EXPLAIN THAT!

GCE 'O' LEVEL PHYSICS

SECOND EDITION

EXAMINER-STYLE ANSWER PHRASINGS TO MUST-KNOW QUALITATIVE QUESTIONS

TAN JUN WEI

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Explain That! is a series of comprehensive guides designed to help students master the skill of answering qualitative questions. Each title comprises a well-curated selection of questions which covers a variety of key ideas and concepts. These books train students to construct their explanations using examiner-style phrasing, giving them greater confidence before and during the examinations.

What's Inside?

- ☑ A collection of common must-know qualitative questions
- ☑ Concise reference answers with examiner-style phrasing
- ☑ Clear diagrams for better visualisation and understanding

Tan Jun Wei graduated with a Bachelor of Engineering with First Class Honours in Electrical Engineering (NUS). He has received an Honourable Mention in the Asian Physics Olympiad. Currently, he trains the Junior Physics Olympiad Team at several top institutions in Singapore, and is the director of Eton Tuition Centre. His strengths lie in helping students build a strong foundation in Physics and teaching them how to apply what they have learnt to real world scenarios.

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Contents

Preface

Through years of interaction, one of the observations I made as an educator was that most students were unable to answer qualitative questions efficiently and effectively. Most books, notes – and even "summaries" – focus on elaborating concepts to instill understanding. However, the detailed paragraphs are often too lengthy to be used in an examination.

Explain That! GCE 'O' Level Physics is packed with suggested solutions for a wide variety of qualitative questions. It helps students identify key ideas and concepts which are sufficient for answering qualitative questions, especially when the clock is ticking by the second.

One of the early methods which I have employed as an educator was to develop worksheets for common qualitative questions. These questions were largely inspired by hundreds of local and overseas examination papers, ranging from school preliminary examinations to the GCE 'O' Level examinations. What I have gathered is that most qualitative questions are formed from pieces of information which I refer to as "building blocks", and different "building blocks" can be combined to create a new qualitative question. With the contributions of my past and present students, my worksheets have improved over the years. Soon, I realised that the growing collection of questions had the potential to become a book containing just the right amount of information.

Another thing I noticed was that students were often confused when faced with a question which has never appeared in the annals of ten-year series and test papers from other schools. This book aims to bridge the gap by including some innovative questions to inspire students to apply their knowledge to new problems. Each question was carefully selected to cover as many concepts as the syllabus dictates without turning this book into an encyclopedia (and subsequently a paperweight). Always remember that the list of questions is not exhaustive, and this book is meant as a reference to help students master the art of answering qualitative questions.

Students are advised to understand and modify the suggested answers when attempting similar questions during exams. This book should be used in conjunction with existing educational resources that students are already using. It does not cover every last piece of information that you will find in the course outline. Content which is not required in answering qualitative questions is most likely expunged from this compendium.

Due to human error (just like what happens in an experiment), controversies may arise from time to time. In such a situation, please send an email to **enquiries@examworld.com.sg** to let us know. A list of errors and corrections will be maintained on our website at http://www.examworld.com.sg .

Tan Jun Wei

About the Author

Tan Jun Wei founded Examworld, an educational consultancy firm which provides students with quality Olympiad training. He graduated with a Bachelor of Engineering with First Class Honours in Electrical Engineering from the National University of Singapore, and has achieved the NUS Innovation Award (Merit). He represented Singapore in the 2001 Asian Physics Olympiad and is ranked Top 39 in Asia. In the same year, he received the Excellence in 'A' Level Physics Award which is given to the top ten performers at the GCE 'A' Level Physics examinations. Currently, he trains students for the Junior Physics Olympiad at several top institutions in Singapore, and is the director of Eton Tuition Centre.

