1.1.1.14 Complete the table to show derived quantities and their units.

	Derived quantity	SI unit for quantity	SI symbol for unit	Dependence on fundamental units
(a)	Acceleration			
(b)	Charge			
(c)	Electric field strength			
(d)	Electrical potential			
(e)	Electrical resistance			
(f)	Energy			
(g)	Force			
(h)	Frequency			
(i)	Heat capacity			
(j)	Magnetic field strength			
(k)	Magnetic flux			
(l)	Momentum			
(m)	Power			
(n)	Pressure			
(o)	Radioactivity			
(p)	Specific heat capacity			
(q)	Velocity			

1.1.1.15 Which of the following contains only *fundamental* SI units?

(A) Coulomb, kilogram, second.
(B) Kelvin, ohm, second.
(C) Ampere, kilogram, mole.
(D) Kilogram, metre, weber.

1.1.1.16 Which one of the following contains a unit which is *not* fundamental?

(A) Ampere, kilogram, second.
(B) Candela, mole, joule.
(C) Ampere, kelvin, metre.
(D) Kilogram, metre, candela.

1.1.1.17 Complete the table to summarise the meaning of the various prefixes used with units.

Multiple	Prefix	Symbol
10^{24}		
10^{21}		
10^{18}		
10^{15}		
		T
		G
		M
		k
	Hecto	
	Deca	

Multiple	Prefix	Symbol
	Deci	
	Centi	
10^{-3}		
10^{-6}		
		n
		p
	Femto	
	Atto	
10^{-21}		
10^{-24}		

Use the information in your completed table to help you answer the following questions.

1.1.1.18 Convert each of the following to fundamental SI units.

(a) 720 g .....

(b) 4.5 tonnes .....

(c) 1056 nm .....

(d) 4.5 light years .....

(e) 2.4 AU (astronomical units) .....

1.1.1.19 Convert the following to SI units.

(a) 28 000 km h^{-1} .....

(b) 45 cm^3 .....

(c) 400 kPa .....

(d) 3000 GL .....

(e) 2.5 MJ .....

1.1.1.20 Calculate the distance travelled by a car which is travelling at 30 km h^{-1} for 45 minutes. Express your answer in SI units.

.....

1.1.1.21 Kepler's law of periods for the motion of planets around the Sun, where R is the orbital radius of a planet, M the mass of the Sun, T the time it takes the planet to orbit the Sun and G is the universal gravitational constant, can be represented by the equation: $\frac{R^3}{T^2} = \frac{GM_{Sun}}{4\pi^2}$

Determine the SI unit for G.

.....

1.1.1.22 A typical household will have an average of 5 lights on for about 6 hours each day during the year. If each light globe is rated at 60 W of electrical power, calculate the energy consumed by these lights during the year. Give your answer in the most appropriate form.

.....

1.1.2 Scientific notation and metric multipliers.

1.1.2.1 Express the following numbers in scientific notation.

(a) 25000 .....

(b) 0.0000043 .....

(c) 253456 (to two significant figures) .....

(d) 0.00003425 (to two significant figures) .....

1.1.2.2 Complete the following table.

	250 g	**0.25 kg**
(a)	1500 mm	m
(b)	1.5 m	cm
(c)	Pa	105 MPa
(d)	m	121 km
(e)	25 mA	A
(f)	10 μm	m

1.1.2.3 Express each of the following quantities using scientific notation and the most appropriate SI unit prefixes.

	Quantity	**Scientific notation**	**SI unit with prefixes**
(a)	0.0005 kg		
(b)	562 m		
(c)	43 000 J		
(d)	5 678 345 Pa		
(e)	6473 V		
(f)	0.006 MJ		
(g)	0.000000005 m		
(h)	0.156 s		
(i)	2 400 000 000 000 000 km		
(j)	64 000 000 A		

1.1.2.4 Submultiples of units may be expressed using a prefix. Which *one* of the following lists the prefixes in *decreasing* order of magnitude?

