ESSENTIAL SKILLS FOR

PHYSICAL SCIENCE

PAPER 1: PHYSICS

MATRIC WORKSHOP

NAME: ---

SCHOOL: --

Philanthropy Initiative with Employees of Allan Gray

SOUTH AFRICAN INSTITUTE OF PHYSICS

UNIVERSITY OF ZULULAND

UNIZULU SCIENCE CENTRE

Physics is a fundamental science that underpins the development of all other science, engineering and technology disciplines. Studying physics imparts transferable skills that are valuable in areas such as medicine, engineering, ICT, Big Data, astronomy, financial analysis and investment management, among others. The South African Institute of Physics (SAIP) aims "To improve physics education and research, develop and nurture an inclusive next generation of physicists for South Africa". If we increase the number of physicists in our country, then we will improve the social and economic status of our country as well as address the Global Sustainable Development Goals (SDGs) such as energy security, health for all, environmental protection and poverty alleviation. Do you know that **"The Physics of Today is the Technology of Tomorrow":** without physics there would be no electricity, internet, computer games, supermarket laser scanners, space rockets, light bulbs, digital cameras, cell phones, aeroplanes, solar panels, fibre optics, DVD players, computers, X-ray and CAT – Scan machines in hospitals.

They say that everyone is a genius because genius is 1% talent and 99% hard work. Physics is for everyone, just put in the effort you will see amazing results, and it will open a world of opportunities for your career. This is why the SAIP decided to support these matric workshops, with generous support from Allan Gray. We wish you all the best in your exam preparations: always review your understanding of physics topics through practising to solve problems. By so doing you are practising physics' core skill, "the art of solving problems" using various tools such as mathematics, graphs and equations.

And remember: no matter how dark the night is, the sun will always shine again:- the COVID19 pandemic will pass!

Brian Masara. CEO: South African Institute of Physics

Follow us on SAIP Facebook, visit our website www.saip.org.za, email: info@saip.org.za for more study materials, support and opportunities related to studying physics and a career as a physicist!

Established in 1960, the University of Zululand recently celebrated its 60th birthday! For more than half that time, Unizulu Science Centre has helped thousands of teachers and pupils in schools surrounding the University. The University has taken Community Engagement seriously, by underwriting the operations of South Africa's premier Science Centre, which has grown from strength to strength in that time. Starting out in a 200 square metre room in 1986, with one staff member seeing 3 000 pupils per year, it now boasts 2 500 square metres, 15 staff members and sees 30 000 pupils through the centre (when COVID allows!) and many more in outreach activities.

Our main outreach activity over this time has been Matric Workshops. Started in 1994, they have run continuously since then and now technology (thanks to Physics!) is providing us with a way to keep them running and to reach pupils across the country.

To all matric pupils and teachers, as you approach your exams:- don't be scared – be prepared! This workshop and booklet offer you a unique tool to prepare for Physical Science Paper 1:- use them well!

Dr Derek Fish. Director: Unizulu Science Centre

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Pg.	Length	CONTENTS	Exam Question	Video Number
		INTRODUCTION		
1	3	Cover and Contents Pages		1.1
4	2	Paper 1 (Physics): Topics, Content and Skills	ALL	
		GRAPHS		
6	2	Graphs: Introduction and Straight-line graphs	VARIOUS	1.2
8	6	**Motion graphs:** summary and experiment	3	2
14	3	Motion graphs: exam examples (Projectile Motion)	3	
17	3	**The Photo-electric effect**: simulation, graphs & exams.	10	3
20	6	**Ohms Law**: experiment, graphs and exam examples	8	4.1
26	5	**Internal resistance**: experiment, graphs and exams	8	4.2
		FREE BODY DIAGRAMS		
31	6	Free Body Diagrams, Normal Force and exam examples.	2, 5, 7	5
		EQUATIONS		
37	1	Solving equations – introduction & PROGRESS method	ALL	6.1
38	3	Data Sheets, variables and constants	ALL	
41	1	Using the PROGRESS method - example	ALL	
42	6	Equations: **Newton's 2nd Law**	2	6.2
48	1	Equations: **Projectile Motion**	3	6.3
49	3	Equations: **Momentum**	4	6.4
52	3	Equations: **Work, Energy and Power**	5	6.5
55	3	Equations: **Doppler Effect**	6	6.6
58	4	Equations: **Electrostatics**	7	6.7
62	4	Equations: **Electrodynamics and Alternating Current**	9	6.9
		MULTIPLE CHOICE and RATIO QUESTIONS		
66	2	"Ratio" questions: introduction and exercise	1	7
68	3	**Multiple Choice** "ratio" questions from previous exams	1	
71	2	**UNIZULU SCIENCE AND ENGINEERING**		

PAPER 1 (PHYSICS): TOPICS AND CONTENT

Topic	Grade	Content (items involving GRAPHS are underlined)
Mechanics	Grade 10	**Introduction to vectors & scalars; Motion in one dimension** (reference frame, position, displacement and distance , average speed, average velocity, acceleration, instantaneous velocity, instantaneous speed, description of motion in words, diagrams, graphs and equations.) **Energy** (gravitational potential energy, kinetic energy, mechanical energy, conservation of mechanical energy (in the absence of dissipative forces)) **30 hours** **Prescribed experiment: Velocity-time graphs and acceleration** **Recommended experiment: Position-time graphs**
Mechanics	Grade 11	**Vectors in two dimensions** (resultant of perpendicular vectors, resolution of a vector into its parallel and perpendicular components), **Newton's Laws and Application of Newton's Laws** (Newton's first, second and third laws and Newton's law of universal gravitation, different kinds of forces: weight, normal force, frictional force, applied (push, pull), tension (strings or cables), force diagrams, free body diagrams & application of Newton's laws (equilibrium and nonequilibrium)) **27 h** **Prescribed experiment: Newton's Second Law: Acceleration-Force (and Accel.-Mass)**
Mechanics	Grade 12	**Momentum and Impulse** (momentum, Newton's second law expressed in terms of momentum, conservation of momentum and elastic and inelastic collisions, Impulse), **Vertical projectile motion in one dimension (1D)** (vertical projectile motion represented in words, diagrams, equations and graphs), **Work, Energy & Power** (work , work-energy theorem, conservation of energy with non-conservative forces present, power) **28 hours** **Prescribed experiment: Conservation of Linear Momentum (X)** **Recommended experiment: Position-time and velocity-time graphs for freefall**
Waves, Sound & Light	Grade 10	**Transverse pulses on a string or spring** (pulse, amplitude superposition of pulses), **Transverse waves** (wavelength, frequency, amplitude, period, wave speed**, Longitudinal waves** (on a spring, wavelength, frequency, amplitude, period, wave speed, sound waves), **Sound (**pitch, loudness, quality (tone), ultrasound), **Electromagnetic radiation** (dual (particle/ wave) nature of electromagnetic (EM) radiation, nature of EM radiation, EM spectrum, nature of EM as particle - energy of a photon related to frequency and wavelength) **16 hours** **Experiment: Demonstration of Sound (pitch, loudness, quality (tone), ultrasound**
Waves, Sound & Light	Grade 11	**Geometrical Optics** (Refraction, Snell's Law, Critical angles and total internal reflection), **2D & 3D Wave fronts** (Diffraction) **13 hours**
Waves, Sound & Light	Grade 12	**Doppler Effect (either moving source or moving observer)** (with sound and ultrasound, with light - red shifts in the universe.) **6 hours**
Electricity & Magnetism	Grade 10	**Magnetism** (magnetic field of permanent magnets, poles of permanent magnets, attraction and repulsion, magnetic field lines, earth's magnetic field, compass), **Electrostatics** (two kinds of charge, force exerted by charges on each other (descriptive), attraction between charged and uncharged objects (polarisation), charge conservation, charge quantization),**Electric circuits** (emf, potential difference (pd), current, measurement of voltage (pd) and current, resistance, resistors in parallel)**14 h** **Prescribed experiment: PD and current in series and parallel circuits (X)**
Electricity & Magnetism	Grade 11	**Electrostatics** (Coulomb's Law, Electric field), **Electromagnetism** (Magnetic field associated with current-carrying wires, Faraday's Law), **Electric circuits** (Energy, Power) **20 hours** **Recommended experiment: Ohm's law: PD and current for resistor and bulb**
Electricity & Magnetism	Grade 12	**Electric circuits** (internal resistance and series-parallel networks), **Electrodynamics** (electrical machines (generators,motors), alternating current) **12h** **Prescribed experiment: Internal Resistance of a battery. Current and PD** **Experiment: Compare PD graphs for alternating and direct current**
Matter & Materials	Grade 12 only	**Optical phenomena and properties of materials** (photo-electric effect, emission and absorption spectra) (**6 hours for physics)** **Experiment (simulation):Kinetic energy-frequency graph for Photo-Electric Effect**