1 Measurement

1.1 Physical Quantities, Units and Measurement

001 **Distinguish between scalar and vector quantities and give examples for each.**

Scalar Quantities	Vector Quantities
Has magnitude only	Has both magnitude and direction
Examples: • distance • speed • time • mass • temperature • energy	Examples: • displacement • velocity • acceleration • weight • force • moment of a force

002 **Suggest why a driver takes a longer time to stop a lorry in reality, compared to the theoretically calculated time.**

Due to human reaction time, the driver delays for a short moment before applying the brakes.

003 What are the different prefixes?

Prefix	Symbol	Factor
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}

Prefix	Symbol	Factor
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

004 What are the orders of magnitudes of various objects?

Object	Order of Magnitude / m
Diameter of atom	10^{-10}
Diameter of virus	10^{-8} to 10^{-7}
Wavelength of visible light	10^{-7}
Diameter of human hair	10^{-4}
Thickness of paper	10^{-4}
Thickness of coin	10^{-3}
Diameter of golf ball	10^{-2}
Length of shoe	10^{-1}
Height of man	10^{0}
Length of saloon car	10^{0}
Length of bus	10^{1}
Height of Mount Everest	10^{3} to 10^{4} (it is 8848 m)
Width of Singapore	10^{4}
Diameter of Moon	10^{6}
Diameter of Earth	10^{7}
Distance from Earth to Moon	10^{8}

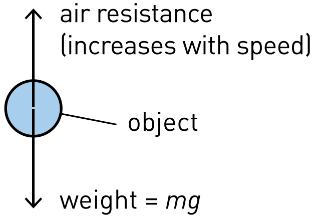
2 Newtonian Mechanics

2.1 Kinematics

005 **Describe qualitatively the motion of a falling object in a uniform gravitational field with air resistance.**

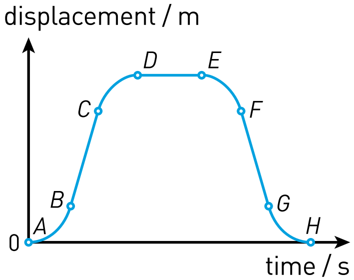
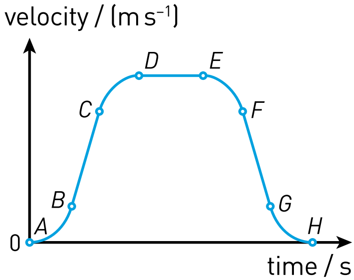
OR **Explain, in terms of the forces acting on a falling object, why it reaches terminal velocity.**

A falling object experiences both weight and air resistance.



Initially, as the object falls, its weight is larger than the air resistance acting on it, and its velocity increases. Air resistance increases with the velocity of the object. Eventually, the object reaches terminal velocity when the air resistance is equal to its weight.

006 Describe the motion of an object based on its displacement-time graph or velocity-time graph.

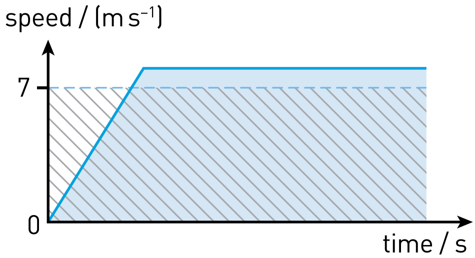
	Displacement-Time Graph	Velocity-Time Graph
		
	Points *A* and *H* are at zero displacement.	Points *A* and *H* are at rest.
AB	non-uniform increasing velocity (object moving away from 0)	non-uniform increasing acceleration
BC	uniform velocity	uniform acceleration
CD	non-uniform decreasing velocity	non-uniform decreasing acceleration
DE	at rest	uniform velocity (zero acceleration)
EF	non-uniform increasing velocity (object moving towards 0)	non-uniform increasing deceleration
FG	uniform velocity	uniform deceleration
GH	non-uniform decreasing velocity	non-uniform decreasing deceleration

007 **A student wants to show that a toy car is moving at a constant speed. Describe how he can show that the speed is constant and state the measurements to be made.**

1. Using a metre rule, make three markings *A*, *B* and *C* on the ground in a straight line one metre apart.
2. Using a stopwatch, measure the time taken for the toy car to move between markings *A* and *B*, and between markings *B* and *C*.
3. The toy car is moving at a constant speed if the two time intervals are the same.