(A) milli- centi- nano- micro-

(B) centi- micro- milli- nano-

(C) milli- micro- centi- nano

(D) centi- milli- micro- nano-

1.1.3 Significant figures.

1.1.3.1 State the number of significant figures in each of the measurements in the table below.

1.1.3.2 Express each of the numbers in the table in scientific notation to two significant figures.

	Measurement	Number of significant figures	In scientific notation to two significant figures
(a)	0.0060		
(b)	0.0061		
(c)	1.0060		
(d)	1.0061		
(e)	1 000 000 000		
(f)	1 780 000 004		
(g)	1 856 000 000.0		
(h)	462.52		
(i)	0.6200		
(j)	4086		

1.1.3.3 Complete each of the following calculations using the appropriate number of significant figures.

(a) $4.62 + 8.9561 + 5.9 =$ .....

(b) $0.005 + 0.46 + 1.09 =$ .....

(c) $46.9 \times 12.4 \times 5.6 =$ .....

(d) $0.62 \times 9.2 \times 1.04 =$ .....

(e) $9.76 - 4.5 - 0.64 =$ .....

(f) $106 - 463 - 230.6 =$ .....

(g) Calculate the area of a square with sides 5.6 cm = ...

(h) Calculate the volume of a cube with sides equal to 1.56 cm = ...

(i) $(6.4 + 5.92 - 4.3) \div 2.25 =$ .....

(j) $\sqrt{(9600 \times 1.25 \div 0.25)} =$ .....

1.1.3.4 The mass of a body is measured to be 0.400 kg and its acceleration to be 2 m s^{-2}. The net force on the body, expressed to the correct number of significant figures is:

(A) 0.8 N
(B) 0.80 N
(C) 1 N
(D) 1.0 N

1.1.3.5 A student hypothesised that F and A may be related by an expression of the form $F = aA$ where a is a constant. In order to test this suggestion, the data shown below are used. The uncertainties in the measurements of F and A are not shown.

F (kg m s^{-2})	A (m^2)	F/A (???)
12.04	8.60	
18.23	11.8	
23.91	17.1	???
31.58	23.6	
44.14	32.2	

(a) What are the correct units for F/A?

(A) kg m^3 s^{-2}

(B) kg m^{-1} s^{-2}

(C) kg m^{-2} s^{-2}

(D) kg m^{-3} s^{-2}

(b) Calculate the magnitude of F/A to the correct number of significant figures for the value of F = 23.91.

(A) 1.39

(B) 1.398

(C) 1.4

(D) 1.40

(c) Evaluate the student's hypothesis. .....

.....

1.1.3.6 An object has an acceleration of 3.5 m s^{-2}. Which of the following gives the change in the speed of the object after 4.00 s to the correct number of significant digits?

(A) 14 m s^{-1}

(B) 14.0 m s^{-1}

(C) 14.00 m s^{-1}

(D) 14.000 m s^{-1}

1.1.4 Orders of magnitude.

1.1.4.1 Define 'order of magnitude'. .....

.....

1.1.4.2 Give the order of magnitude of the numbers in the table.

	Number	Order of magnitude		Number	Order of magnitude
(a)	6.0		(k)	12 678 945	
(b)	0.004		(l)	56 743	
(c)	13		(m)	–578	
(d)	0.02		(n)	–0.0000003	
(e)	156		(o)	1 234 567 890	
(f)	6789		(p)	9 876 543 210	
(g)	42		(q)	449	
(h)	0.78		(r)	3150	
(i)	0.00003		(s)	3200	
(j)	0.00007		(t)	0.008	

1.1.4.3 Discuss when it is appropriate to use orders of magnitudes in answers and when it is appropriate to give exact answers.