UNIZULU SCIENCE CENTRE

SKILLS AND COGNITIVE LEVELS: PHYSICAL SCIENCE (FROM CAPS CURRICULUM GUIDE)

Selected Examinable Topics from Grades 10 & 11	
Physics from grade 11	**Chemistry from grades 10 and 11**
1. Newton's Laws (Newton 1, 2, 3 and Newton's Law of Universal Gravitation) and Application of Newton's Laws. 2. Electrostatics (Coulomb's Law and Electric field) 3. Electric circuits (Ohm's Law, Power and Energy)	1. Representing chemical change (grade 10) 2. Intermolecular forces (grade 11) 3. Stoichiometry (grade 11) 4. Energy and Change (grade 11)

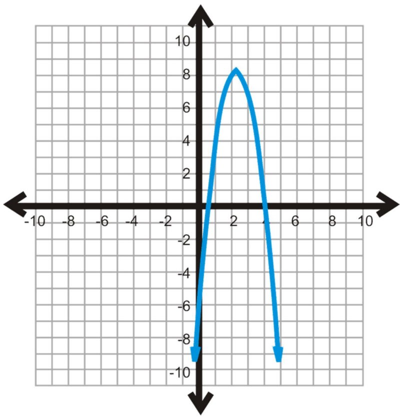
Grade 12 Exam								
					Weighting Of Questions Across Cognitive Levels			
					Level 1	Level 2	Level 3	Level 4
Paper	**Content**	**Marks**	**Total Marks/Paper**	**Duration (hours)**	Recall	Understand	Analyse, Apply	Create, Evaluate
Paper 1: PHYSICS FOCUS	Mechanics	63	150	3	15%	35%	40%	10%
	Waves, Sound & Light	17						
	Electricity & Magnetism	55						
	Matter & Materials	15						
Paper 2: CHEMISTRY FOCUS	Chemical Change	84	150	3	15%	40%	35%	10%
	Chemical Systems	18						
	Matter & Materials	48						

SKILLS FOR PHYSICAL SCIENCE (FROM CAPS CURRICULUM GUIDE)

NO.	SKILL	EXAMPLE / DETAIL
1	Models in Science	E.g. Atomic Model, Periodic Table, Bonding Models
2	Scientific Notation	E.g. 0.0065 m = 6.5×10^{-3} m
3	Conversion of Units	E.g. 7 mm = 0.007 m; metric prefixes (milli, kilo, mega etc.)
4	Changing the subject of a formula	E.g. V = I.R so I = V / R
5	Basic Trigonometry Skills	Define sin, cos and tan of an angle and use in calculations
6	Fractions and Ratios	E.g. Water molecule is ⅓ O and ⅔ H atoms. Ratio of O : H is 1 : 2
7	What is rate - applications	E.g. (Physics) power = rate of doing work; (Chemistry) Reaction Rate
8	Direct and Inverse Proportions	E.g. Acceleration is directly prop. to force, inversely prop. to mass.
9	Constants in Equations (use & meaning)	E.g. Constants like G for gravitation, K for Coulomb's Law etc.
10	Practical Investigation Skills (including safety skills)	Observation, precautions, writing hypothesis & conclusions a) Data collection & handling, tables (see detail below) b) General types of graphs, analysis, c) Identifying variables,
	a) Data collection & handling, tables	Collect data and export into the appropriate form of data presentation (e.g. equation, table, graph, or diagram).
	b) General types of graphs, analysis	Analyse information in a table, graph or diagram (e.g. compute the mean of a series of values or determine the slope of a line).
	c) Identifying variables	Independent, dependent & control variable

GRAPHS

1) What is a graph?



Graphs show: a) **RATE** at which things happen (e.g. position vs time graph shows RATE of change of position:- or velocity, as $v = \Delta x / \Delta t$)

b) **RELATIONSHIP** between variables (eg pressure vs volume graph shows RELATIONSHIP between P and V: that pressure is inversely proportional to volume)

c) **REPRESENTATION** of the data – visually, so it is easy to see relationships and trends. (Common in Life Science)

A GRAPH is **NOT** a PHOTOGRAPH. It is **NOT** a picture of the landscape, hills and valleys etc!

2) What graph skills are expected of you in exams?

1. To be able to analyse and explain trends in a given *sketch*-graph.
2. To be able to read values, gradient & intercept from a given *accurate* graph.
3. To be able to draw a *sketch* graph of a given situation.
4. To be able to plot an *accurate* graph on graph-paper provided.

3) Types of graphs:

- Straight-line $y = mx + c$ $v_f = at + v_i$ (eg velocity-time)
- Parabola $y = ax^2 + bx + c$ $\Delta x = (½ a) t^2 + v_i t$ (eg position-time with acceleration)
- Hyperbola $y = k / x$ $P = k / V$ (eg pressure-volume)
- Inverse square $y = k/ x^2$ $F = k / r^2$ (eg force-distance with gravitation)
- Sine $y = \sin x$ $V = V_0 \sin \acute{\omega} t$ (eg voltage-time for alt. current)
- Exponential $y = e^x$ $I = I_0 e^{-t/RC}$ (eg current-time for a charging capacitor)
- Circle, ellipse, cubic Not commonly used in science experiments

4) How to go about drawing a graph: (T.A.L.S.I.P.P !)

a) T – choose an appropriate **TITLE**

b) A – select variables to go on the **AXES**. Dependant (Y) and independent (X)

c) L – **LABELS** for axes, with Units

d) S – Choose a **SCALE** which allows the graph to fill as much of the page as possible.

e) I – **INTERVALS**: Use the scale to determine how much each small block equals

f) P – **PLOT** your data from the table onto the graph carefully checking the order (X & Y)

g) P – **PLOT** the best fit line (or curve) for the data points. Calculate **intercept** and **gradient**.

Worked examples involving all these steps will be done with experiments.

