A Guide to Work, Energy and Power

Teaching Approach

Work, Energy and Power is a topic which comprise of three concepts which are very closely related – work and energy and power. The words "work" and "power" must be clearly defined as science concepts and it must be further clarified to the learners that these words do not carry the same meaning as when they are used in everyday language.

It is imperative that the learners should clearly understand the definition of work since its conceptual understanding and formula hinges on it. The definition, "Work is done when a force exerted on the object causes the object to move in the direction of the force", should be avoided at all cost since it leads to misconceptions.
The phrase, "component of the force parallel to the plane or parallel to the movement of the object", is very important in the definition work. This phrase clarifies explicitly which force acts on an object and clarifies which force does work.

Work can be defined as the product of the displacement of the object and the component of the force parallel to the plane or the movement of the object. This definition has the following benefits:

1. It facilitates the understanding the mathematical definition of work ($\mathbf{Work} = \mathbf{F\Delta xCos\theta}$) required in the Curriculum and Assessment Policy Statement (CAPS).
2. It helps the learners understand situations where work is done and in situations where work is not or cannot be done.
3. It helps and simplifies the understanding that work is a scalar.

Forces forms a big part of the concept of work and it is important that the conservative forces and non-conservative forces should be explained with examples. The proper understanding of the nature of the forces makes it easier and enhances the understanding of the concepts "negative work" and "positive work".

It must be emphasized that the net work is done by the net force and mathematically this implies: $\mathbf{W_{net}} = \mathbf{F_1\Delta xCos\theta} + \mathbf{F_2\Delta xCos\theta}$. (If there are two forces involved)
The understanding that positive or negative work changes the velocity of an object leads to the understanding of the change in kinetic energy of the object and finally to the understanding of the work energy theorem.

Work and energy are both measured in Joules and are very closely related in the sense that work is energy transferred to an object as a result of the force applied. It is therefore imperative that the principle of conservation of mechanical energy be understood as well.

It should be noted that even though the definition of power is the rate of work done, the emphasis is on average power and the force which causes the average velocity of the object ($\mathbf{P_{av}} = \mathbf{Fv_{av}}$).

The videos can either be used independently for the learners to revise with after learning the content at school, or as part of the lessons. If it is possible, the use of multimedia to explain and reinforce concepts helps the learners understand and grasp new concepts.

The task video has been prepared in such a way as it could be used as either an exercise tool, or it can be used as a complete test for the learners, or as a way for the learners to test their knowledge independently.

The CAPS document should be used as a reference document in order to ensure that all concepts required by the curriculum are taught.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. What is Work?

The video illustrates the everyday examples of work. This will be used to differentiate between the scientific concept of work and the everyday examples of work.

2. Applying the Definition of Work in Calculations

The video provides an example of a problem where the applied force is at an angle and the movement of the object is horizontal. The understanding of the definition of work plays an important role here.

3. Work and Energy

The video provides the definition of energy (ability to do work) and provides an explanation of how work relates to energy. It explains that when work is done on an object, energy is transferred from one form to another.

4. Work Energy Theorem

The video introduces the work energy theorem, provides the definition of the work-energy theorem and provides the work-energy theorem formula

5. Conservation of Energy

The video introduces mechanical energy, provides the definition of mechanical energy and its formula. The principle of conservation of mechanical energy is discussed and explained. The conditions under which the mechanical energy is conserved are also discussed.

6. Power

The video defines power and illustrates the definition of power by animated examples. Examples of problems of power and solutions are provided.

Resource Material

Resource materials are a list of links available to teachers and learners to enhance their experience of the subject matter. They are not necessarily CAPS aligned and need to be used with discretion.

1. What is Work?	https://www.youtube.com/watch?v=-D5r2K8wRZY	[00:33 – 00:50] Everyday examples of work
2. Applying the Definition of Work in Calculations	https://www.youtube.com/watch?v=-D5r2K8wRZY	[07:24 – 08:56] The application of the formula of work and examples work problems and solutions.
3. Work and Energy	https://www.youtube.com/watch?v=-D5r2K8wRZY	[34:50 – 38:30] Definition of energy and how it relates to work.
4. Work Energy Theorem	http://www.youtube.com/watch?feature=player_detailpage	[01:00:37 – 01:16:26] Work energy theorem and its application.
5. Conservation of Energy	http://www.youtube.com/watch?feature=player_detailpage	[48:45 – 52:09] The principle of mechanical energy and its application
6. Power	https://www.youtube.com/watch?v=i6xEsBsP23E	[01:20 – 09:09] The definition of power and examples of problems and solutions

