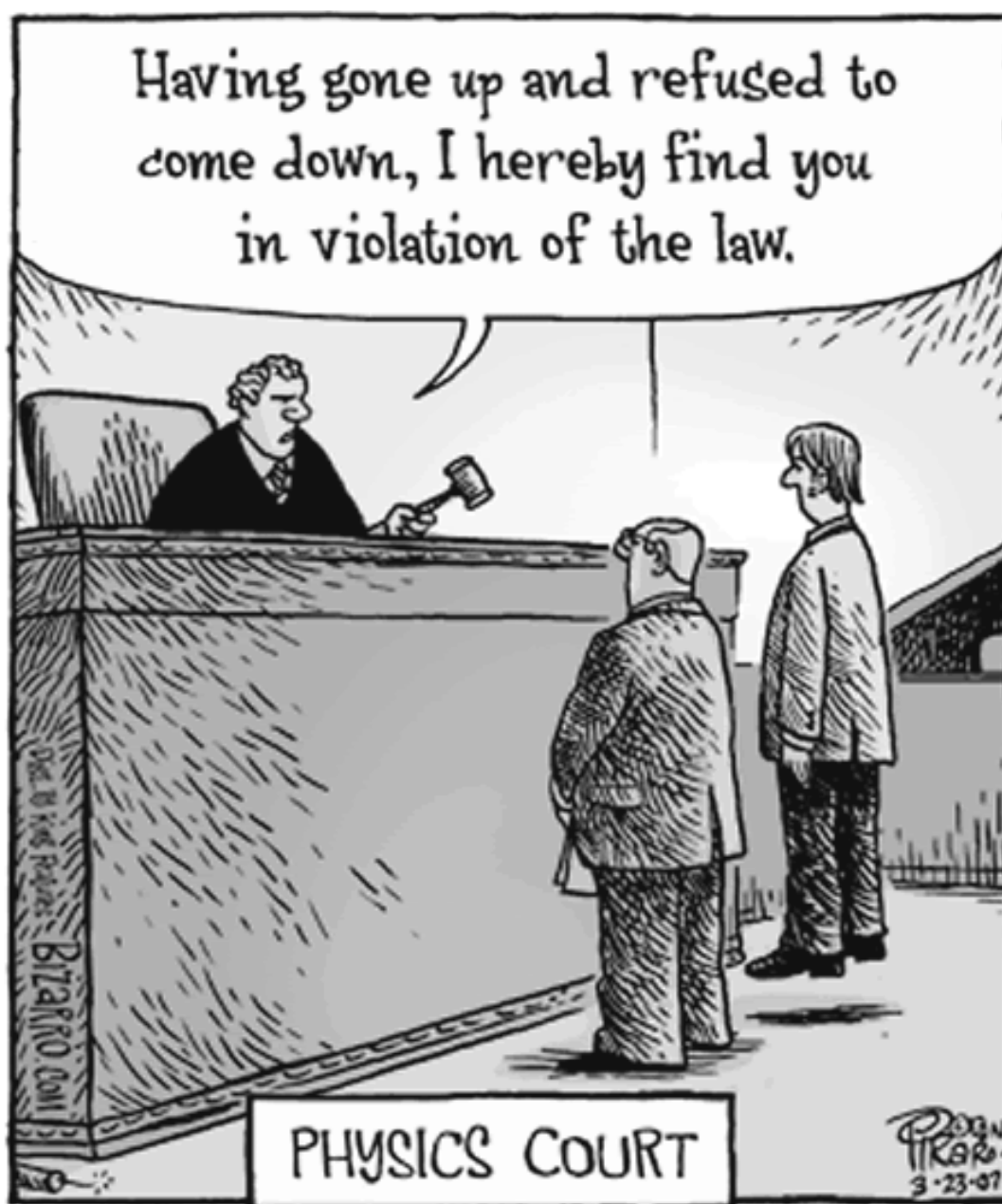# St Ninian's High School

Higher Physics

Course Profile

Course Profile Contents   Page

General Course Information

The Higher Physics course is made up of 3 units.

- Our Dynamic Universe

- Particles & Waves

- Electricity

Each unit is made up of the following sections:

- Our Dynamic Universe

  - 1.1 Motion—Equations and Graphs
  - 1.2 Forces, Energy and Power
  - 1.3 Collisions, Explosions and Impulse
  - 1.4 Gravitation
  - 1.5 Special Relativity
  - 1.6 The Expanding Universe

- Particles & Waves

  - 2.1 Forces On Charged Particles
  - 2.2 The Standard Model
  - 2.3 Nuclear Reactions
  - 2.4 Inverse Square Law
  - 2.5 Wave Particle Duality
  - 2.6 Interference and Diffraction
  - 2.7 Spectra
  - 2.8 Refraction of Light

- Electricity

  - 3.1 Monitoring and Measuring A.C.
  - 3.2 Circuits
  - 3.3 Capacitors
  - 3.4 Semiconductors and P-N Junctions

Homework

The Physics department considers the completion of homework to be the highest priority for every pupil in Higher Grade Physics.

The Higher Grade Physics course is a very fast and demanding course that introduces new concepts daily and requires hard work from every pupil. Due to the practical work and new theory introduced during class time, there is usually little time left for written problems. For this reason, problems will be issued on a regular basis. The homework is not considered to be an 'optional extra', it is essential to the understanding of new concepts and to the successful completion of the course. Past paper homework booklets will also be used throughout the year.

Only if all homework is completed fully and to the best of a pupil's ability can any degree of success be expected.

What you will be issued

1. The Course Profile booklet

    This gives an overview of the course and contains the study guides for the course.

2. Printed notes for every unit and problems for every section.

    The Physics department website contains these materials and more , such as past paper homework booklets, assignment advice and past papers and solutions.

Assessment

1. You will be assessed throughout the year; multiple choice section tests, past paper homework, end of unit tests, laboratory reports etc.

2. Prelim Examination

    At the start of February you will be tested upon the work covered to that date. The examination will be in a similar format to the final examination. The grade obtained in the this exam will determine your estimate grade and gives a clear indication of how you are performing.

3. Course Assessment

    The Course assessment will consist of three components: two question papers and an assignment.

    Question paper 1 is a multiple choice paper which is worth 25 marks. Candidates will have 45 minutes to complete this paper.

    Question paper 2 contains restricted and extended response questions and will be scaled from 130 to 95 marks. Candidates will have 2 hours and 15 minutes to complete this paper

    Marks will be distributed approximately proportionately across the units. The majority of the marks will be awarded for applying knowledge and understanding. The other marks will be awarded for applying scientific inquiry, scientific analytical thinking and problem solving skills.

    A data booklet containing relevant data and formulae will be provided.
    (See the following pages)

    The assignment requires candidates to apply skills, knowledge and understanding to investigate a relevant topic in physics. It will assess the application of skills of scientific inquiry and related physics knowledge and understanding.

    The assignment is worth 20 marks, which will be scaled to 30 marks.

    The final course award is based upon your performance in the assignment, which is carried out during the year, and the external SQA examination, at the end of the school year. The course assessment is graded A to D and is determined by the total mark for all course assessments together.