STRAIGHT LINE GRAPHS: GRADIENT AND INTERCEPT

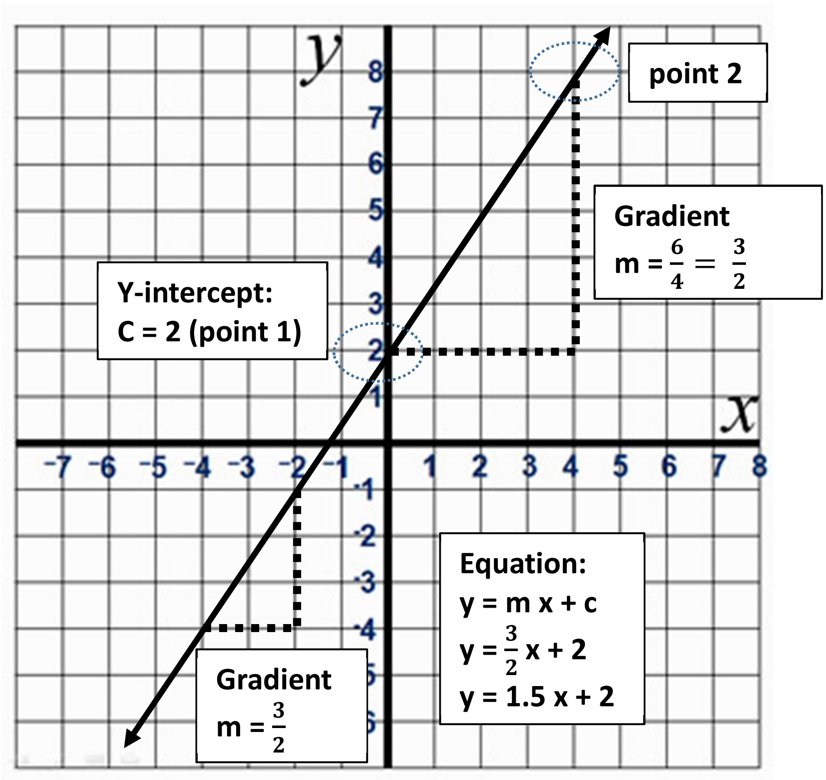
Graph-ing Lines
PhET INTERACTIVE SIMULATIONS

From Maths: the equation for a straight line graph is in the form:

y = mx + c

This contains two variables, and two constants as follows:

VARIABLES		CONSTANTS	
y	The DEPENDENT variable, on the vertical axis This quantity DEPENDS on the other one. It is a result of the other one and we cannot set it.	**m**	The gradient or slope of the graph. The vertical change/ horizontal change Rise up / Run across
x	The INDEPENDENT variable on the horizontal axis We can adjust this quantity as we like.	**c**	The y-intercept. Where the graph cuts the y-axis (when x = 0)



We can also calculate the gradient from two points on the graph:

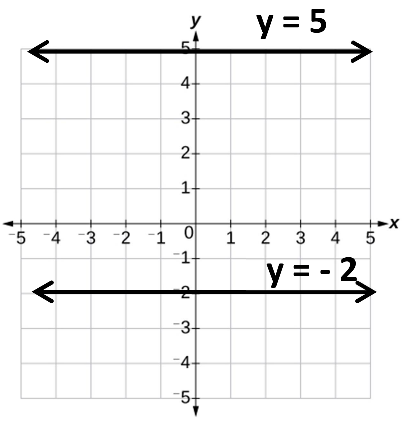
$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{rise\ up}{run\ across}$$

Using the points 1 & 2 on the graph:
- Point 1 is: (0; 2) (the y-intercept)
- Point 2 is: (4; 8)

So: $m = \frac{(8-2)}{(4-0)} = \frac{6}{4} = \frac{3}{2}$

Graphs in Physics are usually only in the first quadrant (as quantities are usually only positive)

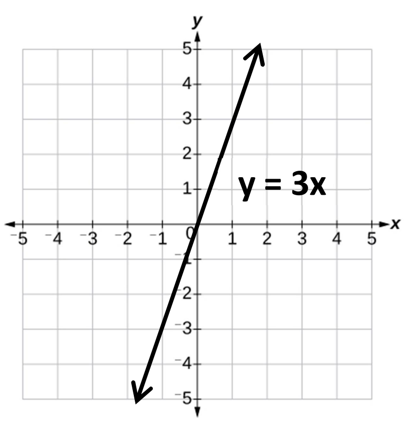
Graphs with no X-intercept (m = 0)



Horizontal Straight Lines do not have an X-intercept
y = Number
These lines have no "x" term in their equation, and every coordinate has the exact same y value.
m = Zero (Flat)
Two of these types of Lines are shown on the graph on the left.

In this case y is constant and not affected by x in any way, so the quantities are not related. Gradient m = 0.
E.g. v is constant and not related to t when a = 0

Graphs with Y-intercept, (c) = 0



y = 3 x = 3 x + 0
The value of c gives us the y-intercept: c = 0
m is the gradient slope which is the:
Rise UP / Run ACROSS
m = 3/1 = 3
From the y-intercept (0) go UP 3 blocks and ACROSS 1. Connect the two dots with the graph line.

In this case y directly proportional to x and the y-intercept: c = 0
E.g. Velocity (v_f) is directly proportional to t when v_i = 0