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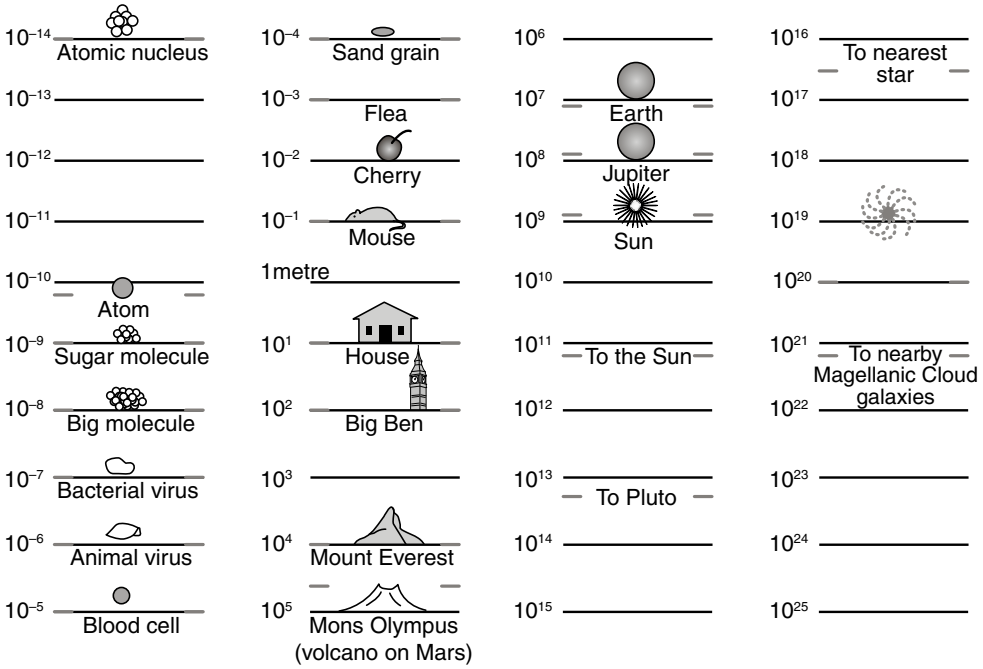
1.1.4.4 Complete the following tables to show the orders of magnitude of distances, masses and times in the Universe.

	Mass in kg	Order of magnitude of quantity
(a)	Mass of the Universe	
(b)	Mass of the Earth	
(c)	Average mass of a car	
(d)	Mass of a tennis ball	
(e)	Mass of a fly	
(f)	Mass of a hydrogen atom	
(g)	Mass of an electron	

	Distance in km	Order of magnitude of quantity
(h)	Size of visible Universe	
(i)	Distance to nearest star (Proxima Centauri)	
(j)	Distance to the Sun	
(k)	Diameter of the Earth	
(l)	Height of average person	
(m)	Thickness of a spider web strand	
(n)	Diameter of an atom	

	Time in seconds	Order of magnitude of quantity
(o)	Age of the Universe	
(p)	Time since dinosaurs were on Earth	
(q)	Human life span	
(r)	One year	
(s)	One day	
(t)	Time a meson 'lives'	
(u)	Period of visible light	

1.1.4.5 The information shows the order of magnitude of the size of various objects in the Universe. Use it to answer this question.



According to this data (express answers in orders of magnitude):

(a) How much larger is an atom than an atomic nucleus? .....

(b) How much larger is a blood cell than a bacterial virus? .....

(c) How much larger is a grain of sand than a blood cell? .....

(d) How much larger is a cherry than a grain of sand? .....

(e) How much larger is a mouse than an atom? .....

(f) How much larger is a house than a mouse? .....

(g) How much larger is Mount Everest than a house? .....

(h) How much larger is the Earth than an atomic nucleus? .....

(i) How much larger is the Earth than a house? .....

(j) Compare the distance to the Sun with that to Pluto. .....

(k) Compare the distance to the Sun to that to the nearest star. .....

(l) Compare the size of the Earth to that of the galaxy. .....

1.1.5 Estimation

1.1.5.1 Estimate the size of each of the following to two significant figures and express each estimate to the nearest order of magnitude. *Do not* use a calculator on mathematical examples!