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	Symbol	Value	Quantity	Symbol	Value
Speed of light in vacuum	c	$3 \cdot 00 \times 10^8$ m s^{-1}	Planck's constant	h	$6 \cdot 63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1 \cdot 60 \times 10^{-19}$ C	Mass of electron	m_e	$9 \cdot 11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6 \cdot 67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	$1 \cdot 675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9 \cdot 8$ m s^{-2}	Mass of proton	m_p	$1 \cdot 673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2 \cdot 3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	Refractive index	Substance	Refractive index
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	Wavelength/nm	Colour	Element	Wavelength/nm	Colour
Hydrogen	656	Red	Cadmium	644	Red
	486	Blue-green		509	Green
	434	Blue-violet		480	Blue
	410	Violet			
	397	Ultraviolet			
	389	Ultraviolet			

			Lasers		
			Element	Wavelength/nm	Colour
			Carbon dioxide	9550 } 10590 }	Infrared
Sodium	589	Yellow	Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	Density/kg m^{-3}	Melting Point/K	Boiling Point/K
Aluminium	$2 \cdot 70 \times 10^3$	933	2623
Copper	$8 \cdot 96 \times 10^3$	1357	2853
Ice	$9 \cdot 20 \times 10^2$	273	. . . .
Sea Water	$1 \cdot 02 \times 10^3$	264	377
Water	$1 \cdot 00 \times 10^3$	273	373
Air	$1 \cdot 29$	. . . .	. . . .
Hydrogen	$9 \cdot 0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1 \cdot 01 \times 10^5$ Pa.

Relationships required for Physics Higher

$d = \bar{v}t$

$s = \bar{v}t$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u+v)t$

$W = mg$

$F = ma$

$E_W = Fd$

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$P = \frac{E}{t}$

$p = mv$

$Ft = mv - mu$

$F = G\dfrac{m_1 m_2}{r^2}$

$t' = \dfrac{t}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$

$l' = l\sqrt{1 - \left(\frac{v}{c}\right)^2}$

$f_o = f_s\left(\dfrac{v}{v \pm v_s}\right)$

$z = \dfrac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$

$z = \dfrac{v}{c}$

$v = H_0 d$

$W = QV$

$E = mc^2$

$E = hf$

$E_k = hf - hf_0$

$E_2 - E_1 = hf$

$T = \dfrac{1}{f}$

$v = f\lambda$

$d \sin \theta = m\lambda$

$n = \dfrac{\sin \theta_1}{\sin \theta_2}$

$\dfrac{\sin \theta_1}{\sin \theta_2} = \dfrac{\lambda_1}{\lambda_2} = \dfrac{v_1}{v_2}$

$\sin \theta_c = \dfrac{1}{n}$

$I = \dfrac{k}{d^2}$

$I = \dfrac{P}{A}$

path difference $= m\lambda$ or $\left(m + \dfrac{1}{2}\right)\lambda$ where $m = 0, 1, 2 \ldots$

$\text{random uncertainty} = \dfrac{\text{max. value} - \text{min. value}}{\text{number of values}}$

$V_{peak} = \sqrt{2}V_{rms}$

$I_{peak} = \sqrt{2}I_{rms}$

$Q = It$

$V = IR$

$P = IV = I^2 R = \dfrac{V^2}{R}$

$R_T = R_1 + R_2 + \ldots$

$\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

$E = V + Ir$

$V_1 = \left(\dfrac{R_1}{R_1 + R_2}\right)V_s$

$\dfrac{V_1}{V_2} = \dfrac{R_1}{R_2}$

$C = \dfrac{Q}{V}$

$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\dfrac{Q^2}{C}$

Additional Relationships

Circle

$\text{circumference} = 2\pi r$

$\text{area} = \pi r^2$

Sphere

$\text{area} = 4\pi r^2$

$\text{volume} = \frac{4}{3}\pi r^3$

Trigonometry

$\sin\theta = \dfrac{\text{opposite}}{\text{hypotenuse}}$

$\cos\theta = \dfrac{\text{adjacent}}{\text{hypotenuse}}$

$\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}}$

$\sin^2\theta + \cos^2\theta = 1$

Electron Arrangements of Elements

Key

Atomic number
Symbol
Electron arrangement
Name

Group 1 (1)

Atomic number	Symbol	Electron arrangement	Name
1	H	1	Hydrogen
3	Li	2,1	Lithium
11	Na	2,8,1	Sodium
19	K	2,8,8,1	Potassium
37	Rb	2,8,18,8,1	Rubidium
55	Cs	2,8,18,18,8,1	Caesium
87	Fr	2,8,18,32,18,8,1	Francium

Group 2 (2)

Atomic number	Symbol	Electron arrangement	Name
4	Be	2,2	Beryllium
12	Mg	2,8,2	Magnesium
20	Ca	2,8,8,2	Calcium
38	Sr	2,8,18,8,2	Strontium
56	Ba	2,8,18,18,8,2	Barium
88	Ra	2,8,18,32,18,8,2	Radium

Transition Elements

Group	Atomic number	Symbol	Electron arrangement	Name
(3)	21	Sc	2,8,9,2	Scandium
(3)	39	Y	2,8,18,9,2	Yttrium
(3)	57	La	2,8,18,18,9,2	Lanthanum
(3)	89	Ac	2,8,18,32,18,9,2	Actinium
(4)	22	Ti	2,8,10,2	Titanium
(4)	40	Zr	2,8,18,10,2	Zirconium
(4)	72	Hf	2,8,18,32,10,2	Hafnium
(4)	104	Rf	2,8,18,32,32,10,2	Rutherfordium
(5)	23	V	2,8,11,2	Vanadium
(5)	41	Nb	2,8,18,12,1	Niobium
(5)	73	Ta	2,8,18,32,11,2	Tantalum
(5)	105	Db	2,8,18,32,32,11,2	Dubnium
(6)	24	Cr	2,8,13,1	Chromium
(6)	42	Mo	2,8,18,13,1	Molybdenum
(6)	74	W	2,8,18,32,12,2	Tungsten
(6)	106	Sg	2,8,18,32,32,12,2	Seaborgium
(7)	25	Mn	2,8,13,2	Manganese
(7)	43	Tc	2,8,18,13,2	Technetium
(7)	75	Re	2,8,18,32,13,2	Rhenium
(7)	107	Bh	2,8,18,32,32,13,2	Bohrium
(8)	26	Fe	2,8,14,2	Iron
(8)	44	Ru	2,8,18,15,1	Ruthenium
(8)	76	Os	2,8,18,32,14,2	Osmium
(8)	108	Hs	2,8,18,32,32,14,2	Hassium
(9)	27	Co	2,8,15,2	Cobalt
(9)	45	Rh	2,8,18,16,1	Rhodium
(9)	77	Ir	2,8,18,32,15,2	Iridium
(9)	109	Mt	2,8,18,32,32,15,2	Meitnerium
(10)	28	Ni	2,8,16,2	Nickel
(10)	46	Pd	2,8,18,18,0	Palladium
(10)	78	Pt	2,8,18,32,17,1	Platinum
(10)	110	Ds	2,8,18,32,32,17,1	Darmstadtium
(11)	29	Cu	2,8,18,1	Copper
(11)	47	Ag	2,8,18,18,1	Silver
(11)	79	Au	2,8,18,32,18,1	Gold
(11)	111	Rg	2,8,18,32,32,18,1	Roentgenium
(12)	30	Zn	2,8,18,2	Zinc
(12)	48	Cd	2,8,18,18,2	Cadmium
(12)	80	Hg	2,8,18,32,18,2	Mercury
(12)	112	Cn	2,8,18,32,32,18,2	Copernicium