Task

Question 1

Define the following terms

1.1 Work

1.2 Energy

1.3 Power

1.4 Conservative force

Question 2

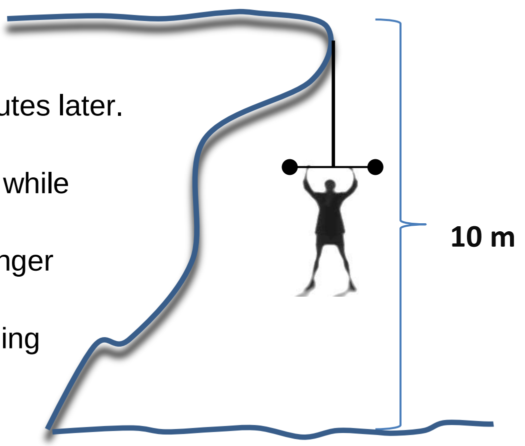
2.1 State the principle of conservation of mechanical energy.

2.2 State the work energy theorem.

Question 3

Consider the following situations:

A cliff hanger hangs stationary from a rope below a cliff which is 10 m high from the ground. After a while the rope snapped and the cliff hanger fell, reaching the ground 4 minutes later.



3.1 Name the conservative forces acting on the cliff hanger while hanging under the cliff.

3.2 Name the non-conservative forces acting on the cliff hanger while hanging under the cliff.

3.3 Was there any work done on the cliff hanger while hanging under the cliff? Justify you answer.

3.4 Which force did positive work on the cliff hanger after the rope snapped?

Question 4

Consider the following situations and state whether work is done or work is not done. Justify your answer in each case:

A boy lifts up water bucket, rests it on his head and walked away with the bucket. On arrival at home, he placed the water bucket on the kitchen table.

4.1 Was there any work done on the bucket when it was lifted up from the ground?

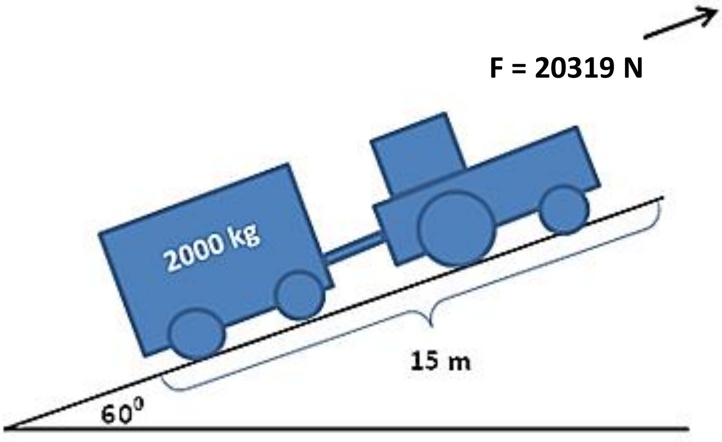
4.2 Was there any work done on the bucket while resting on the boy's head?

Question 5

Write down the mathematical expression of the definition of work

Questions 6

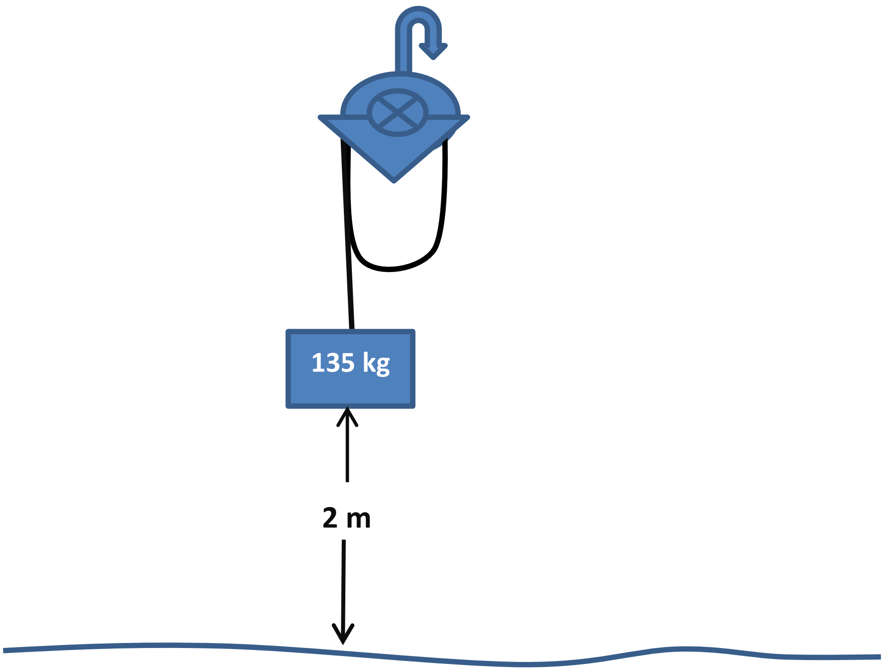
A tractor applies a force of 20 319 N to pull a 2 000 kg trailer from rest for 15 m to the top of a bridge as shown in the diagram



