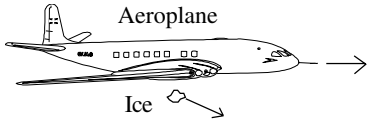
Physics Factsheet

www.curriculum-press.co.uk Number 104

Difficulties with Motion and Energy problems

Examiners' reports point out repeated difficulties students experience with problems involving motion and energy. We will look at a sample question of this sort, and discuss the techniques that should be used.

Here is the problem we will consider:

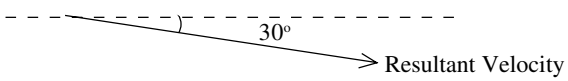


(a) A chunk of ice of mass 3.0kg falling from an aircraft's wing soon reaches terminal velocity in the vertical component of its motion. Explain why its vertical velocity becomes constant. (3 marks)

(b) The constant vertical velocity reached is 22.5ms^{-1}. Find the kinetic energy due to the vertical motion of the ice block. (3 marks)

(c) Gravitational force is exerted on the ice block as it falls through a distance. From W = Fs, we know that work is being done. Describe and explain the energy transfer that occurs. (2 marks)

(d) When the chunk of ice reaches its vertical terminal velocity, its direction of motion is 30° below the horizontal.



Calculate its horizontal velocity, v_x, at this time.

Part (a)

A chunk of ice of mass 3.0kg falling from an aircraft's wing soon reaches terminal velocity in the vertical component of its motion. Explain why its vertical velocity becomes constant. (3 marks)

Mark Scheme

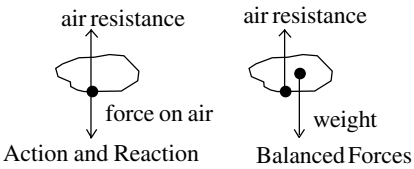
Any 3 marks from-
gravity/weight causes a downward acceleration (1)
air resistance/drag/friction acts upwards (1)
the upward force increases with the speed of the block (1)
zero acceleration/uniform velocity reached when forces balance (1)

A candidate's response

Gravity acts on the ice and it accelerates downwards. When it gets fast enough, its acceleration is cancelled by the air resistance, and it pushes as hard on the air as the air does on the ice. Constant velocity is reached.

Comments

A confused answer. A **force** must be balanced by **another force**, not by motion such as acceleration. Newton's Third Law (action and reaction) is always obeyed, but is not relevant to this question. The forces that must balance are the two forces acting **on the ice** – its weight and the air resistance.



In addition, the student was not precise enough as he didn't state the direction of the resistive force.

Marks gained: 1 / 3 (the first marking point only)

Action and reaction forces are always equal to each other. Two forces on a body will be equal in an equilibrium situation. You must be clear which situation you are dealing with.

Part (b)

The constant vertical velocity reached is 22.5ms^{-1}. Find the kinetic energy due to the vertical motion of the ice block. (3 marks)

Mark Scheme

$KE = ½mv^2$ (1) $= ½ \times 3.0 \times 22.5^2$ (1) $= 759J$ (1)

A candidate's response

$KE = 0.5mv^2 = 0.5 \times 3 \times 22.5^2 = 33.75^2 = 1139W$

Comments

The candidate has squared ½mv, rather than just the velocity. He has incorrectly stated the answer to 4 significant figures. He has also used the wrong unit for energy. This is just carelessness. Fortunately all of these errors occur in the same marking point – sometimes you get lucky.

Marks gained: 2 / 3

Part (c)

Gravitational force is exerted on the ice block as it falls through a vertical distance. From W = Fs, we know that work is being done. Describe and explain the energy transfer that occurs. (2 marks)

Mark Scheme

Any 2 marks from-
work done as a force has been exerted through a distance (1)
no gain in KE of block as velocity uniform (1)
kinetic/thermal energy gained by air as ice moves through it (1)

A candidate's response

As an object falls, gravitational potential energy is transformed into kinetic energy. Potential energy lost equals kinetic energy gained.

Comments

This candidate has not read the question. He has just stated the standard GCSE response where there is no air resistance. This question is quite clearly about work being done on an object where a resistive force is in play.

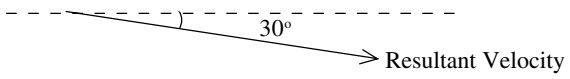
Beware of churning out stock answers to what appear to be standard situations. If you don't read the question, you're not likely to gain many, if any, marks.

Marks gained: 0 / 3

***Exam Hint**: Read the question carefully. Often standard situations are altered slightly to see if you can adjust your thinking.*

Part (d)

When the chunk of ice reaches its vertical terminal velocity, its direction of motion is 30° below the horizontal.



Calculate its horizontal velocity, v_x, at this time.

Mark Scheme

$\tan 30^o = \frac{22.5}{v_x}$ (1)

$v_x = \frac{22.5}{\tan 30^o}$ (1) $= 39.0 ms^{-1}$ (1)

A candidate's response

$\tan è = \frac{v_y}{v_x}$

$\tan 30 = \frac{22.5}{v_x}$

$v_x = 22.5 \tan 30 = 13 ms^{-1}$

Comments

The candidate has used the correct equation, substituted correctly, and used the correct unit in his answer. Unfortunately, carelessness in rearranging the equation has cost him dearly. It is easy to ignore this step when checking your calculation, but it is a common source of error.

Marks gained: 1 / 3

> ***Exam Hint:*** *When checking a calculation, it is as important to check that the numbers have been substituted correctly, and that the equation has been rearranged correctly, as it is to check the actual calculation done.*

Final comment

Questions of this sort involve forces, motion, and work/energy considerations. It is important to be clear which is most relevant in each part of the question. In this question, part (a) involves forces and motion, and part (c) involves work and energy. Analyse each part of the question before you attempt it.

An exercise for you to attempt

A candidate's answer to a question is given below. Identify three correct points that the candidate makes, and three incorrect or contradictory points.

Problem

A parachutist jumps from an aeroplane. She accelerates for a few seconds, then opens her parachute and decelerates quickly before continuing towards the earth at a uniform speed.

Explain her motion in terms of forces and energy. Consider only her vertical motion.

Candidate's answer

Her gravitational potential energy is greatest at the top. As she falls, this potential energy changes to kinetic energy, but her total energy is fixed. Friction with the air is transformed into heat energy.

The gravitational force acting on her is constant, regardless of her velocity or altitude. She accelerates because her weight is greater than air resistance. Opening her parachute does not affect her weight, but does affect air resistance and potential energy.

She slows down because air resistance is greater than weight, and finally falls with uniform speed as air resistance keeps increasing.

Solution

Correct points-
GPE greatest at the top
gravitational force (weight) constant
accelerates because weight greater than friction
parachute does not affect weight, but affects air resistance
slows as the air resistance is greater than the weight

Incorrect points-
PE changes to KE (only true at the beginning of the fall)
her total energy is fixed
friction transformed into heat energy (a force cannot become an energy)
opening the parachute affects the PE
air resistance keeps increasing at uniform speed

Acknowledgements:
This Physics Factsheet was researched and written by Paul Freeman
The Curriculum Press,Bank House, 105 King Street,Wellington, Shropshire, TF1 1NU

ISSN 1351-5136