Group 3 (13)

Atomic number	Symbol	Electron arrangement	Name
5	B	2,3	Boron
13	Al	2,8,3	Aluminium
31	Ga	2,8,18,3	Gallium
49	In	2,8,18,18,3	Indium
81	Tl	2,8,18,32,18,3	Thallium

Group 4 (14)

Atomic number	Symbol	Electron arrangement	Name
6	C	2,4	Carbon
14	Si	2,8,4	Silicon
32	Ge	2,8,18,4	Germanium
50	Sn	2,8,18,18,4	Tin
82	Pb	2,8,18,32,18,4	Lead

Group 5 (15)

Atomic number	Symbol	Electron arrangement	Name
7	N	2,5	Nitrogen
15	P	2,8,5	Phosphorus
33	As	2,8,18,5	Arsenic
51	Sb	2,8,18,18,5	Antimony
83	Bi	2,8,18,32,18,5	Bismuth

Group 6 (16)

Atomic number	Symbol	Electron arrangement	Name
8	O	2,6	Oxygen
16	S	2,8,6	Sulfur
34	Se	2,8,18,6	Selenium
52	Te	2,8,18,18,6	Tellurium
84	Po	2,8,18,32,18,6	Polonium

Group 7 (17)

Atomic number	Symbol	Electron arrangement	Name
9	F	2,7	Fluorine
17	Cl	2,8,7	Chlorine
35	Br	2,8,18,7	Bromine
53	I	2,8,18,18,7	Iodine
85	At	2,8,18,32,18,7	Astatine

Group 0 (18)

Atomic number	Symbol	Electron arrangement	Name
2	He	2	Helium
10	Ne	2,8	Neon
18	Ar	2,8,8	Argon
36	Kr	2,8,18,8	Krypton
54	Xe	2,8,18,18,8	Xenon
86	Rn	2,8,18,32,18,8	Radon

Lanthanides

Atomic number	Symbol	Electron arrangement	Name
57	La	2,8,18,18,9,2	Lanthanum
58	Ce	2,8,18,20,8,2	Cerium
59	Pr	2,8,18,21,8,2	Praseodymium
60	Nd	2,8,18,22,8,2	Neodymium
61	Pm	2,8,18,23,8,2	Promethium
62	Sm	2,8,18,24,8,2	Samarium
63	Eu	2,8,18,25,8,2	Europium
64	Gd	2,8,18,25,9,2	Gadolinium
65	Tb	2,8,18,27,8,2	Terbium
66	Dy	2,8,18,28,8,2	Dysprosium
67	Ho	2,8,18,29,8,2	Holmium
68	Er	2,8,18,30,8,2	Erbium
69	Tm	2,8,18,31,8,2	Thulium
70	Yb	2,8,18,32,8,2	Ytterbium
71	Lu	2,8,18,32,9,2	Lutetium

Actinides

Atomic number	Symbol	Electron arrangement	Name
89	Ac	2,8,18,32,18,9,2	Actinium
90	Th	2,8,18,32,18,10,2	Thorium
91	Pa	2,8,18,32,20,9,2	Protactinium
92	U	2,8,18,32,21,9,2	Uranium
93	Np	2,8,18,32,22,9,2	Neptunium
94	Pu	2,8,18,32,24,8,2	Plutonium
95	Am	2,8,18,32,25,8,2	Americium
96	Cm	2,8,18,32,25,9,2	Curium
97	Bk	2,8,18,32,27,8,2	Berkelium
98	Cf	2,8,18,32,28,8,2	Californium
99	Es	2,8,18,32,29,8,2	Einsteinium
100	Fm	2,8,18,32,30,8,2	Fermium
101	Md	2,8,18,32,31,8,2	Mendelevium
102	No	2,8,18,32,32,8,2	Nobelium
103	Lr	2,8,18,32,32,9,2	Lawrencium

OUR DYNAMIC UNIVERSE

Study Guide

At the end of section **1.1 Motion – Equations and Graphs** you should be able to :

❑ 1   state that acceleration is the change in velocity per unit time.

❑ 2   describe the principles of a method for measuring acceleration.

❑ 3   use the terms 'constant velocity' and 'constant acceleration' to describe motion represented in graphical or tabular form.

❑ 4   draw and interpret velocity–time graphs.

❑ 5   draw and interpret acceleration–time graphs using information obtained from a velocity–time graph for motion with a constant acceleration.

❑ 6   draw and interpret displacement–time graphs using information obtained from a velocity–time graph for motion with a constant acceleration.

❑ 7   interpret motion-time graphs for bouncing objects and objects thrown vertically.

❑ 8   show how the following relationships - the equations of motion - can be derived from basic definitions in kinematics:

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

❑ 9   carry out calculations using the above kinematic relationships.

OUR DYNAMIC UNIVERSE

Study Guide

At the end of section **1.2 Forces, Energy and Power** you should be able to :

❑   1   explain the motion of an object by using Newton's laws.

❑   2   define the newton.

❑   3   carry out calculations involving the relationship between unbalanced force (F), mass (m) and acceleration (a) in situations where resolution of forces is not required.

$$F = ma$$

❑   4   use free body diagrams to analyse the forces acting upon an object in one dimension.

❑   5   explain terminal velocity.

❑   6   identify on a velocity-time graph of a falling object when the forces are balanced or unbalanced.

❑   7   identify and calculate forces acting at an angle to the direction of motion, and interpret the resultant motion.

❑   8   resolve a force into two perpendicular components.

❑   9   resolve the weight of an object on a slope into a component acting down the slope and a component acting normal to the slope.

❑   10   use the principle of conservation of energy and appropriate relationships to solve problems involving work done, potential energy, kinetic energy and power.

$$E_w = Fd$$

$$E_p = mgh$$

$$E_k = \frac{1}{2}mv^2$$

$$P = \frac{E}{t}$$

OUR DYNAMIC UNIVERSE

Study Guide

At the end of section **1.3 Collisions, Explosions and Impulse** you should be able to :

❑   1   define the momentum (p) of an object as a vector quantity that is the product of the mass (m) and velocity (v) of the object.

$$p \ = \ mv$$

❑   2   define the law of conservation of linear momentum as the total momentum before a collision is equal to the total momentum after a collision in the absence of net external forces.

❑   3   state that the law of conservation of linear momentum can be applied to the interaction of two objects moving in one dimension.

❑   3   define an elastic collision as one in which both momentum and kinetic energy are conserved.

