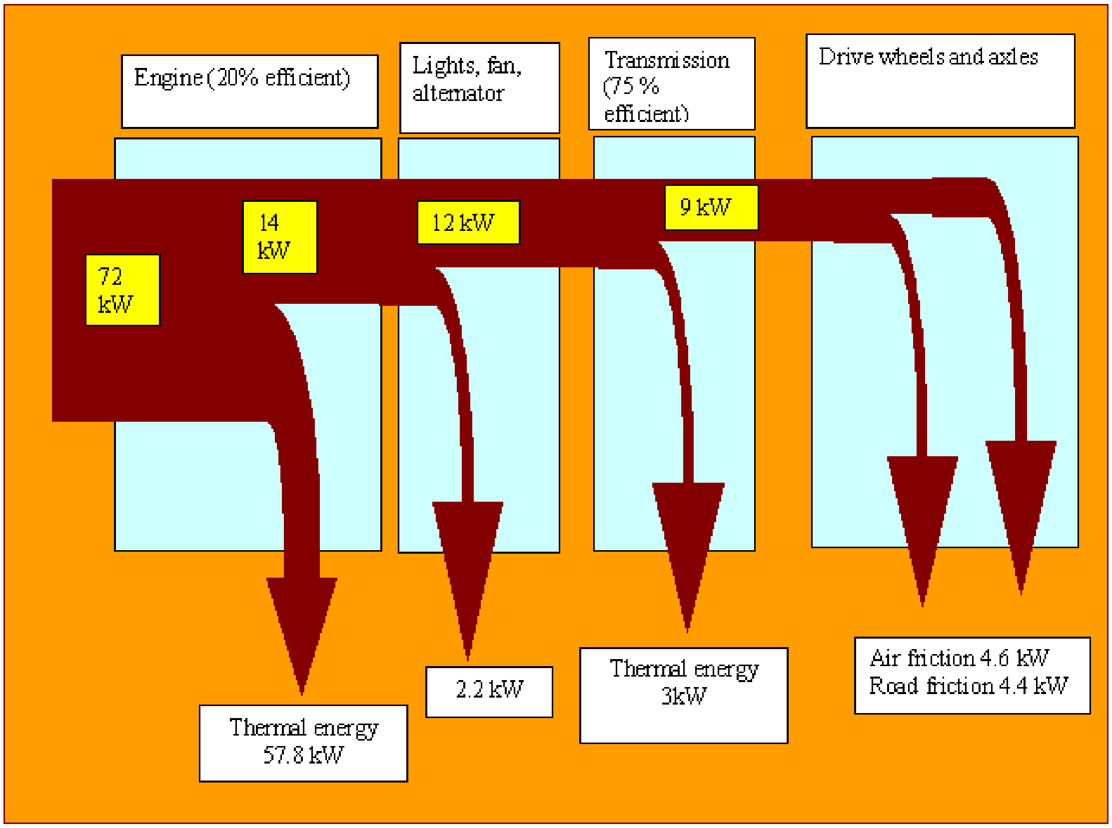
Student questions:

Including calculations

These questions make use of the idea that, in a frictionless system, gravitational energy is converted to kinetic energy when an object falls; i.e. $mgh = ½mv^2$.

TAP 217-3: Energy conservation

TAP 217- 1: Sankey diagram for a motor vehicle



TAP 217- 2: Free transport?

From here to there on nearly nothing

Reducing losses to a minimum is often an aim in transportation systems – sometimes critically so. Often the less the power available the more crucial this aim becomes. Going faster under human power is more about reducing losses than any other factor, for example. Here you look at one system where reducing losses is crucial.

