Notes 1: The realm of physics

Objective 1: Express quantities to the nearest order of magnitude (OoM).

1. Very large and very small decimal numbers are conveniently expressed in terms of powers of ten. Numbers expressed with the aid of powers of ten are said to be in ***scientific notation***.

2. In doing rough calculations or comparisons, we sometimes round off a number to the nearest power of ten. Such a number is called an ***order of magnitude***.

3. OoM is determined by finding the logarithm (base 10) of the number, rounding the log to the nearest whole number, and using that as the power of 10 for OoM. Thus...

   ...for 1000 $\Rightarrow$ log 1000 = 3 for an OoM of 10^3;

   ...for 151 $\Rightarrow$ log 151 = 2.17898 for an OoM of 10^2;

   ...for 490,000 $\Rightarrow$ log 490,000 = 5.6902 for an OoM of 10^6;

Objective 2: State and compare the range of OoM for size, mass, and time.

4. Sizes range from 10^{-15} m to 10^{+25} m (sub-atomic particles to extent of the visible universe).

5. Masses range from 10^{-30} kg to 10^{+52} kg (the mass of an electron to the mass of the universe).

6. Times range from 10^{-23} s to 10^{+18} s (passage of light across a nucleus to the age of universe).

The Universe by Orders of Magnitude					
Size or Distance	(m)	Mass	(kg)	Time Interval	(s)
Proton	10^{-15}	Electron	10^{-30}	Time for light to cross nucleus	10^{-23}
Atom	10^{-10}	Proton	10^{-27}	Period of visible light radiation	10^{-15}
Virus	10^{-7}	Amino acid	10^{-25}	Period of microwaves	10^{-10}
Giant amoeba	10^{-4}	Hemoglobin	10^{-22}	Half-life of muon	10^{-6}
Walnut	10^{-2}	Flu virus	10^{-19}	Period of highest audible sound	10^{-4}
Human	10^{0}	Giant amoeba	10^{-8}	Period of human heartbeat	10^{0}
Highest mountain	10^{4}	Ant	10^{-2}	Half-life of free neutron	10^{3}
Earth	10^{7}	Human	10^{2}	Period of earth's rotation	10^{5}
Sun	10^{9}	Saturn V rocket	10^{6}	Period of earth revolution about sun	10^{7}
Distance of earth to sun	10^{11}	Pyramid	10^{10}	Lifetime of human	10^{9}
Solar system	10^{13}	Earth	10^{24}	Half-life of plutonium-239	10^{12}
Distance to nearest star	10^{16}	Sun	10^{30}	Lifetime of mountain range	10^{15}
Milky Way galaxy	10^{21}	The Milky Way	10^{41}	Age of earth	10^{17}
Visible universe	10^{26}	Visible Universe	10^{52}	Age of universe	10^{18}

Objective 3: Express ratios of quantities as differences in OoM.

7. Example, how does the mass of a proton compare to the mass of an electron?

$$\frac{m_p}{m_e} = \frac{10^{-27}}{10^{-30}} = 10^3$$

8. Therefore, the proton's mass is 3 orders of magnitude larger than the electron's mass.

Objective 4: Express numbers in scientific notation.

9. Handling very large or very small numbers is simplified by using scientific notation, i.e., the number is written as a product of a number and a power of 10.

   - Atomic mass of O_2 = 0.000000000000000000000332 kg = 3.32×10^{-21} kg

   - Speed of Light = 300,000,000 m/s = 3×10^8 m/s

10. It is much easier to write and use numbers written in scientific notation !!

Objective 5: Multiply, divide, add, and subtract numbers in scientific notation.

11. When numbers in scientific notation are multiplied, the exponents are added. When numbers are divided, the exponents are subtracted.

Multiplying: $(3.0 \times 10^8)(2.0 \times 10^{-9}) = (3)(2) \times 10^{8+(-9)} = 6.0 \times 10^{-1}$

Dividing: $(3.0 \times 10^8) \div (2.0 \times 10^{-9}) = (3 \div 2) \times 10^{8-(-9)} = 1.5 \times 10^{17}$

12. Care is required when adding or subtracting numbers written in scientific notation. You must first put all numbers into the same power of 10.

Adding: $(8.0 \times 10^2) + (2.0 \times 10^4) = (0.080 \times 10^4) + (2.0 \times 10^4) = 2.08 \times 10^4$

Subtracting: $(8.0 \times 10^2) - (2.0 \times 10^4) = (0.080 \times 10^4) - (2.0 \times 10^4) = -1.92 \times 10^4$

13. When raising a power to another power, the exponents are multiplied.

$(10^2)^4 = 10^2 \times 10^2 \times 10^2 \times 10^2 = 10^8$

$(10^2)^{0.5} = 10^1$