❑   4   define an inelastic collision as one in which momentum is conserved but kinetic energy is lost.

❑   5   carry out calculations concerned with collisions in which the objects move in only one dimension.

❑   6   carry out calculations concerned with explosions in one dimension.

❑   7   apply the law of conservation of momentum to the interaction of two objects moving in one dimension to show that:
-      the changes in momentum of each object are equal in size and opposite in direction.
-      the forces acting on each object are equal in size and opposite in direction.

❑   8   define impulse acting upon an object as a vector quantity that is the product of the force acting upon the object and the time of interaction.

❑   9   define impulse as the change in momentum of an object. .

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Study Guide

❑   10   carry out calculations involving the relationships between impulse, force, time and momentum.

$$Ft = mv - mu$$

❑   11   explain that the force acting during an interaction is not constant.

❑   12   explain the effects of changing the interaction time between objects on the force acting during the interaction.

❑   13   find the impulse from the area under a force-time graph.

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Study Guide

At the end of section **1.4 Gravitation** you should be able to :

❑   1   describe the principles of a method for measuring the acceleration of a falling object.

❑   2   describe projectiles as objects in free-fall with a constant horizontal velocity component.

❑   3   state that the horizontal motion and vertical motion of a projectile are independent of each other.

❑   4   resolve the initial velocity of a projectile into horizontal and vertical components.

❑   5   carry out calculations, using the equations of motion, for projectiles.

❑   6   explain the link between satellite motion and projectile motion.

❑   7   understand the factors that determine the gravitational field strength of planets, natural satellites etc.

❑   8   use Newton's Universal Law of Gravitation to calculate the gravitational force between two objects of known mass.

$$F = G\,\frac{m_1 m_2}{r^{\cdot 2}}$$

OUR DYNAMIC UNIVERSE

Study Guide

At the end of section **1.5 Special Relativity** you should be able to :

☐ 1 state that the speed of light in a vacuum is the same for all observers in all reference frames.

☐ 2 state that the measurements of space, time and distance for a moving observer are changed relative to those for a stationary observer, giving rise to time dilation and length contraction.

☐ 3 explain how the constancy of the speed of light led Einstein to derive his theory of Special Relativity.

☐ 4 use the time dilation formula to analyse real and observed times.

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

☐ 5 use the length contraction formula to analyse real and observed lengths.

$$l' = l\sqrt{1 - \frac{v^2}{c^2}}$$

☐ 6 explain that relativistic effects are only observed when objects are moving with velocities close to the speed of light.

OUR DYNAMIC UNIVERSE

Study Guide

At the end of section **1.6 The Expanding Universe** you should be able to :

❑   1   describe the Doppler Effect in terms of the changing frequencies of sound and light for moving objects.

❑   2   use the Doppler Effect equation for calculations involving the sound emitted by moving objects.

$$f_o = f_s \left[\frac{v}{v \, {}^+_- \, v_s} \right]$$

❑   3   understand that light from distant galaxies is moved to longer wavelengths (red-shifted) because they are moving away from the Earth.

❑   4   state that the Doppler Effect equations used for sound cannot be used with light from fast moving galaxies because relativistic effects need to be taken into account.

❑   5   use appropriate relationships to solve problems involving red-shift, observed wavelength, emitted wavelength and the recessional velocity of a distant galaxy.

$$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}} \qquad\qquad z = \frac{v}{c}$$

❑   6   explain Hubble's law as the relationship between the recessional velocity of a galaxy and its distance from the observer.

❑   7   use Hubble's Law to solve problems involving the Hubble constant, the recessional velocity of a galaxy and its distance from us.

$$v = H_o d$$

❑   8   explain how the Hubble-Lemaitre Law allows us to estimate the age of the universe.

❑   9   state that measurements of the velocities of galaxies and their distance from us lead to the theory of the expanding Universe.

❑   10   state that the mass of a galaxy can be estimated by the orbital speed of the stars within it.

OUR DYNAMIC UNIVERSE

Study Guide

❑   11   explain that the measurements of the mass of our galaxy and others lead to the conclsion that there is significant mass that cannot be detected - dark matter.

❑   12   explain that the measurements of the accelerating rate of the expansion of the universe lead to the conclusion that there is something that overcomes the force of gravity – dark energy.

❑   13   describe the relationship between the temperature of a stellar object and the distribution of emitted radiation over a wide range of wavelengths.

❑   14   state that the peak wavelength of the distribution of emitted radiation is shorter for objects with a greater temperature.

❑   15   state that objects with greater temperature emit more radiation per unit surface area per unit time. The greater the temperature of a star, the greater the irradiance.

❑   16   provide evidence to support the Big Bang theory and subsequent expansion of the Universe.

PARTICLES & WAVES

Study Guide

At the end of section **2.1 Forces on Charged Particles** you should be able to :

❑ 1   state that, in an electric field, a charge experiences a force.

❑ 2   state that electric fields exist around charged particles and between charged parallel plates.

❑ 3   sketch electric field patterns for single-point charges and systems of two-point charges.

❑ 4   sketch electric field patterns between two charged parallel plates.

❑ 5   identify the direction of free electric charges in an electric field.

❑ 6   state that an electric field applied to a conductor causes the free electric charges in it to move.

❑ 7   state that work is done when a charge is moved in an electric field.

❑ 8   state that the potential difference (V) between two points in an electric field is a measure of the work done (W) in moving one coulomb of charge (Q) between the two points.

❑ 9   state that if one joule of work is done moving one coulomb of charge between two points, the potential difference between the two points is one volt.

❑ 10   carry out calculations involving the relationship between potential difference, work and charge.

$$W \;=\; QV$$

❑ 11   use the conservation of energy principle to calculate the speed of a charged particle in an electric field.

$$QV \;=\; \frac{1}{2}mv^2$$

PARTICLES & WAVES

Study Guide

❑   12   understand that a moving charge produces a magnetic field.

❑   13   determine the direction of the force on a charged particle moving in a magnetic field.

❑   14   state the three types of particle accelerator.

❑   15   state that high energy collisions of charged particles produce other particles.

❑   16   describe the basic operation of three different types of particle accelerator in terms of acceleration, deflection and collision of charged particles.

PARTICLES & WAVES
Study Guide

At the end of section **2.2 The Standard Model** you should be able to :

❑   1   define the standard model as a model of fundamental particles and interactions.

❑   2   state that the range of orders of magnitude studied in Physics range from the very small to the very large.

❑   3   place objects in order in relation to their relative size.

❑   4   state that fundamental particles are not composed of any other particles.

❑   5   state that all particles are either Fermions or Bosons.

❑   6   name the three generations of Quark pairs.

❑   7   explain that evidence for the existence of quarks comes from high energy collisions between electrons and nucleons.

❑   8   name the three generations of Lepton pairs.

❑   9   describe beta decay as the first evidence for the neutrino.

❑   10   state that Fermions are the matter particles and consist of quarks and leptons.

❑   11   state that hadrons are composite particles made of quarks.

❑   12   state that Baryons are made from three Quarks.

❑   13   state that Mesons are made from two Quarks, one Quark and an anti-Quark.