You will need

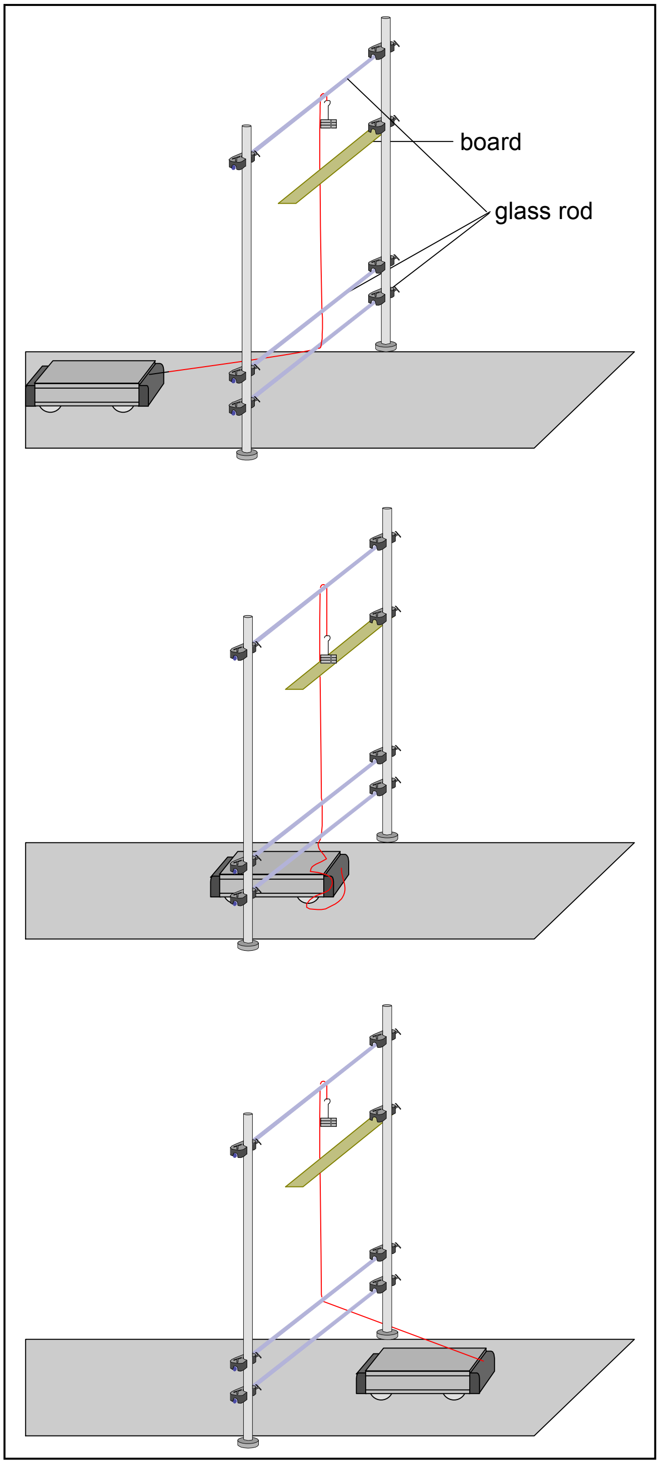
- ✓ dynamics trolley and runway or track
- ✓ two retort stands
- ✓ 3 smooth rods
- ✓ six bosses
- ✓ hanger masses, 10 g
- ✓ nylon monofilament
- ✓ a pendulum, supported on a retort stand clamped to the bench with a G-clamp
- ✓ a 6 inch nail held in a boss

Safety

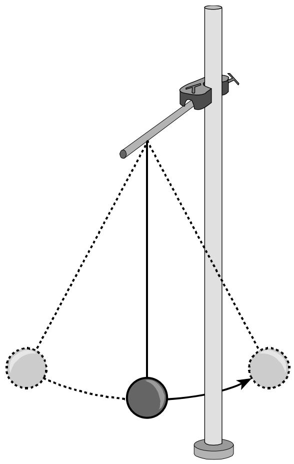
Large trolley runways are too heavy for one person to manipulate or carry. Ensure that two people share the load.

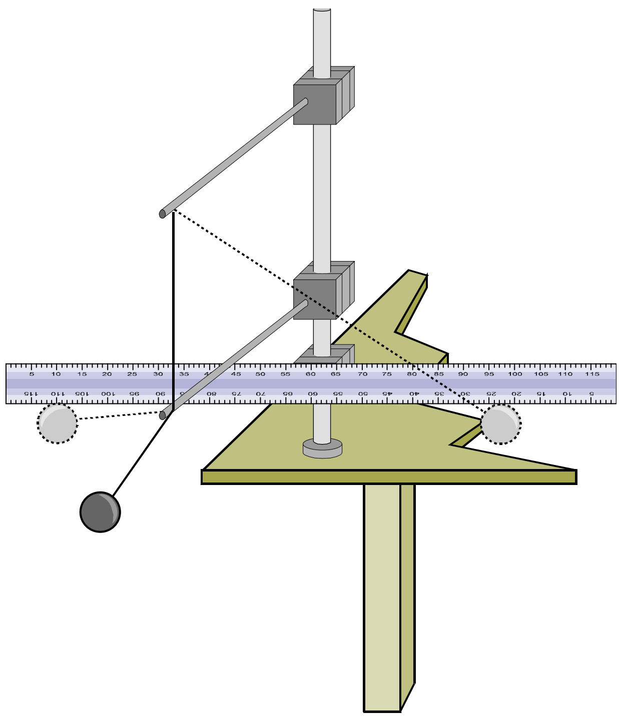
Planning and demonstrating energy transfers

When setting up the apparatus take care to reduce the frictional forces as much as possible. Carry out the sequence shown and devise a commentary to go with it. Add masses to the load. Repeat, notice the differences and script a new commentary. Now load the trolley. What difference does this make? Prepare another commentary to go with this.



Now reduce the friction, trying these two arrangements in succession.





(Remember to clamp the retort stand in the diagram above to the bench.)

Again both will need to give an explanation.

When you are ready show others what you have done and try out your commentaries.

Have you shown?