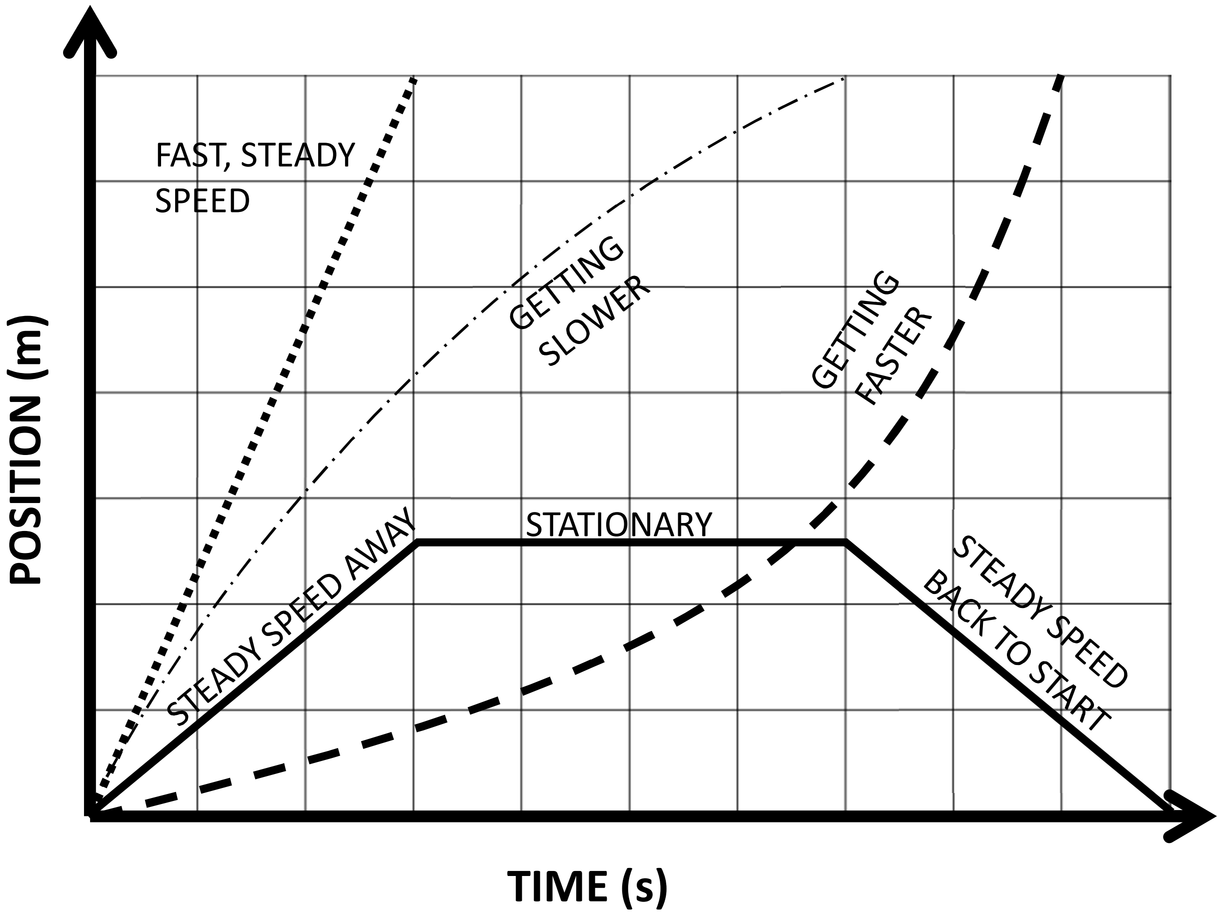
MOTION GRAPHS 1: POSITION-TIME

Graph Quad-ratics

POSITION-TIME GRAPHS:

- Flat line = stopped or stationary
- Sloping up = constant speed *away from* the start
  - The steeper (up) the gradient, the faster the speed
- Sloping down = constant speed back *towards* the start
  - The steeper (down) the gradient, the faster the speed
- Curved line = changing speed = accelerating
  - Curve up = speeding up (accelerating)
  - Curve down = slowing down (decelerating)
- Two lines with equal gradients show equal speeds
- The object is *at the starting point* when the graph is at zero position (on the x-axis)