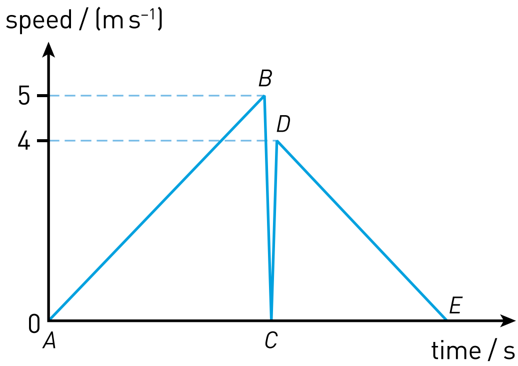
008 **A sprinter competes in a 100-metre race along a straight track. If the sprinter runs at an average speed of 7 m s^{-1}, suggest why his speed must exceed 7 m s^{-1} at some point during the race.**

The average speed is given by the total distance travelled over the total time taken. The sprinter accelerates from rest, so it is unlikely that he runs at a constant speed throughout the race. Hence, the speed of the sprinter is below 7 m s^{-1} at some times and above 7 m s^{-1} at other times.



Note: The area under the speed-time graph (▭) represents the distance travelled (100 metres), which is equal to the area bounded by the dashed line (average speed of 7 m s^{-1}) and the horizontal axis (▨) for the same time period.

009 **The diagram below shows the speed-time graph of a ball that is dropped from a height. State the change in velocity after the ball bounces off and explain your answer based on the graph.**



After the ball bounces off the ground, the change in velocity is 9 m s^{-1} upwards.

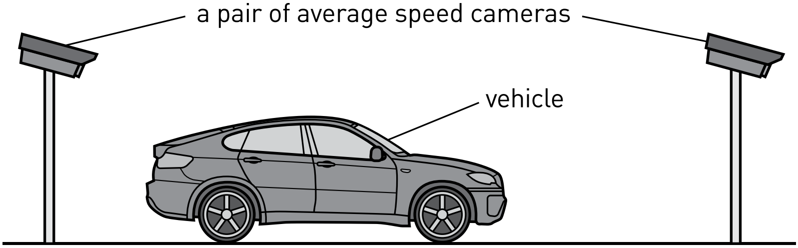
Note: The change in velocity of the ball should include both the magnitude (9 m s^{-1}) and direction (upwards).

From *A* to *B*, the ball is falling from a height. From *D* to *E*, the ball is travelling upwards after it bounces off. *BCD* refers to the time when the ball is in contact with the ground.

This means that the velocity of the ball is 5 m s^{-1} downwards before the ball bounces off the ground, and 4 m s^{-1} upwards after the ball bounces off the ground. Hence, the change in velocity is $4 - (-5) = 9$ m s^{-1} upwards.

Note: Change in velocity is equal to final velocity (*v*) – initial velocity (*u*). We use –5 to represent 5 m s^{-1} downwards since the ball travels at 4 m s^{-1} in the opposite direction (upwards) after it bounces off the ground.

010 **The diagram shows a pair of average speed cameras that can be used to determine the average speed of a vehicle travelling between two points along a road.**



(i) Suggest the measurements that can be made in order to determine the average speed of a vehicle travelling between two points along a road.

(ii) Explain how this setup can be used to identify vehicles which have been travelling above the speed limit along a road, even if the instantaneous speed of the vehicle is below the speed limit in front of the two cameras.