6.1 Draw a free body diagram of all the forces acting on the trailer.
6.2 Calculate the net work done on the trailer.
6.3 Determine the velocity with which the trailer reaches the top of the bridge.

Question 7

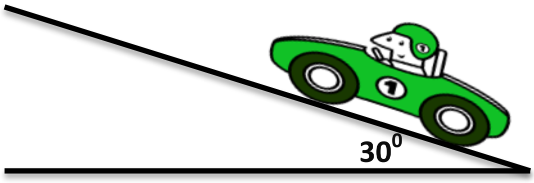
A 135 kg load is hoisted vertically upwards from the ground by a chain-block and reaches a height of 2 m at 1 m·s^{-1} (ignore the effects of air friction)



7.1 Identify a non-conservative force.
7.2 Calculate the work done by the non-conservative force.

Question 8

A 276 kg racing car crosses a bridge at constant average velocity of 43 m·s^{-1}. The bridge is inclined at 30° to the horizontal.



Calculate the average power required to maintain the average velocity against the non-conservative forces.

Task Answers

Question 1

1.1 Work is the product of the displacement of the object and the component of the force parallel to the plane or the movement of the object.
1.2 Energy is the ability of to do work.
1.3 Power is the rate at which work is done.
1.4 The conservative force is the force which does no net work on an object which is on a closed path.

Question 2

2.1 In an isolated system, the mechanical energy is conserved.
2.2 When a net force acts on an object, the net work done is equal to the change in kinetic energy.

Question 3

3.1 The tension on the rope.
3.2 Force of gravity.
3.3 No. The cliff hanger was stationary. He was not moving in the direction of the force acting on him.
3.4 The force of gravity

Question 4

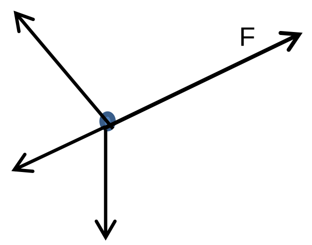
4.1 Yes there was work done on the bucket when it was lifted up from the ground because the boy applied an upward force (lifting force) and the bucket moved in the direction as the force, upward.
4.2 No, there was no work done on the bucket while it was resting on the boy's head because the bucket is not moving in the direction of the force of gravity or normal force.

Question 5

$W = F\Delta x \cos\theta$

Question 6

6.1



6.2 $F_{nc} = F_g Sin\theta$

$F_{nc} = 2000\ x\ 9{,}8\ x\ Sin\ 60°$

$F_{nc}\ 16974{,}1\ N$

Therefore:

$W_{net} = F\Delta x Cos\theta + f\Delta x Cos\theta$

$W_{net} = 20319\ x\ 15\ x\ Cos0° + 16974\ x\ 15\ x\ Cos\ 180°$

$W_{net} = 50173{,}5\ J$

6.3 $W_{net} = \Delta E_K$

$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$50173{,}5 = 0{,}5\ x\ 2000\ x\ v^2 - 0$

$v = 7,08\ m \cdot s^{-1}$

Question 7

7.1 Force of gravity

7.2 $W_{nc} = \Delta E_k + \Delta E_P$

$W_{nc} = E_{Kf} - E_{Ki} + E_{Pf} - E_{Pi}$

$W_{nc} = \frac{1}{2}(135)(1) - 0 + (135)(9{,}8)(2) - 0$

$W_{nc} = 2\ 713,5\ J$

Question 8

$F_{nc} = mgSin\theta$

$F_{nc} = 276 \times 9{,}8\ Sin\ 30°$

$F_{nc} = 1352,4\ N$

The bike travels at constant average velocity. The net force is zero, therefore, the applied force = non-conservative forces.

$\therefore \quad P_{av} = Fv_{av}$

$P_{av} = 1352,4 \times 43$

$P_{av} = 60\ kW$

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