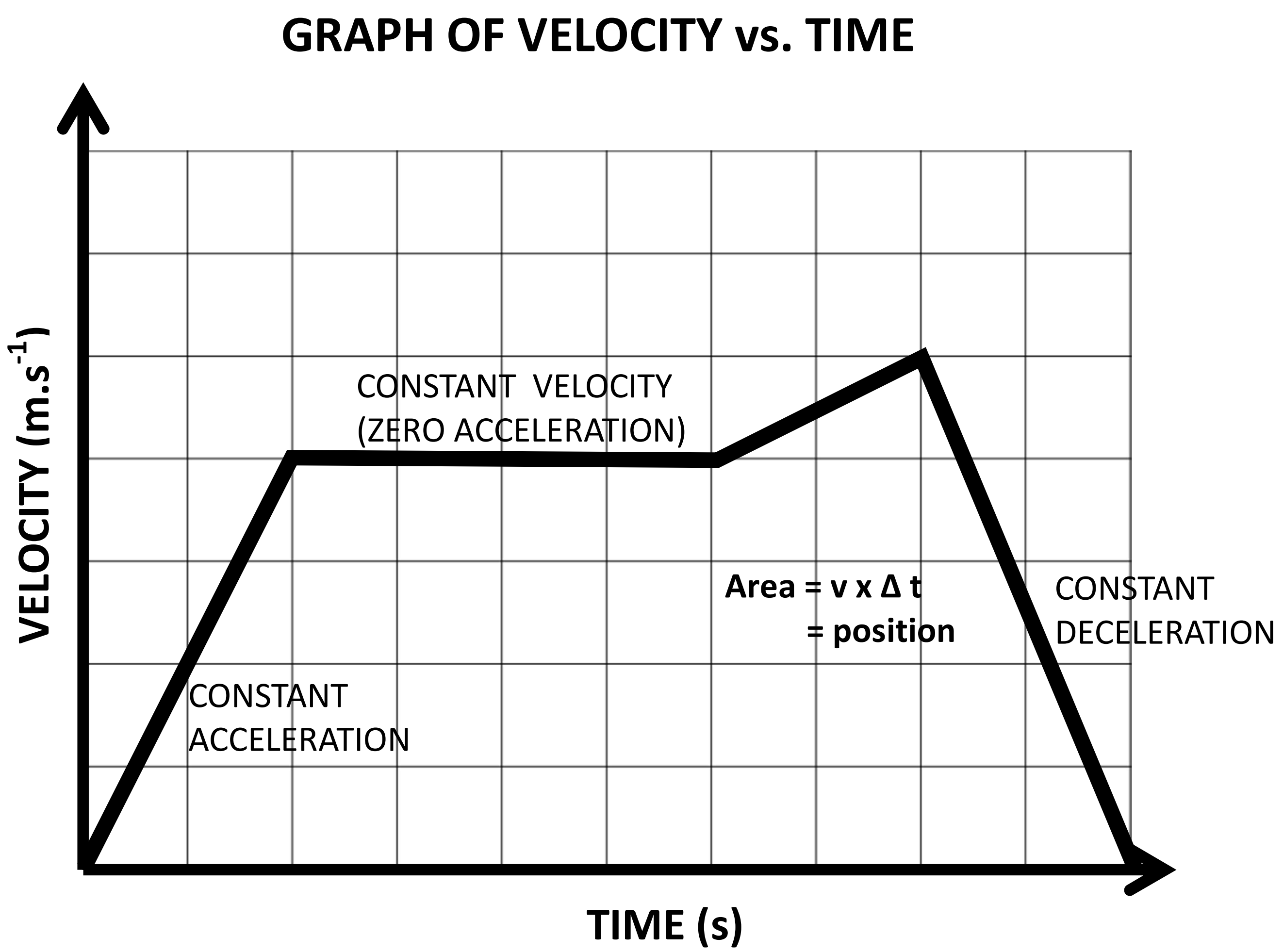
GRAPH OF POSITION vs. TIME

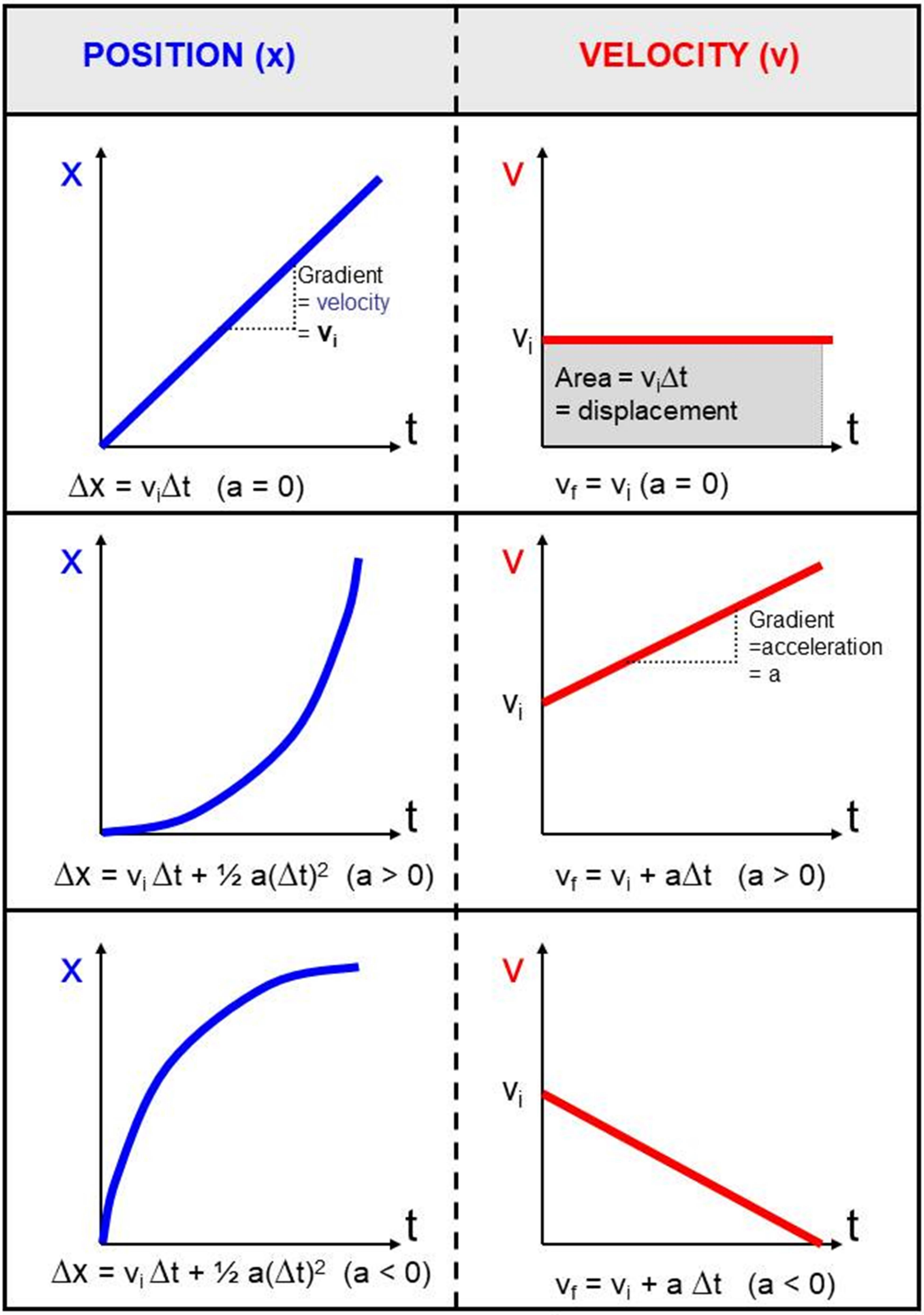


MOTION GRAPHS 2: VELOCITY-TIME

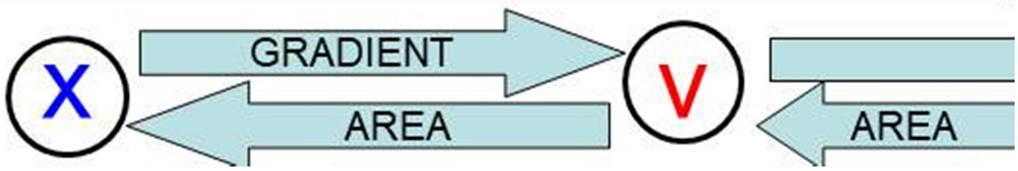
VELOCITY-TIME GRAPHS:

- Flat line = constant velocity (zero acceleration) ($V_2 - V_1 = 0$)
- Sloping up = constant acceleration (positive), increasing speed
  - The steeper (up) the gradient, the greater the acceleration
- Sloping down = constant deceleration (negative), decreasing speed
  - The steeper (down) the gradient, the greater the deceleration
- Curved line = changing acceleration [NOT COVERED IN SCHOOL SCIENCE!]
- Two lines with equal gradients show equal accelerations
- The object is *stationary* when the graph is at zero velocity (on the x-axis)

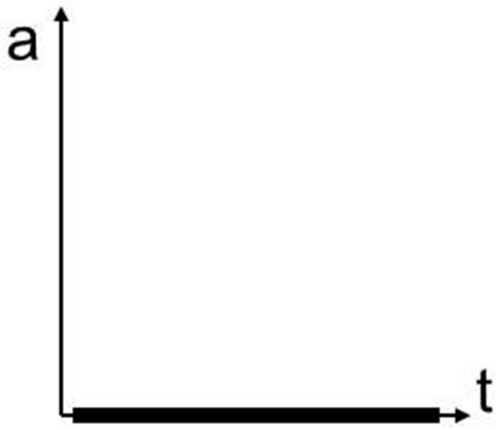
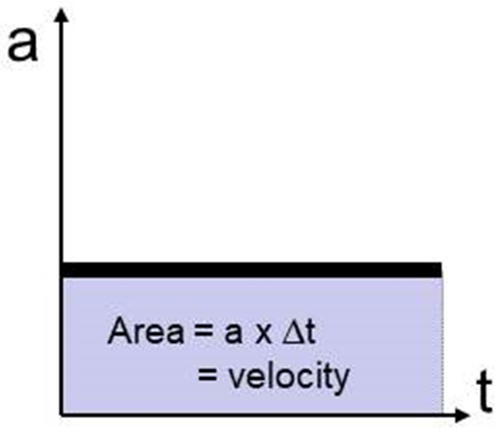
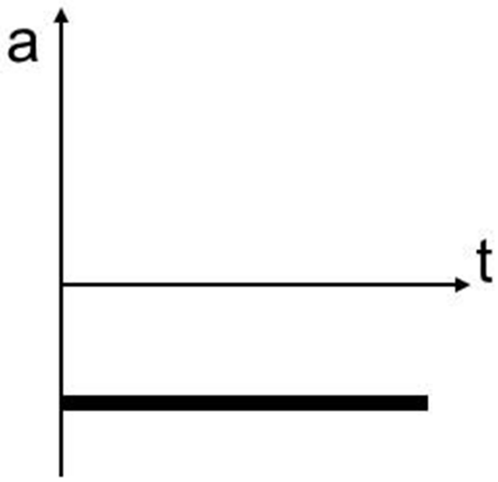


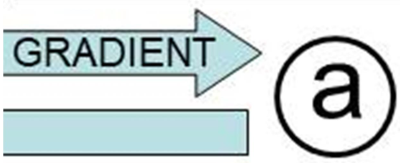


POSITION (x)
VELOCITY (v)
x
t
Gradient
= velocity
= vi
Δx = viΔt (a = 0)
v
vi
Area = viΔt
= displacement
t
vf = vi (a = 0)
x
t
Δx = vi Δt + ½ a(Δt)2 (a > 0)
v
Gradient
=acceleration
= a
vi
t
vf = vi + aΔt (a > 0)
x
t
Δx = vi Δt + ½ a(Δt)2 (a < 0)
v
vi
t
vf = vi + a Δt (a < 0)



