

Episode 216: Energy changes

This episode extends the ideas from kinetic energy (and velocity) to braking distance and work. Two experiments are included, both of which connect work done in braking to the initial kinetic energy of the decelerating body.

Summary

Discussion: Work, force, distance. (5 minutes)

Student experiment: Moving a block along the bench. (30 minutes)

Demonstration or student experiment: Braking force and distance. (15 minutes)

Student questions: Energy changes. (40 minutes)

Discussion:

Work, force, distance

You have established that work = force \times distance. Before embarking on the practical work it may help to make the link between initial kinetic energy and work done in deceleration, as clear as possible.

A body has 1 MJ of kinetic energy and is decelerated to rest. What is its final K.E? (0 J) Hence, how much work has been done on the body? (1 MJ)

This might be a good point to rehearse the SUVAT equation: $v^2 = u^2 + 2as$

Thus when a car is accelerated from u to v m s^{-1} , the change in KE = $\frac{1}{2} mv^2 - \frac{1}{2} mu^2$

This just equals the work done by the accelerating force = Fs

using Newton's Second Law: $F = ma$

Thus $\frac{1}{2} mv^2 - \frac{1}{2} mu^2 = mas$

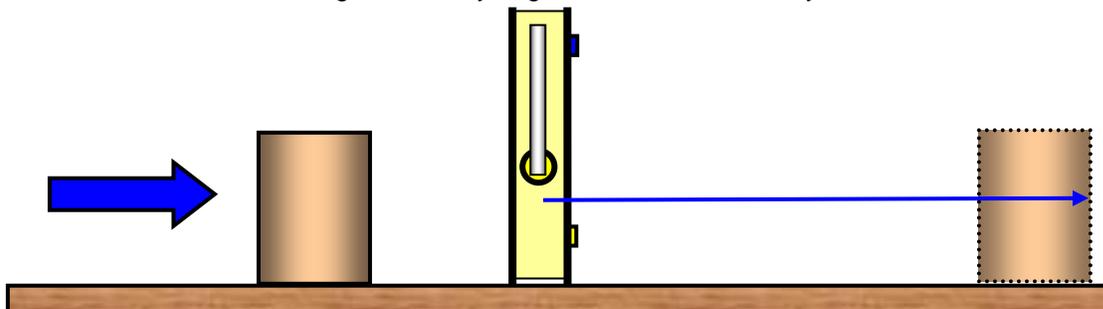
i.e. $v^2 = u^2 + 2as$

Student experiment:

Moving a block along the bench

This is a very effective and simple experiment. A block is given an initial push so that it slides along the bench. It passes through a light gate, so that its velocity is measured; the distance travelled beyond the gate is then measured.

Students should be able to gather a very large number of results. If you have access to



computers and spreadsheets in the lab you can combine all the results together and let Excel produce the graphs (scatter graphs with no lines drawn allow the students to practise interpreting points and scatter).

Using a circular mass means that the exact path it takes through the light gates is not important. With carefully set-up equipment you will find that the mass is tall enough to break the light beam as required.

It does not matter if the measuring apparatus calculates velocity for you or only measures a time period – the latter just gives the students another task.

You should emphasise the dependence of stopping distance on the square of the velocity. This ties in to the Highway Code data analysed below (in the Student Questions).

TAP 216-1: Braking distance and velocity

Student questions:

Energy changes

These questions, about a car running down the tracks of different shapes, require a good understanding of the energy changes involved.

TAP 216-2: A slide

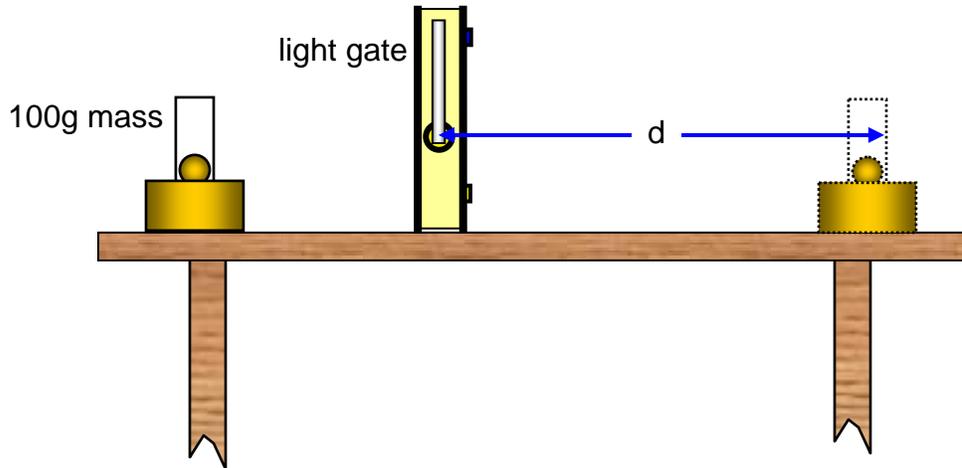
Some further questions, concerning energy changes and work done, for a high jumper.

TAP 216-3: The high jump – energy changes

TAP 216- 1: Braking distance and velocity

Apparatus:

- ✓ Light gate assembly (to measure velocity) plus datalogger/computer
- ✓ 100g mass
- ✓ metre rule
- ✓ suitable surface (e.g. bench top)



Procedure

- Push the 100 g mass so that it slides freely through the light gate and measure the distance it travels until rest.
- Repeat this process for as many different speeds as possible.
- Record your results in a suitable table or spreadsheet.
- Draw a graph of velocity against stopping distance.
- Draw a graph of velocity squared against stopping distance.