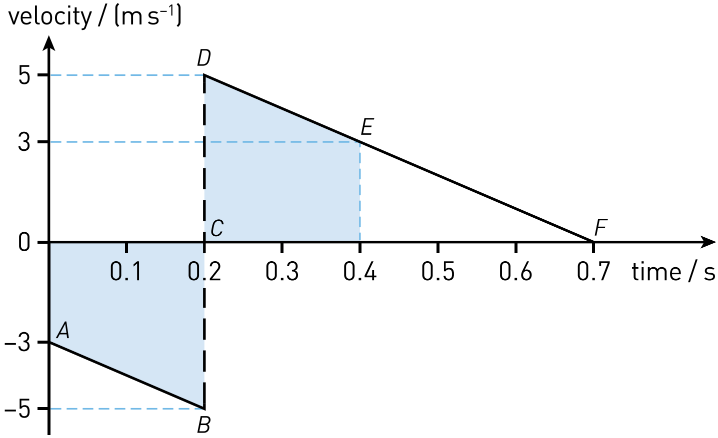
(i) Measure the distance between the two cameras along the road. Find the difference between the two recorded times to determine the time taken by the vehicle to travel between the two cameras. The average speed of the vehicle is the distance divided by the time taken.

(ii) The average speed refers to the total distance travelled divided by the total time taken. If the average speed of the vehicle calculated in **(i)** is higher than the speed limit, the vehicle must have been travelling above the speed limit at some point between the two cameras, even if the instantaneous speed of the vehicle is below the speed limit in front of the two cameras. Hence, the setup can be used to identify vehicles which have been speeding along a stretch of road.

011 **A student throws a ball vertically downwards. The ball leaves her hand at a speed of 3 m s^{-1} and hits the ground 0.2 seconds later, changing its direction of motion.**

Assuming that no energy is lost when the ball hits the ground or due to air resistance, draw a velocity-time graph for the ball's journey, from the point where the ball leaves the student's hand to the point where the ball reaches its maximum height. Explain the shape of your graph.

In this question, we take upwards as the positive direction.

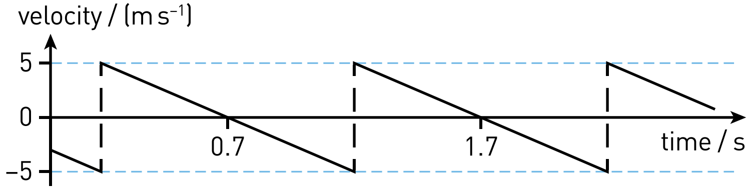


The acceleration due to gravity is –10 m s^{-2}. In 0.2 seconds, the velocity of the ball changes by 2 m s^{-1}, from –3 m s^{-1} at point *A* to –5 m s^{-1} at point *B*.

At point *A*, the ball is travelling downwards with an initial velocity of –3 m s^{-1}. At point *B*, the ball hits the ground at a velocity of –5 m s^{-1}. At point *D*, the ball bounces off and travels upwards at 5 m s^{-1} as the kinetic energy remains constant (principle of conservation of energy). At point *E*, the ball passes its initial position and continues travelling upwards, decelerating at 10 m s^{-2}. At 0.7 seconds, the ball is momentarily at rest when it reaches its highest point *F*.

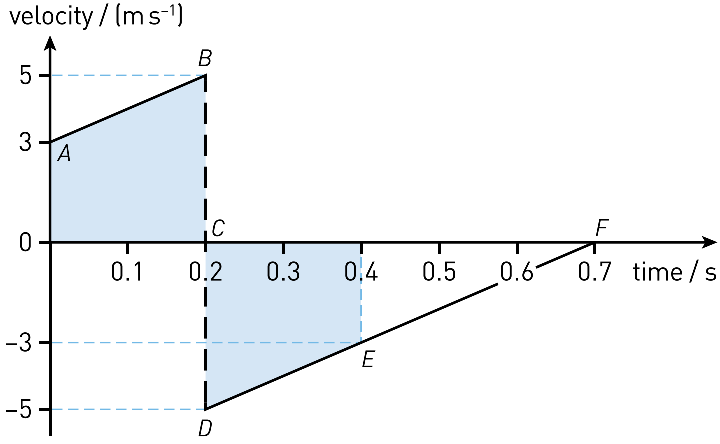
Notes:

1. Beyond the maximum height (after 0.7 seconds), the straight line *EF* will be extended until the velocity of the ball reaches –5 m s^{-1}. This is where the ball bounces off the ground and the shape of the graph repeats.