	Object	Estimate in appropriate unit	Nearest order of magnitude	Tick if you were 'close'
(a)	Length of your arm in cm			
(b)	Width of a page of this book in mm			
(c)	Mass of an orange in grams			
(d)	$6.67 \times 10^{-11} \times 5.974 \times 10^{24} \times 3 \times 10^{5} \div (4.2 \times 10^{7})$			
(e)	Volume of a coffee mug			
(f)	Volume of a bucket			
(g)	Volume of a grain of rice			
(h)	Number of grains of rice in a cup			
(i)	Dimensions of a typical calculator			
(j)	Molecules of water in a full tea cup			
(k)	$\sqrt{(100^2 - 75^2 / 100^2)}$			
(l)	Diameter of a basketball			
(m)	Height of a can of soft drink			
(n)	Mass of a loaf of bread			
(o)	$(42\ 380\ 000)^3/(86\ 400)^2$			
(p)	$3 \times 10^{21} \div 1.5 \times 10^{12}$			
(q)	Mass of a can of soft drink			
(r)	Distance between Earth and the Moon			
(s)	Volume of the Earth			
(t)	$9 \times 10^{9} \times 2.5 \times 10^{-8} \times 4.0 \times 10^{-8} \div 0.5^2$			

1.2 Uncertainties and errors.

1.2.1 Random and systematic errors.

1.2.1.1 Outline five examples of random errors.

1.2.1.2 Identify four ways to reduce random errors.

1.2.1.3 Outline five examples of systematic errors.

1.2.1.4 Identify four ways to reduce systematic errors.

1.2.1.5 Both random and systematic errors are present in the measurement of a particular quantity in an experiment. What changes, if any, would repeated measurements of this quantity have on the random and systematic errors?

(A) Both would be reduced.

(B) Random would be reduced, systematic would be unchanged.

(C) Random would be unchanged, systematic would be reduced.

(D) Both would be unchanged.

1.2.1.6

(a) Define the accuracy of a measurement. .....

.....

.....

(b) How is the accuracy of a measurement indicated? .....

.....

.....

1.2.1.7

(a) Define 'precision of a measurement' .....

.....

.....

(b) How is the precision of a measurement indicated? .....

.....

.....

1.2.1.8 Two readings taken during an experiment were X = 5.00 ± 0.2 and Y = 5.0 ± 0.02. Which choice best describes the characteristics of these two measurements?

(A) X has high accuracy while Y has high precision.

(B) X has high accuracy while Y has low precision.

(C) X has low accuracy while Y has high precision.

(D) X has low accuracy while Y has low precision.

1.2.1.9 A meter has a zero reading of 0.5. Which statement about readings taken on this meter is correct?

(A) Neither the precision nor the accuracy of the reading will be affected.

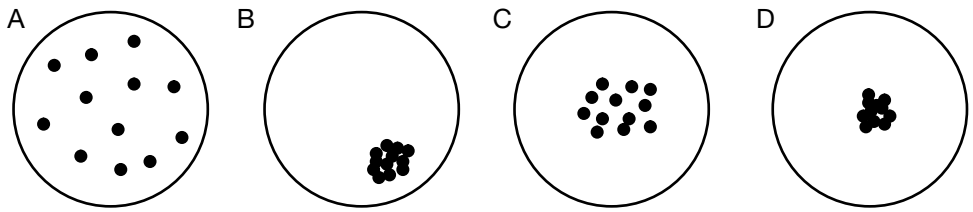
(B) Both the precision nor the accuracy of the reading will be affected.

(C) The precision will be affected but not the accuracy.

(D) The accuracy will be affected but not the precision.

Use the following information to answer the next FOUR questions.

Imagine four archers firing arrows at a target. The object of the exercise was to hit the target in the centre. The diagrams show where their arrows hit.



1.2.1.10 Which archer was the least accurate and the least precise?

(A) A
(B) B
(C) C
(D) D

1.2.1.11 Which archer was precise but not accurate?

(A) A
(B) B
(C) C
(D) D

1.2.1.12 Which archer was accurate and precise?

(A) A
(B) B
(C) C
(D) D

1.2.1.13 Compare the accuracy and the precision of the archer you have not yet chosen with the other three archers.

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1.2.1.14 The reading of a constant force is made four times by a student. The readings are:

2.532, 2.535, 2.534 and 2.532. The student averages these readings but does not take into account the zero error on the force balance. The average measurement of the force is:

(A) Both precise and accurate.
(B) Precise but not accurate.
(C) Accurate but not precise.
(D) Neither accurate nor precise.

1.2.2 Absolute, fractional and percentage uncertainties.

1.2.2.1 Define the following terms.

(a) Limit of reading of a measuring instrument. .....

.....

(b) Maximum degree of uncertainty of a measuring instrument. .....