1. That the same energy turns up in gravitational potential energy and kinetic energy?
2. That transferring more potential energy results in more kinetic energy?
3. That reducing dissipative forces results in more and more energy ending up where you can measure it.

Practical advice

These experiments are not hard to set up, but do take care. A high-quality dynamics trolley is essential. The emphasis should be on the commentary: can the students (optimally two or three) handle the apparatus and use it to explain their understanding of energy transfers? The sequence moves steadily towards the less dissipative environment, extrapolation from here gives simple reason to believe in the conservation of energy.

Alternative approaches

Selected videotaped sequences could be substituted, but 'making nature behave' should be part of the students' experience at some stage.

Social and human context

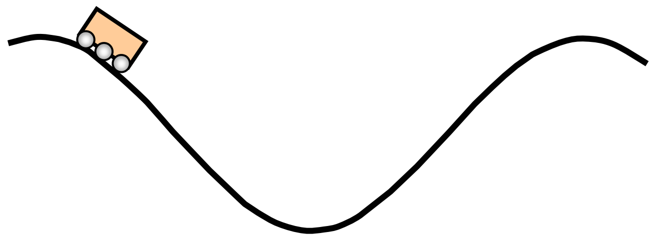
The role of extrapolation and thought experiment in the foundations of dynamics has been, and is essential! Physics proceeds by making things very simple.

External references

This activity is taken from Advancing Physics Chapter 9, 300P

TAP 217- 3: Energy conservation

1. A roller coaster car is at the top of its track. It is released from rest and reaches maximum speed at the bottom of the dip.

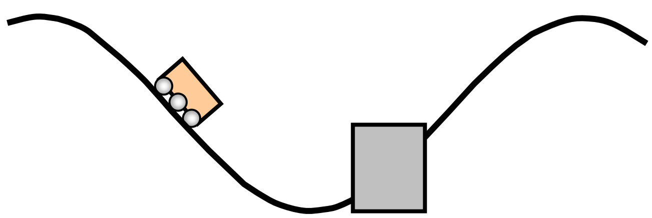


In order to make the speed of the car at the bottom of the dip **twice as fast** should you:

- double the starting height;
- double the mass of the trolley;
- make the starting height four times as high?

Explain your answer by referring to the conservation of energy.

2. Another roller coaster uses a cushioning system to bring the car to rest:



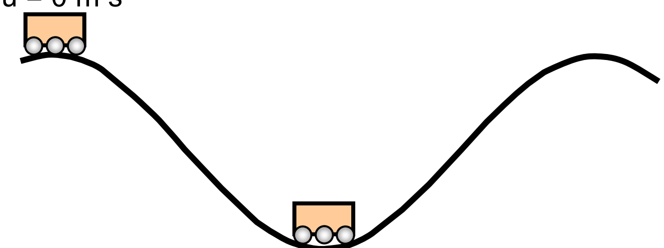
When the car is released from half way up the roller coaster it penetrates x metres into the cushion before coming to rest.

How far would the car penetrate into the cushioning if the release height was doubled?

- x
- $2x$
- $4x$

Explain your answer by referring to the equation *work done = force* × *distance.*

3. When the roller coaster is released from the top of the track at rest (u = 0 m s^{-1}), it reaches a speed of 16 m s^{-1} at the bottom of the track.



(a) Use the principle of conservation of energy applied to gravitational potential energy and kinetic energy to show that the original height of the roller coaster was about 13 m.

(b) In another run the car started from the same height but was given an initial speed of 10 m s^{-1}.

Show that the speed of the car at the bottom of the track was about 19 m s^{-1}. (You may find it helpful to consider the relationship between velocity and kinetic energy in this question.)

(Acceleration due to gravity = 9.8 m s^{-2})

Answers and worked solutions

1. Make the starting height four times as high, as velocity squared is proportional to initial potential energy (= maximum kinetic energy).

2. $2x$; assuming constant retarding force, twice as much kinetic energy means that twice as much work needs to be done to bring the car to rest.

   As *work done* = *force* × *distance,* the distance will double.

3.

(a) $mg\Delta h = ½mv^2$ so $½v^2 = g\Delta h$

$\Delta h = v^2/ (2g) = 16^2 / (2 \times 9.8)$

Δh =13.06 m = 13 m (2sf)

(b) This question is quite testing. You must add energies rather than speeds. To do this without a given mass will really stretch some students. Explain carefully why to get the answer they must add the square of the velocities and then take the square root of the sum. You can work this through with an assumed value of mass (say 1000 kg) and show the students that the answer is independent of mass.

$mg\Delta h + ½mu^2 = ½mv^2$ so $g\Delta h + ½u^2 = ½v^2$

$(9.8 \times 13.06) + ½ (10)^2 = ½v^2$

$128 + 50 = ½v^2$

$178 \times 2 = v^2$

v = 18.86 m s^{-1} v = 18.9 m s^{-1} nearly 19 m s^{-1}

External references

This activity is taken from Resourceful Physics http://resourcefulphysics.org/