2. The area between *ABC* and the horizontal axis represents the distance travelled downwards, from the point where the ball leaves the student's hand to the point where the ball hits the ground. This area is equal to the area between *CDE* and the horizontal axis.

3. If downwards was taken as the positive direction, the graph would be reflected across the horizontal axis as shown below.



2.2 Dynamics

012 **What do you understand by the resultant force on a body?**

The resultant force on a body is due to a non-zero vector sum of two or more forces acting on the body. It results in an acceleration which can be determined according to Newton's Second Law.

013 **Explain why an object moving in a circle at a uniform speed experiences a resultant force.**

When an object is moving in a circle at a uniform speed, the magnitude of its velocity does not change, but the direction of its velocity changes constantly. Since velocity is changing, there is an acceleration. By Newton's Second Law, there is a resultant force on the object.

014 **Explain, in terms of the forces acting on a driver, how the seat belt acts as a safety device to prevent the driver from moving forwards abruptly when the car brakes suddenly.**

OR **Using ideas about acceleration, explain how an airbag reduces the force on a driver during a car crash.**

A seat belt or an airbag increases the length of time it takes for the driver to come to rest. Since the change in velocity remains the same, the magnitude of deceleration decreases, hence the force on the driver decreases.

015 **A skydiver weighing 700 N jumps off an aeroplane. Some time after jumping off, he is falling towards the Earth at a constant speed. He then opens his parachute.**

Using Newton's laws of motion, state and explain how the motion of the skydiver changes after he opens his parachute.

The air resistance acting on the skydiver is greater than his weight, hence there is a resultant force acting upwards.

By Newton's Second Law, $F_{net} = ma$, so there is an upward acceleration. Since the velocity is downwards, the skydiver decelerates. Air resistance, which is proportional to velocity, decreases until it is equal to the skydiver's weight (700 N). At this point, the skydiver falls at a lower terminal velocity.

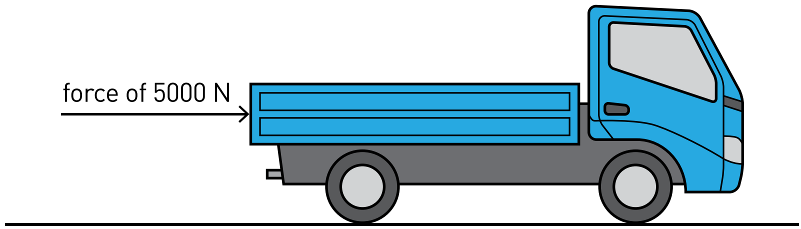
016 **A person walking along a pavement at a constant speed exerts a horizontal force of 50 N on the pavement for every step he takes. State and explain the magnitude and direction of friction between the person and the ground.**

For every step, the friction between the person and the ground is 50 N, acting horizontally in the direction of the person's motion (i.e. forwards).

When the person is walking along the pavement, he exerts a horizontal frictional force of 50 N on the pavement in the direction opposite to his motion. By Newton's Third Law, the pavement exerts an equal but opposite horizontal frictional force of 50 N on the person, in the direction of the person's motion.

017 **When a force of 5000 N is exerted on the back of a truck, the truck remains stationary.**

State the magnitude of the frictional force acting on the same truck when a force of 1000 N is exerted on the back of the truck. Explain your answer.



The truck remains stationary when a force of 5000 N is exerted on its back. Since the resultant force is zero, the frictional force acting on the truck is 5000 N. The amount of frictional force is not constant and can vary from 0 N to a certain maximum value F_{max} which is at least 5000 N. Hence, when a force of 1000 N is exerted onto the back of the truck, the friction acting on the truck is also 1000 N.