❑   14   give some examples of sub atomic particles.

❑   15   explain that every particle has an antiparticle and that the production of energy in the annihilation of particles is evidence for the existence of antimatter.

PARTICLES & WAVES

Study Guide

❑   16   state that antimatter is a particle which has the same mass as their equivalent particle but opposite charge.

❑   17   state that bosons are the force mediating particles.

❑   18   state that the Strong and Weak Forces only act over short distances relative to the size of an atom.

❑   19   state that the force mediating particle for the Strong Force is the Gluon.

❑   20   state that the force mediating particles for the Weak Force are the W- and Z- boson.

❑   21   state that the Electromagnetic Force is responsible for all electrical and magnetic phenomena.

❑   22   state that the force mediating particle for the Electromagnetic Force is the Photon.

❑   23   state that the Gravitational Force is responsible for the large scale structure of the Universe.

❑   24   state that the force mediating particle for the Gravitational Force is the Graviton.

PARTICLES & WAVES

Study Guide

At the end of section **2. 3 Nuclear Reactions** you should be able to :

❑ 1 describe how Rutherford showed that:

- the nucleus has a relatively small diameter compared with that of the atom

- most of the mass of the atom is concentrated in the nucleus.

❑ 2 state what is meant by alpha, beta and gamma decay of radionuclides.

❑ 3 identify the processes occurring in nuclear reactions written in symbolic form.

❑ 4 state that in fission a nucleus of large mass number splits into two nuclei of smaller mass numbers, usually with the release of neutrons.

❑ 5 state that fission may be spontaneous or induced by neutron bombardment.

❑ 6 state that in fusion two nuclei combine to form a nucleus of larger mass number.

❑ 7 explain, using $E = mc^2$, how the products of fission and fusion acquire large amounts of kinetic energy.

❑ 8 carry out calculations involving the relationship between energy (E) and mass (m) loss for fission and fusion reactions.

$$E = mc^2$$

❑ 9 state that nuclear fusion reactors require charges at a very high temperature (plasma).

❑ 10 state that magnetic fields are used to contain charged particles in nuclear fusion reactors.

❑ 11 state that in a fusion reactor the coolant must be **contained** so that it doesn't vaporise and cool the reaction down.

❑ 12 state that in a fusion reactor the coolant must be **confined** to ensure that more energy is given out than is absorbed.

PARTICLES & WAVES

Study Guide

At the end of section **2. 4 Inverse Square Law** you should be able to :

❑   1   state that the irradiance at a surface on which radiation is incident is the power per unit area.

❑   2   carry out calculations involving irradiance, the power of radiation incident on a surface and the area of the surface.

$$I = \frac{P}{A}$$

❑   3   describe the principles of a method for showing that the irradiance is inversely proportional to the square of the distance from a point source.

❑   4   carry out calculations involving the relationship between irradiance and distance.

$$I_1 d_1^2 = I_2 d_2^2$$

❑   5   explain that if N photons per second are incident per unit area on a surface, the irradiance at the surface is given by I = Nhf.

PARTICLES & WAVES

Study Guide

At the end of section **2. 5 Wave Particle Duality** you should be able to :

❑ 1 state that the photoelectric effect is evidence for the particle model of light.

❑ 2 state that photoelectric emission from a surface occurs only if the frequency of the incident radiation (f) is greater than some threshold frequency (f_o) which depends on the nature of the surface.

❑ 3 state that for frequencies smaller than the threshold value, an increase in the irradiance of the radiation at the surface will not cause photoelectric emission.

❑ 4 state that for frequencies greater than the threshold value, the photoelectric current produced by monochromatic radiation is directly proportional to the irradiance of the radiation at the surface.

❑ 5 state that a beam of radiation can be regarded as a stream of individual energy bundles called photons, each having an energy (E) dependent on the frequency of the radiation (f).

❑ 6 carry out calculations involving the relationship between the energy (E), Planck's constant (h) and the frequency of photons (f).

$$E = hf$$

❑ 7 state that photoelectrons are ejected with a maximum kinetic energy which is given by the difference between the energy of the incident photon and the work function of the surface.

❑ 8 carry out calculations involving the maximum kinetic energy (E_k), the threshold frequency of the material (f_o) and the frequency of the photons (f).

$$E_k = hf - hf_o$$

PARTICLES & WAVES

Study Guide

At the end of section **2.6 Interference and Diffraction** you should be able to :

❏   1   state that interference is the test for a wave.

❏   2   use correctly in context the terms: 'in phase', 'out of phase' and 'coherent', when applied to waves.

❏   3   explain the meaning of: 'constructive interference' and 'destructive` interference', in terms of superposition of waves.

❏   4   state that reflection, refraction, diffraction and interference are characteristic behaviours of all types of waves.

❏   5   state the conditions for maxima and minima in an interference pattern formed by two coherent sources in the form:

$$Path\ difference = \ m\lambda \qquad \text{for maxima, and}$$

$$Path\ difference = \left(m + \tfrac{1}{2}\right)\lambda \qquad \text{for minima, where m is an integer.}$$

❏   6   carry out calculations using the relationships for maxima and minima in an interference pattern formed by two coherent sources.

❏   7   carry out calculations involving the grating spacing, wavelength, order number and the angle to the maximum.

$$m\lambda = d\sin\theta$$

❏   8   describe the effect of grating on a monochromatic light beam.

❏   9   carry out calculations involving the relationship between wavelength, order, slit separation and angle for gratings.

❏   10   describe the principles of a method for measuring the wavelength of a monochromatic light source, using a grating.

❏   11   state approximate values for the wavelengths of red, green and blue light.

PARTICLES & WAVES

Study Guide

❑   12   describe and compare the white light spectra produced by: a grating and a prism.

PARTICLES & WAVES

Study Guide

At the end of section **2.7 Spectra** you should be able to :

❑   1   state that electrons in a free atom occupy discrete energy levels (the Bohr model of the atom).

❑   2   draw a diagram which represents qualitatively the energy levels of a hydrogen atom.

❑   3   use the following terms correctly in context: ground state, excited state, ionisation level.

❑   4   state that an emission line in a spectrum occurs when an electron makes a transition between an excited energy level and a lower level.

❑   5   state that an absorption line in a spectrum occurs when an electron in a lower energy level absorbs radiation and is excited to a higher energy level.

❑   6   carry out calculations involving energy level transitions, photon energy and photon frequency.

$$E_2 - E_1 = hf$$

❑   7   explain the occurrence of absorption lines (Fraunhofer lines) in the spectrum of sunlight.

PARTICLES & WAVES

Study Guide

At the end of section **2. 8 Refraction of Light** you should be able to :

❑ 1 state that the ratio $\frac{sin\theta_1}{sin\theta_2}$ is a constant when light passes obliquely from medium 1 to medium 2.

❑ 2 state that the refractive index of air is treated the same as that of a vacuum.

❑ 3 state that the absolute **refractive index, n**, of a medium is the ratio $\frac{sin\theta_1}{sin\theta_2}$ where θ_1 is in a vacuum (or air as an approximation) and θ_2 is in the medium.