X
GRADIENT
AREA
V
AREA

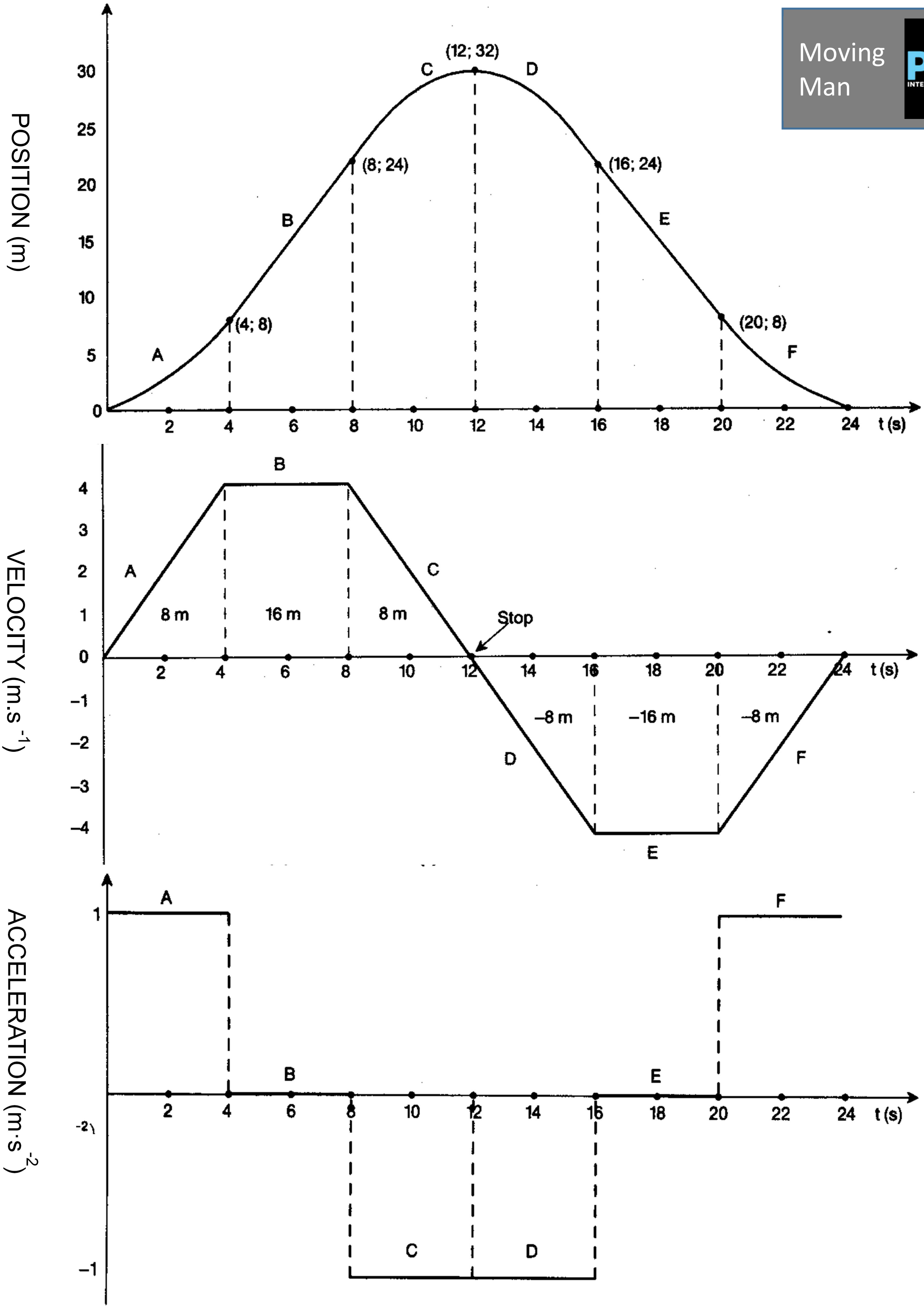
ACCELERATION (a)	NOTES
	***ZERO* ACCELERATION**  **$a = 0$** **→ $v_i > 0$** **A car travels forwards at <u>constant velocity</u> Newton's First Law**
	***POSITIVE* ACCELERATION**  **→ $a > 0$** **→ $v_i > 0$** **A car <u>speeds up</u> while travelling forwards Newton's Second Law**
	***NEGATIVE* ACCELERATION**  **← $a < 0$** **→ $v_i > 0$** **A car <u>slows down (brakes)</u> while travelling forwards Newton's Second Law**



GRAPHS OF MOTION

Moving Man

PhET INTERACTIVE SIMULATIONS

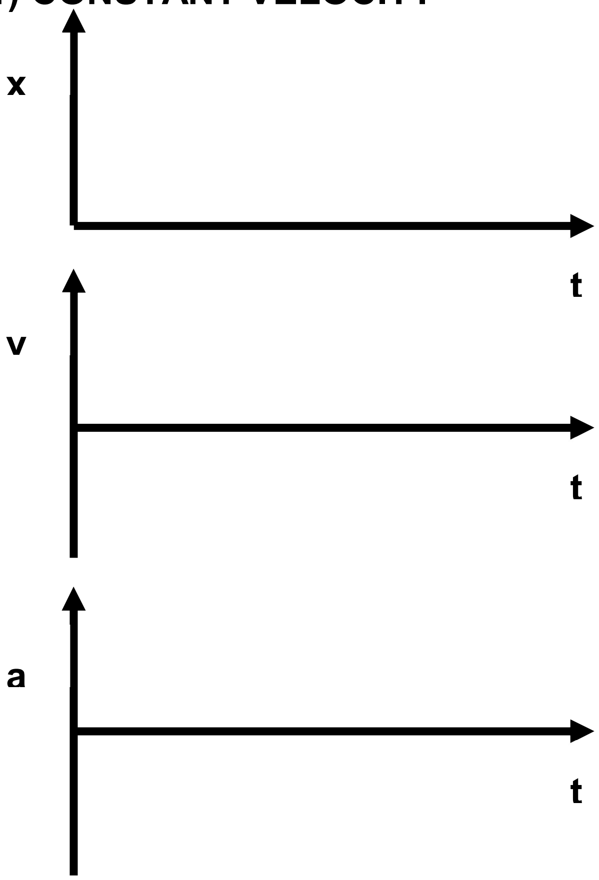


VERBAL DESCRIPTION OF THE MOTION:

A) A car starts from rest and speeds up <u>away</u> from home for 4 s.
B) The car travels at a constant speed of 4m·s^{-1} for 4 s <u>away</u> from home.
C) The car (still traveling <u>away</u>) slows down at a constant rate for 4 s until it stops
D) The car immediately starts from rest and speeds up <u>towards</u> home for 4 s.
E) The car travels at a constant speed of 4m·s^{-1} for 4 s <u>towards</u> home.
F) The car (still traveling <u>towards</u>) slows down at a constant rate for 4 s until it stops at home.

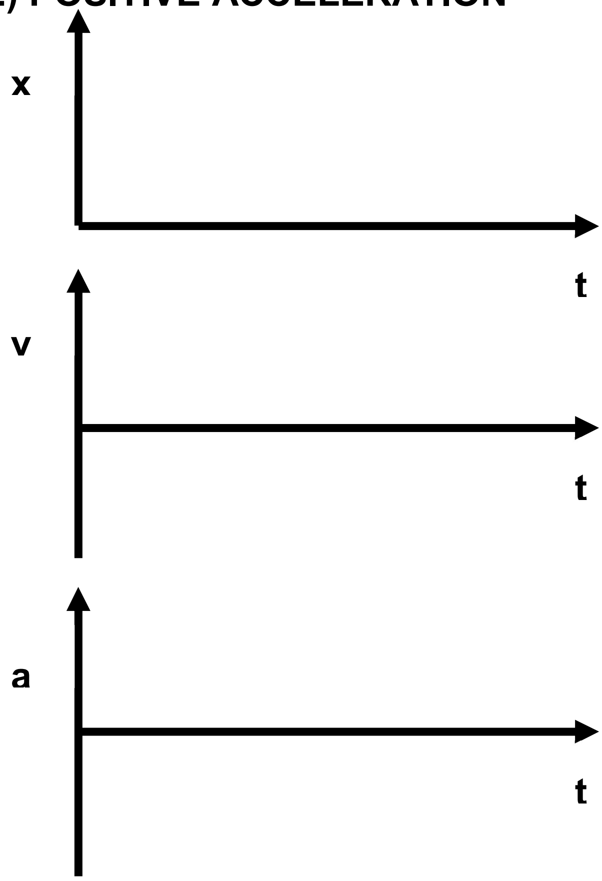
EXERCISE: TRY TO DRAW SKETCH GRAPHS FOR THE FOLLOWING:

1) CONSTANT VELOCITY



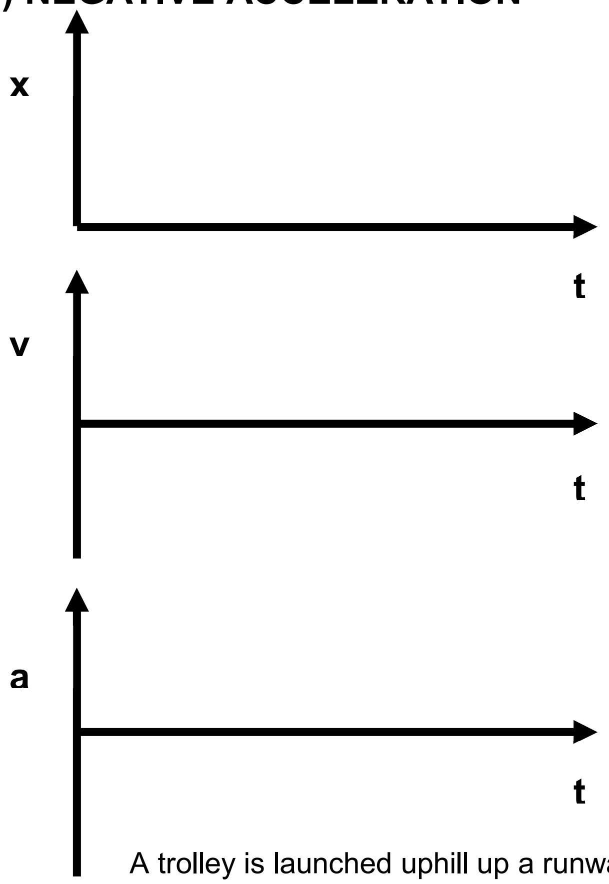
A trolley rolls along a flat, frictionless runway

2) POSITIVE ACCELERATION



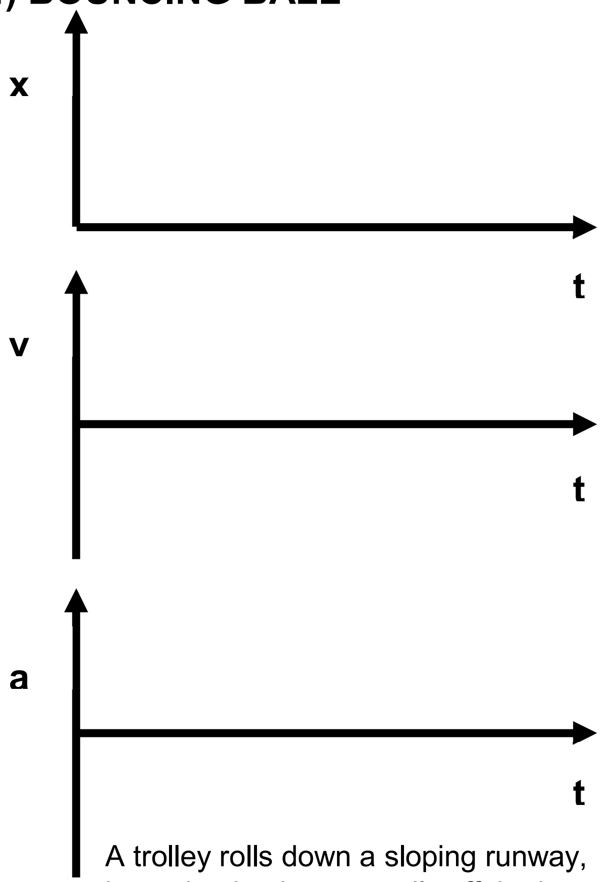
A trolley rolls down a sloping runway

3) NEGATIVE ACCELERATION



A trolley is launched uphill up a runway, rolling back from the top

4) BOUNCING BALL



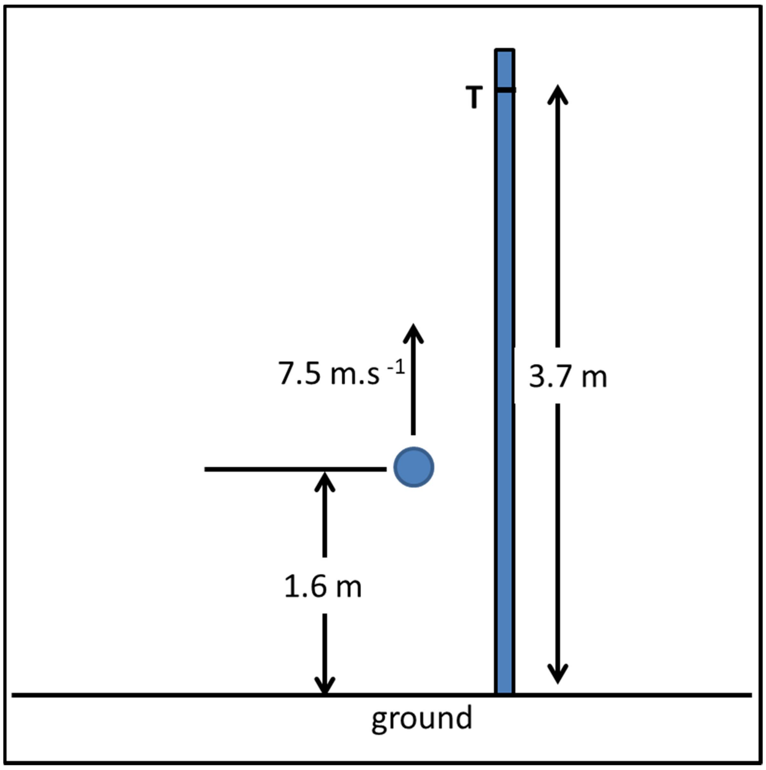
A trolley rolls down a sloping runway, bouncing back repeatedly off the bottom

MOTION GRAPHS: EXAM EXAMPLE (NOV 2018)

QUESTION 3

In a competition, participants must attempt to throw a ball vertically upwards past point T, marked on a tall vertical pole. Point T is 3.7 m above the ground. Point T may, or may not, be the highest point during the motion of the ball.

One participant throws the ball vertically upwards at a velocity of 7.5 m·s^{-1} from a point that is 1.6 m above the ground, as shown in the diagram below. Ignore the effects of air resistance.



3.1 In which direction is the net force acting on the ball while it moves towards point T? Choose from: UPWARDS or DOWNWARDS. Give a reason for the answer. (2)

3.2 Calculate the time taken by the ball to reach its highest point. (3)

3.3 Determine, by means of a calculation, whether the ball will pass point T or not. (6)

3.4 Draw a velocity-time graph for the motion of the ball from the instant it is thrown upwards until it reaches its highest point

Indicate the following on your graph:

- The initial and final velocity
- Time taken to reach the highest point

(2)

[13]

MOTION GRAPHS: EXAM EXAMPLE (NOV 2019)

QUESTION 3

Stone **A** is thrown vertically upwards with a speed of 10 m·s^{-1} from the edge of the roof of a 40 m high building, as shown in the diagram below.
Ignore the effects of air friction.

Take the ground as reference.