Note: When the force exerted on the back of the truck is greater than F_{max}, the truck starts moving forwards since the amount of frictional force is smaller than the amount of force exerted on the back of the truck. In this case, there is a non-zero resultant force acting on the truck.

018 **Give an example where work done by friction is positive.**

When a person is walking forwards, he pushes his feet backwards on the ground. The frictional force acting on the ground is backwards. By Newton's Third Law, the friction acting on his shoes is forwards. Since the frictional force acting on the person's shoe is in the same direction as his displacement (forwards), work done by friction is positive.

019 **Explain the similarities and differences between frictional forces and viscous forces (including air resistance).**

Similarity: Both forces oppose relative motion

Differences:

Frictional Forces	Viscous Forces
Act along the surfaces in contact between two solids	Act along the surfaces in contact between a fluid (liquid or gas) and a solid
Remain constant and are not affected by the relative motion of two surfaces	Increase when the relative velocity of the fluid and the moving object increases
Exist even when the object is at rest	Do not exist when there is no relative motion
Energy is lost only if there are movements; no energy is lost when stationary	Energy is always lost because of movements

2.3 Mass, Weight and Density

020 **Earth and Mars have different values of gravity. Explain if there are any differences for a force to give an object the same horizontal acceleration on Earth and on Mars.**

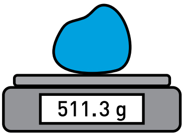
Although the values of gravity on both planets are different, the mass of the object is the same. By Newton's Second Law, the force needed to give the object the same horizontal acceleration on Earth and on Mars is the same.

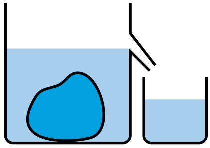
021 **Describe the concept of weight as the effect of a gravitational field on a mass.**

An object placed in a gravitational field experiences a gravitational force. The gravitational force experienced by the object is the weight of the object.

weight = mass × acceleration due to gravity ($W = mg$)

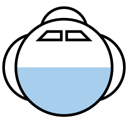
022 **Briefly describe the process of finding the density of an object with an irregular shape.**



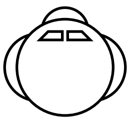


1. Find the mass *m* of the object using a mass balance.
2. Find the volume *v* of the object using a displacement can.
3. The density (ρ) is calculated using $\rho = m \div v$.

023 **A submarine has ballast tanks that can be filled with air or seawater. Using the concepts of density, explain how a submarine made of iron can float or sink in the sea.**



submarine half-filled with seawater



submarine completely empty

When the ballast tanks are filled with air, the average density of the submarine is less than that of seawater, so the submarine floats. When the ballast tanks are filled with seawater, the mass of the submarine increases without an increase in overall volume. The submarine sinks when its average density is higher than the density of seawater.

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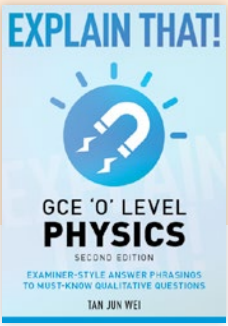
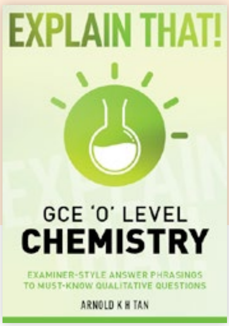
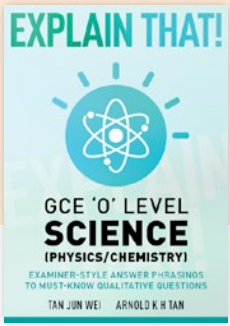
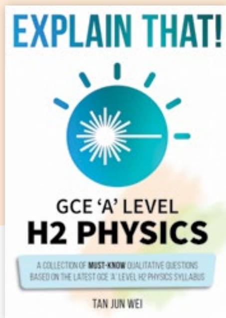






GCE 'A' LEVEL



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