❑ 4 describe an experiment to determine the refractive index of a medium.

❑ 5 state that when light enters an optically more dense medium the speed decreases, the wavelength decreases but the **frequency** remains **unchanged**.

❑ 6 state that the refractive index is the ratio of the speed of light in a vacuum (air) to the speed of light in the material. It is also the ratio of the wavelengths.

❑ 7 state that the refractive index depends on the frequency of the incident light.

❑ 8 carry out calculations involving the relationships between refractive index, angle, wavelength, speed and frequency.

$$\frac{sin\theta_1}{sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

❑ 9 explain what is meant by total internal reflection.

❑ 10 explain what is meant by critical angle θ_C.

❑ 11 describe the principles of a method for measuring a critical angle.

❑ 12 derive the relationship between critical angle and absolute refractive index of a medium.

PARTICLES & WAVES

Study Guide

❑   13   carry out calculations involving the relationship between critical angle and absolute refractive index of a medium.

$$sin\theta_c = \frac{1}{n}$$

ELECTRICITY

Study Guide

At the end of section **3.1 Monitoring & Measuring A.C.** you should be able to :

❑   1   describe a.c. as a current which changes direction and instantaneous value with time.

❑   2   determine the frequency of an a.c. signal from its period.

$$T = \frac{1}{f}$$

❑   3   determine the frequency and peak voltage of an a.c. supply using an oscilloscope.

❑   4   state that the r.m.s. voltage is equivalent to a d.c. voltage that produces the same power.

❑   5   state the relationship between the peak and r.m.s. values for a sinusoidally varying voltage and current.

❑   6   carry out calculations involving peak and r.m.s. values of voltage and current.

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} \qquad I_{rms} = \frac{I_{peak}}{\sqrt{2}}$$

ELECTRICITY

Study Guide

At the end of section **3.2 Circuits** you should be able to :

❑ 1   state that voltage is defined as the energy transformed per unit of charge

❑ 2   carry out calculations involving the relationship between energy, voltage and charge.

$$V = \frac{W}{Q}$$

❑ 3   state that the energy supplied to each coulomb of charge which passes through a source is known as the electromotive force (e.m.f.).

❑ 4   state that the energy transformed into another form of energy by a circuit component is known as the potential difference (p.d.)

❑ 5   carry out calculations involving the relationships between power, current, voltage and resistance in circuits containing resistors.

$$V = IR \qquad P = IV = I^2R = \frac{V^2}{R} \qquad R_T = R_1 + R_2 + \cdots \qquad \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

❑ 6   state that a potential divider consists of a number of resistors, or other components, connected in series across a supply.

❑ 7   carry out calculations involving potential differences and resistances in potential divider circuits.

$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right) V_S \qquad\qquad \frac{V_1}{V_2} = \frac{R_1}{R_2}$$

❑ 8   state that an electrical source is equivalent to a source of e.m.f. (E) with a resistor in series, the internal resistance (r).

❑ 9   describe the principles of a method for measuring the e.m.f. (E) and internal resistance (r) of a source.

❑ 10   determine the e.m.f. (E), internal resistance (r) and short circuit current from a graph.

ELECTRICITY

Study Guide

❑   11   explain why the e.m.f. of a source is equal to the open circuit p.d. across the terminals of the source.

❑   12   state that the closed circuit p.d. across the terminals of a source is equal to the terminal potential difference (t.p.d.).

❑   13   state that the e.m.f. of a cell is equal to the sum of the t.p.d. and the lost volts.

❑   14   carry out calculations involving the relationship between the e.m.f., t.p.d. and the lost volts.

$$E = V + Ir$$

❑   15   state that R = r for maximum transfer of energy between a source and a load.

❑   16   use the following terms correctly in context: electromotive force (E), internal resistance (r), lost volts, terminal potential difference (t.p.d.), short circuit and open circuit.

ELECTRICITY

Study Guide

At the end of section **3.3 Capacitors** you should be able to :

☐ 1 state that the charge Q on two parallel conducting plates is directly proportional to the p.d. V between the plates.

☐ 2 state that capacitance is the ratio of charge to p.d.

☐ 3 state that the unit of capacitance is the farad and that one farad is one coulomb per volt.

☐ 4 carry out calculations involving the relationship between capacitance, charge and potential difference.

$$C = \frac{Q}{V}$$

☐ 5 calculate the charge stored on a capacitor for a constant charging current.

$$Q = It$$

☐ 6 explain why work must be done to charge a capacitor.

☐ 7 state that the work done to charge a capacitor is given by the area under the graph of charge against p.d.

☐ 8 carry out calculations involving the relationships between capacitance, charge, potential difference and energy stored in a capacitor.

$$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

☐ 9 describe an experiment to investigate the variation of current in a capacitor and voltage across a capacitor with time, for the charging and discharging of capacitors.

☐ 10 draw qualitative graphs of current against time and of p.d. against time for the charge and discharge of a capacitor in a d.c. circuit containing a resistor and capacitor in series.

☐ 11 carry out calculations involving p.d. and current in CR circuits.

ELECTRICITY
Study Guide

At the end of section **3.4 Semiconductors & P-N Junctions** you should be able to :

❑   1   state that materials can be divided into three broad categories according to their electrical properties – conductors, insulators and semiconductors.

❑   2   state that the electrons in atoms are contained in energy levels and when atoms come together, the electrons then become contained in energy levels separated by gaps.

❑   3   state that in conductors the highest occupied band is not completely full and this allows electrons to move therefore conduct. This band is known as the conduction band.

❑   4   state that highly conductive metals have free electrons and partially filled electron bands. Some metals have overlapping valence and conduction bands. Each band is partially filled and therefore they are conductive.

❑   5   state that in insulators the highest occupied band (called the valence band) is full. The band above the valence band is the conduction band.

❑   6   state that for an insulator the gap between the valence band and the conduction band is large and at room temperature there is not enough energy available to move electrons from the valence band in to the conduction band where they would be able to contribute to conduction.

❑   7   state that for a semiconductor the gap between the valence band and the conduction band is smaller and at room temperature there is sufficient energy available to move some electrons from the valence band in to the conduction band allowing some conduction to take place.

❑   8   state that an increase in temperature increases the conductivity of a semiconductor.

❑   9   state that the addition of impurity atoms to a pure semiconductor (a process called doping) decreases its resistance.

❑   10   explain how doping can form an n-type semiconductor in which the majority of the charge carriers are negative, or a p-type semiconductor in which the majority of the charge carriers are positive.

ELECTRICITY

Study Guide

❑   11   describe the movement of the charge carriers in a forward/reverse-biased p–n junction diode.

❑   12   state that p-n junctions are used in a number of devices.

❑   13   state that LEDs are forward biased p-n junction diodes which emit photons when a current is passed through the junction.

❑   14   explain how the movement of electrons across the p-n junction of an LED results in recombination with holes causing photons to be omitted.

❑   15   state that solar cells are p-n junctions designed so that a potential difference is produced when photons are incident upon it. This is the photovoltaic effect.

❑   16   explain how the creation of electron-hole pairs within the p-n junction of an solar cell causes a potential difference to be produced.