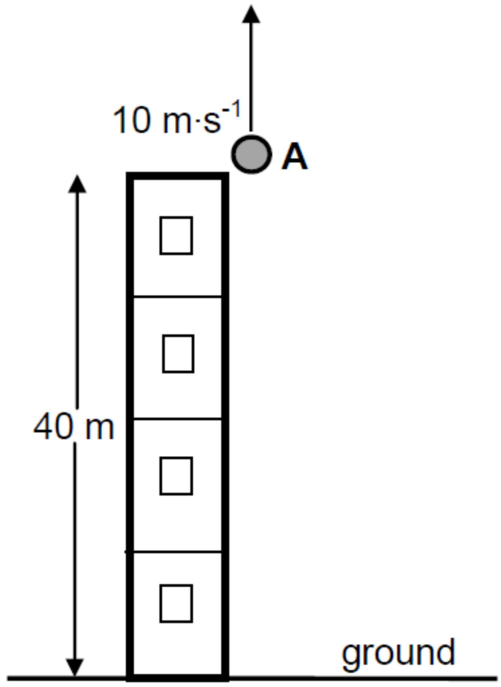
3.1 Define the term free fall. (2)

3.2 Calculate the maximum HEIGHT ABOVE THE GROUND reached by stone A. (4)

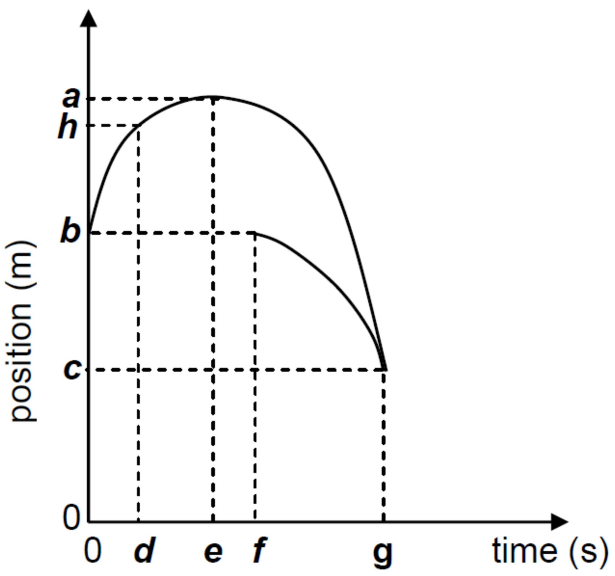
3.3 Write down the magnitude and direction of the acceleration of stone A at this maximum height. (2)

Stone B is dropped from rest from the edge of the roof, x seconds after stone A was thrown upwards.

3.4 Stone A passes stone B when the two stones are 29,74 m above the ground. Calculate the value of x. (6)



3.5 The graphs of position versus time for part of the motion of both stones are shown below.



Which of labels **a** to **h** on the graphs shown represents EACH of the following?

3.5.1 The time at which stone **A** had positive velocity? (1)

3.5.2 The maximum height reached by stone **A**? (1)

3.5.3 The time when stone **B** was dropped? (1)

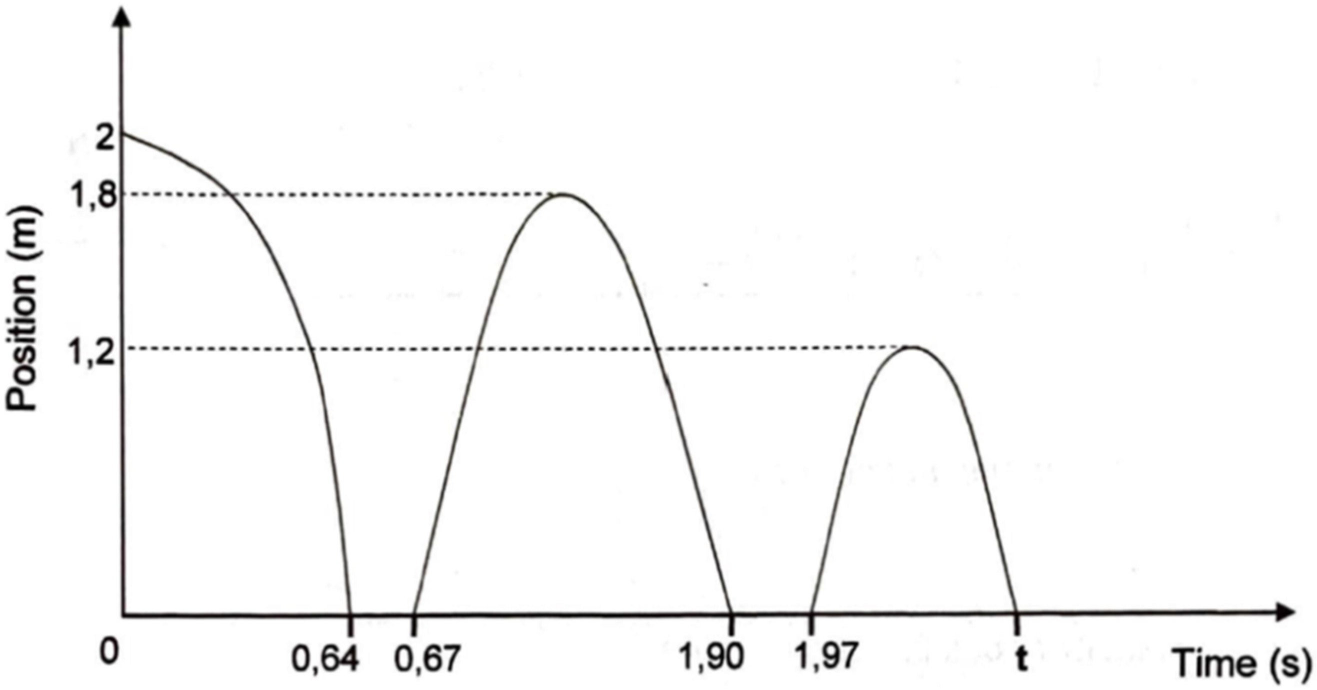
3.5.4 The height at which the stones pass each other? (1) **[18]**

MOTION GRAPHS: EXAM EXAMPLE (NOV 2020)

QUESTION 3

A small ball is dropped from a height of 2 m and bounces a few times after landing on a cement floor. Ignore air friction.

The position-time graph below, not drawn to scale, represents the motion of the ball.



3.1 Define the term *free fall*. (2)

3.2 Use the graph and determine:

3.2.1 The time that the ball is in contact with the floor before the first bounce (2)

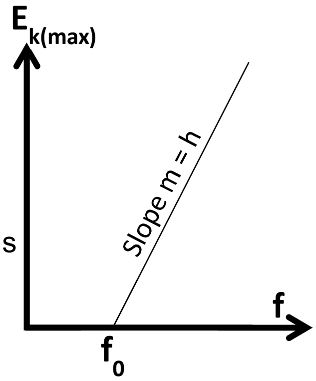
3.2.2 The time it takes the ball to reach its maximum height after the first bounce (2)

3.2.3 The speed at which the ball leaves the floor at the first bounce (3)

3.2.4 Time **t** indicated on the graph (6)

[15]

THE PHOTO-ELECTRIC EFFECT: SIMULATION



Albert Einstein received the Nobel Prize in Physics in 1921 for the photoelectric effect. He showed that light of sufficiently high energy could actually cause electrons to be emitted from a metal plate (like zinc) according to the equation:

$$E_{k(max)} = hf - W_0 \qquad \text{OR} \qquad E_{k(max)} = h(f - f_0)$$

- $E_{k(max)}$ = Max.Kinetic energy of electrons in J • h = Planck's Constant = 6.63 x 10^{-34} J·s
- f = Frequency of incident light in Hz • W_0 = Work function of the metal in J
- f_o = Threshold frequency of the metal, where $W_0 = hf_o$