Safety

The metre rule can be used as a barrier to prevent the mass flying off the end of the bench when pushed too violently.

Questions:

What can you conclude from the graphs you have drawn?

Estimate the frictional force on the mass.

Practical advice

A cylinder of dark-coloured paper can be attached to the mass to ensure that it breaks the light beam. (The diameter of the cylinder will be needed by the software)

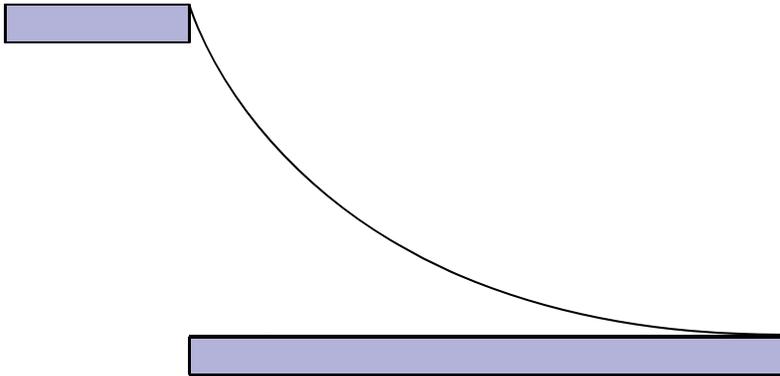
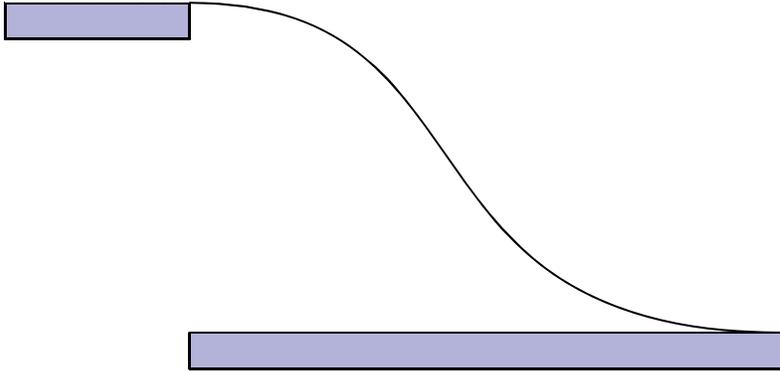
$Fs = \frac{1}{2} mv^2$ so a graph of v^2 against s should have gradient $\frac{1}{2} m/F$. Knowing the mass (in kg) enables an average frictional force to be calculated from the gradient.

External references

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

TAP 216- 2: A slide

A child is playing with a nearly frictionless car down a smooth flexible track. She arranges the identical length of track in two ways.



In both arrangements the track runs from the same place on the edge of a table to floor level.

1. She thinks that the car runs off the track at very nearly the same speed in both arrangements when started from rest at the top of the track (the point nearest the table). Is she right or wrong? Give a reason for your answer.

2. She thinks the car takes longer to run down the top arrangement than down the bottom arrangement, when started from rest at the top of the track. Is she right or wrong? Again, justify your answer.

3. Suppose she now lets a car of twice the mass of the previous one run from rest down the top arrangement. Will this car, which has twice as great a mass, take a shorter, the same, or a longer time to run down the track? Give a reason for your answer.

Practical advice

These questions concentrate on the conversion of potential energy to kinetic energy.

Answers and worked solutions

1. Right, as both cars have the same amount of kinetic energy on leaving the track. A good answer would relate this to the same drop in height, explicitly linking the change in potential energy to the change in kinetic energy.
2. Right, as the bottom arrangement gains kinetic energy more quickly, making the average speed greater. A good answer would relate this more rapid change in kinetic energy to the steepness of the slope—the top arrangement gets faster sooner!
3. Same, assuming the frictional forces are really negligible as the change in kinetic energy equated to the change in potential energy soon gives:

$$v = \sqrt{2gh}.$$

External references

This activity is taken from Advancing Physics Chapter 9, 90S

TAP 216- 3: The high jump – energy changes

Note: $g = 9.8 \text{ N kg}^{-1} = 9.8 \text{ m s}^{-2}$

1 A jumper of mass 75 kg jumps a height of 1.9 m

- (a) Calculate the gravitational potential energy of the jumper at his highest point.

- (b) Calculate the vertical velocity of the jumper just before impact with the crash mat. (HINT: what was the vertical velocity of the jumper at the top of his jump?)

- (c) Show that the kinetic energy associated with his vertical velocity is equal to the gravitational potential energy at the top of his jump.

- (d) The jumper is stopped over a distance of 0.3 m when he lands on the crash mat. Calculate the average force on the jumper as he comes to rest.

Answers and worked solutions

1)

- (a) Gravitational potential energy = $mgh = 70 \times 9.8 \times 1.9 = 1303.4 \text{ J} = 1300 \text{ J}$ to 2sf as required by the data
- (b) $v^2 = u^2 + 2as$ $u = 0$ so $v = \sqrt{2gh}$. $v = (2 \times 9.8 \times 1.9)^{0.5}$ so $v = 6.1 \text{ m s}^{-1}$
- (c) $\frac{1}{2} m v^2 = 1302 \text{ J} = 1300 \text{ J}$ to 2sf (a circular argument, of course) which emphasises that the suvat equation used in part (b) is derived from conservation of energy
- (d) $Fs = 1304 \text{ J}$ so $F = 1304/0.3 = 4345 \text{ N} = 4300 \text{ N}$ to 2sf

External references

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