UNCERTAINTIES
Study Guide

At the end of section **4.1 Uncertainties** you should be able to :

❑   1   State that measurement of any physical quantity is liable to uncertainty.

❑   2   Distinguish between random uncertainties and recognised systematic effects.

❑   3   State that the scale-reading uncertainty is a measure of how well an instrument scale can be read.

❑   4   Explain why repeated measurements of a physical quantity are desirable.

❑   5   Calculate the mean value of a number of measurements of the same physical quantity.

❑   6   State that this mean is the best estimate of a 'true' value of the quantity being measured.

❑   7   State that where a systematic effect is present the mean value of the measurements will be offset from a 'true' value of the physical quantity being measured.

❑   8   Calculate the approximate random uncertainty in the mean value of a set of measurements using the relationship:

$$\text{approximate random uncertainty in mean} = \frac{\text{max. value} - \text{min. value}}{\text{no. of measurements}}$$

❑   9   Estimate the scale-reading uncertainty incurred when using an analogue display and a digital display.

❑   10   Express uncertainties in absolute or percentage form.

❑   11   Identify, in an experiment where more than one physical quantity has been measured, the quantity with the largest percentage uncertainty.

❑   12   State that this percentage uncertainty is often a good estimate of the percentage uncertainty in the final numerical result of the experiment.

❑   13   Express the numerical result of an experiment in the form: final value ± uncertainty.

PREFIXES
Study Guide

At the end of section **4.2 Units, Prefixes and Scientific Notation** you should be able to :

❑   1   Use SI units of all physical quantities appearing in the content statements.

❑   2   Give answers to calculations to an appropriate number of significant figures.

❑   3   Check answers to calculations.

❑   4   Use prefixes (p, n, μ, m, k, M, G).

❑   5   Use scientific notation.

UNCERTAINTIES

It is important to realise a degree of uncertainty is associated with any measured physical quantity.

Systematic Effects

These can occur when the measurements are affected all in the same way e.g. a metre stick might have "shrunk", thus giving consistently incorrect readings.
At this level, the systematic effect tends to be small enough to be ignored.
Where accuracy is of the utmost importance, the apparatus would be calibrated against a known standard.
Note that a systematic effect might also be present if the experimenter is making the same mistake each time in taking a reading.

Random Uncertainty

Random fluctuations can affect measurements from reading to reading, e.g. consecutive timings of the period of a pendulum can differ. The best estimate of the true value is given by repeating the readings and then calculating the mean value. The random uncertainty is then calculated using the formula below.

$$\text{Random uncertainty} = \frac{\text{maximum reading - minimum reading}}{\text{number of readings}}$$

Scale Reading Uncertainty

This value indicates how well an instrument scale can be read.

An estimate of reading uncertainty for an **analogue scale** is generally taken as:

$$\pm \text{ half the least division of the scale.}$$

Note: for widely spaced scales, this can be a little pessimistic and a reasonable estimate should be made.

For a **digital scale** it is taken as

$$\pm \text{ 1 in the least significant digit displayed.}$$

Examples
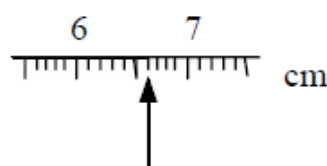
(6.60 ± 0.05) cm

Length lies between
(6.55 and 6.65) cm
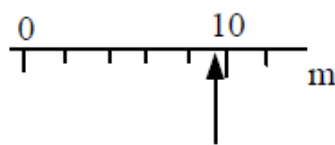
(9.0 ± 0.5) m

Length lies between
(8.5 and 9.5) m
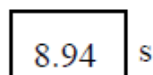
(8.94 ± 0.01) s

Time lies between
(8.93 and 8.95) s.

Example

The times for 10 swings of a pendulum are: 1.1, 1.4, 1.2, 1.3 and 1.1 s

Mean value = 1.2 s

$$Random\ uncertainty\ =\ \frac{maximum\ -\ minimum}{number\ of\ readings}\ =\ \frac{1.4\ -\ 1.1}{5}\ =\ 0.06\ s$$

Time for 10 swings = (1.2 ± 0.1) s = 1.2 s ± 5 %

Note: *when the uncertainty is expressed in units then it is known as the* **absolute uncertainty**. *In this case this is + 0.06 s, or ± 0.1 s.*

Comparison of Uncertainties

When comparing uncertainties, it is important to take the **percentage** in each.
Suppose in an experiment the following uncertainties were found.

Systematic	=	0.1 %
Scale Reading	=	2 %
Random	=	0.5 %

The overall uncertainty should be taken as the highest percentage uncertainty.
In this case, this would be the reading uncertainty at 2 %.

Note: since accuracy is now being quantified, it is essential when using a calculator that all the figures are not taken down, since every number stated indicates the degree of accuracy.

As a general rule, your answer should contain the same number of significant figures as the least accurate reading.

Examples

1. *Refer to the example at the top of the page. The mean value is 1.22 s and the random uncertainty 0.06 s. However, all the readings are to two significant figures hence the final answer must be written as (1.2 ± 0.1)s as shown.*

2. *Calculate the average speed and absolute uncertainty from the following readings.*

$s = (1.54 ± 0.02)\ m$ $\qquad\qquad$ $t = (1.69 ± 0.01)\ s$

% uncertainty in s $= \dfrac{0.02}{1.54} × 100$ $\qquad$ *% uncertainty in t* $= \dfrac{0.01}{1.69} × 100$

$\qquad\qquad = 1.3\ %$ $\qquad\qquad\qquad\qquad\qquad = 0.6\ %$

Highest uncertainty taken = 1.3 %

$\dfrac{s}{v} = \dfrac{s}{t} = \dfrac{1.54}{1.69} = 0.911\ ms^{-1} ± 1.3%$

1.3 % of 0.911 m s⁻¹ = 0.012 m s⁻¹ (converts % to absolute uncertainty)

$$v = (0.91 ± 0.01)\ m\ s^{-1}$$

ACTIVITY

Title: Uncertainties

Aim: to find the average speed of a trolley moving down a slope, estimating the uncertainty in the final value.

Apparatus: 1 ramp, 1 metre stick, 1 trolley, 1 stop clock.

Instructions

- Set up a slope and mark two points 85 cm apart.

- Note the scale reading uncertainty.

- Calculate the percentage uncertainty in the distance.

- Ensuring the trolley starts from the same point each time, measure how long it takes the trolley to pass between the two points.

- Repeat 5 times, calculate the mean time and estimate the random uncertainty.

- Note the scale reading uncertainty in the time.

- Calculate the percentage uncertainty in the time.

- Calculate the average speed and associated uncertainty.