.....

(c) Absolute uncertainty. .....

.....

(d) Fractional or relative uncertainty. .....

.....

(e) Percentage uncertainty. .....

.....

(f) Percentage discrepancy. .....

.....

1.2.2.2 A student rolls a ball across a tabletop a distance of 1.00 m. This measurement has a 2% error associated with it. She measures the time the ball takes to roll this distance with a 5% error. She uses these measurements to calculate the average speed of the ball as it rolled. What is the error associated with the speed calculation?

(A) 2% (B) 3% (C) 5% (D) 7%

1.2.2.3 The kinetic energy of a moving object is calculated using the formula $KE = \frac{1}{2}mv^2$. The mass of an object was measured with a 4% uncertainty and its velocity with a 3% uncertainty. What will be the uncertainty in its calculated kinetic energy?

(A) 1% (B) 7% (C) 10% (D) 11%

1.2.2.4 Three variables are related according to the equation $X = YZ^3$. In an experiment students measured X with an uncertainty of 4% and Y with an uncertainty of 5%. They then used these values to calculate a value for Z. The uncertainly with the value for Z would be:

(A) 1% (B) 3% (C) 9% (D) 19%

1.2.2.5 The mass of the Earth is 5.974×10^{24} kg. What is the uncertainty associated with this measurement?

(A) 0.0005 (B) 0.0005 kg (C) 0.0005×10^{24} (D) 0.0005×10^{24} kg

1.2.2.6 If $X = 35 \pm 0.5$ m and $Y = 15 \pm 0.7$ m, then which is the best answer for $3X - 2Y$?

(A) 75 ± 0.1 (B) 75 ± 1.2 (C) 75 ± 2.9 (D) 75 ± 7.3

1.2.2.7 The result of a calculation is 0.678901 μm with an absolute error of $\pm$ 0.0006 μm. How should this result be stated?

(A) 0.678901 ± 0.0006 μm
(B) 0.6789 ± 0.0006 μm
(C) 678.9 ± 0.6 nm
(D) 678.901 ± 0.0006 nm

1.2.2.8 A student measured the current flowing through a 5 Ω resistor with a constant potential different across it. He obtained the following readings from repeated measurements.

1.65 A	1.54 A	1.72 A	1.67 A	1.48 A	1.53 A	1.66 A	1.81 A	1.73 A	1.14 A	1.69 A

(a) What was the limit of reading of the meter used? .....

(b) What was the absolute error in each reading? .....

(c) What was the fractional error in the first reading? .....

(d) What was the percentage error in the second reading? .....

(e) What is the greatest deviation of any reading from the mean reading? .....

(f) What current and uncertainty should he report? .....

1.2.2.9 A student measured the angle of inclination of a ramp used in an experiment as 37° ± 2°. In his calculations he had to use the sine of this angle. How would he record this?

.....

1.2.2.10 How should the volume of a cube with sides 4.5 ± 0.1 cm be reported? .....

1.2.2.11 If $T^2 = 46.5 \pm 0.4$, what is an appropriate value for T? .....

1.2.2.12 If $X = 18 \pm 0.5$ and $Y = 9.0 \pm 0.4$, find appropriate values, including errors, for:

(a) $X + Y$ .....

(b) $X - Y$ .....

(c) $X + 2Y$ .....

(d) $2X - 3Y$ .....

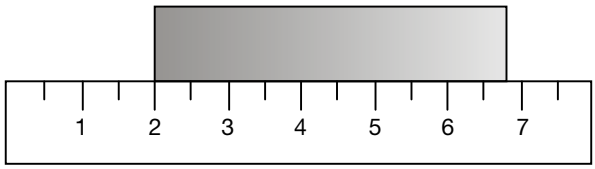
(e) $X \times Y$ .....

(f) $X \div Y$ .....

(g) $\sqrt{XY}$ .....

(h) XY^3 .....

1.2.2.13 Consider the diagram of an object below next to a centimetre rule.



(a) What is the limit of reading of the rule? .....

(b) What will be the uncertainty of the measurement? .....

(c) What is the length of the figure, including error? .....

(d) What is the relative error? .....

(e) What is the percentage error? .....