- Express your result in the form:

$$(speed \pm absolute\ uncertainty)\ m\ s^{-1}$$

Problems

1.   Calculate the percentage uncertainties for the following absolute readings:

      a) (4.65 ± 0.05) V   b) (892 ± 5) cm   c) (1.8 ± 0.4) A

      d) (2.87 ± 0.02) s   e) (13.8 ± 0.5) Hz   f) (5.2 ± 0.1) m

2.   State the three types of uncertainty, explaining the difference between them.

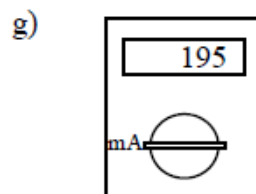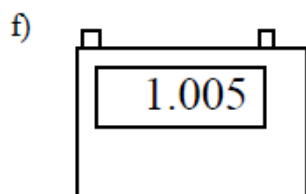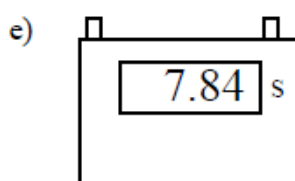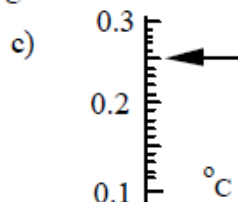3.   Manufacturers of resistors state the uncertainty in their products by using colour codes.

                Gold - 5 % accuracy.   Silver - 10 % accuracy.

    Calculate the possible ranges for the following resistors for each colour.

      a) $1 \, k\Omega$ b) $10 \, k\Omega$ c) $22 \, \Omega$

4.   For each of the following scales, write down the reading and estimate the uncertainty.
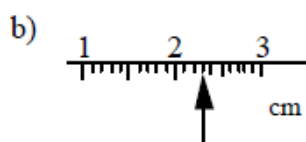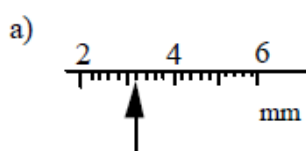
5.   Calculate the mean time and random uncertainty for the following readings:

                0.8 s, 0.6 s, 0.5 s, 0.6 s and 0.4 s.

6.   A student uses light gates and suitably interfaced computer to measure the acceleration of a trolley as it moves down a slope. The following results were obtained.

          $a \, / \, m \, s^{-2}$ 5.16, 5.24, 5.21, 5.19, 5.12, 5.20, 5.17, 5.19.

    Calculate the mean acceleration and the corresponding random uncertainty.

7.   AB is measured using a metre stick.
    A trolley is timed between AB.
    The following results were obtained.
    $AB = (60.0 + 0.1)$ cm
    t/s 1.21, 1.21, 1.26, 1.27, 1.24 and 1.28.
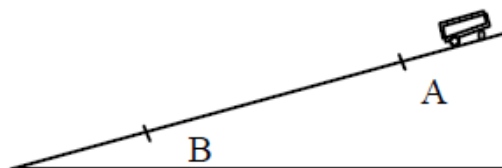
    Express the average speed in the form (value $\pm$ absolute uncertainty).

Solutions

1. (a) uncertainty $= \dfrac{0.05}{4.65} \times 100 = 1.1\,\%$ (b) 0.6 %   (c) 22 %

    (d) 0.7 %   (e) 3.6 %   (f) 1.9 %

2. Systematic effect: affects all readings in the same way. Can be due to apparatus
    limitations or fault in experimental approach.
    Reading uncertainty: accuracy limited by quality of scale
    $\pm$ half the least division (analogue) or good estimate.
    $\pm$ 1 in the least significant digit (digital).
    Random uncertainty: random fluctuations between readings.
    Effect is minimised by repeating readings.

    $$\text{Uncertainty} = \frac{\text{maximum reading} - \text{minimum reading}}{\text{number of readings}}$$

3. (a) Gold 5 % of $1k\Omega = 0.05\,k\Omega$ Range is $(0.95 - 1.05)\,k\Omega$ $= (950 - 1050)\,\Omega$
        Silver 10 % of $1k\Omega = 0.1k\Omega$ Range is $(0.9 - 1.1)\,k\Omega$ $= (900 - 1100)\,\Omega$
    (b) Silver $(9000 - 11000)\,\Omega$ Gold $(9500 - 10500)\,\Omega$
    (c) Silver $(19.8 - 24.2)\,\Omega$ Gold $(20.9 - 23.1)\,\Omega$

4. (a) (3.2 ± 0.1) mm   (b) (2.30 ± 0.05) cm   (c) $(0.250 \pm 0.005)\,^{0}C$
    (d) (2.4 ± 0.2) g   (e) (7.84 ± 0.01) s   (f) (1.005 ± 0.001) s
    (g) (195 ± 1) mA

5. $$\text{Mean time} = \frac{(0.8 + 0.6 + 0.5 + 0.6 + 0.4)}{5} = 0.6\,\text{s}$$

    $$\text{Random uncertainty} = \frac{(0.8 - 0.4)}{5} = 0.08\,\text{s}$$

    $t = (0.6 \pm 0.1)$ s

6. $\text{Mean } a = 5.19\ \text{m s}^{-2}$ $\text{Random error} = \dfrac{5.24 - 5.12}{8} = 0.015\ \text{ms}^{-2}$

    $$a = (5.19 \pm 0.02)\ \text{m s}^{-2}$$

7. $AB = (60.0 \pm 0.1)$ cm $= 60$ cm $\pm 0.17\,\%$

    $\text{Random uncertainty in } t = \dfrac{1.28 - 1.21}{6} = +0.012\,\text{s}$

    Mean $t = (1.25 \pm 0.01)$ s $= 1.25$ s $\pm 0.8\,\%$

    Greatest percentage uncertainty is 0.8 % in the time.

    $\overline{v} = \dfrac{s}{t} = \dfrac{6.0}{1.25} \pm 0.8\% = 48.0\ \text{cm s}^{-1} \pm 0.8\% = (48.0 \pm 0.4)\ \text{m s}^{-1}$

PREFIXES

The following are prefixes used to denote multiples and sub-multiples of any unit used to measure a physical quantity.

Name	Symbol	Power of 10	
tera	T	$\times 10^{12}$	
giga	G	$\times 10^{9}$	multiples
mega	M	$\times 10^{6}$	
kilo	k	$\times 10^{3}$	
centi	c	$\times 10^{-2}$	
milli	m	$\times 10^{-3}$	
micro	μ	$\times 10^{-6}$	sub-multiples
nano	n	$\times 10^{-9}$	
pico	p	$\times 10^{-12}$	

Questions

Use scientific notation to write the measurements in the units shown.

1.	12 gigahertz	=	12 GHz	=	Hz
2.	4.7 megohms	=	4.7 MΩ	=	Ω
3.	46 kilometres	=	46 km	=	m
4.	3.6 millivolts	=	3.6 mV	=	V
5.	0.55 milliamps	=	0.55 mA	=	A
6.	25 microamps	=	25 μA	=	A
7.	630 nanometres	=	630 nm	=	m
8.	2200 picofarads	=	2200 pF	=	F

Rewrite the following quantities in the units shown. -

1.	14×10^3 m	=		km		
2.	2.3×10^7 Ω	=		MΩ		
3.	5.6×10^8 Hz	=		GHz	=	MHz
4.	4.6×10^{-3} V	=		mV	=	μV
5.	2.5×10^{-5} A	=		μA	=	mA
6.	4.50×10^{-7} m	=		nm		
7.	4.70×10^{-9} F	=		pF	=	μF