

# 1 - Measurement

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## 1 Measurement

### 1.1 Physical Quantities

- (1999) Mention two applications and two limitations of dimensional analysis.
- (1999) The frequency  $f$  of a note produced by a taut wire stretched between two supports depends on the distance  $l$  between the supports, the mass per unit length of the wire,  $\mu$  , and the tension  $T$  . Use dimensional analysis to find how  $f$  is related to  $l$  ,  $\mu$ , and  $T$  .
- (1999) The period  $T$  of vibrations of a tuning fork may be expected to depend on the density  $D$  , Young's Modulus  $Y$  of the material of which it is made and the length  $a$  of its prongs. Using dimensional analysis deduce an expression for  $T$  in terms of  $D$  ,  $Y$  and  $a$ .
- (2000) The speed  $v$  of a wave is found to depend on the tension  $T$  in the string and the mass per unit length  $u$  (linear mass density). Using dimensional analysis derive the relationship between  $v$  ,  $T$  and  $u$  .
- (2007) Mention two(2) uses of dimensional analysis.
- (2007) The frequency  $f$  of a note given by an organ pipe depends on the length,  $l$  , the air pressure  $P$  and the air density  $D$  . Use the method of dimensions to find a formula for the frequency.
  - What will be the new frequency of a pipe whos original frequency was 256 Hz if the air density falls by 2% and the pressure increases by 1% ?
- (2010) Mention two uses of dimensional analysis.
- (2010) The critical velocity of a liquid flowing in a certain pipe is 3 m/s, assuming that the critical velocity  $v$  depends on the density  $\rho$  of the liquid. its viscosity  $\mu$ , and the diameter  $d$  . of the pipe.
  - Use the method of dimensional analysis to derive the equation of the critical velocity of the liquid in a pipe of half the diameter.
  - Calculate the value of critical velocity.
- (2014) What is the importance of dimensional analysis inspite of its drawbacks?
- (2015) State the law of dimensional analysis.

- (2015) The largest mass,  $m$  of a stone that can be moved by the flowing river depends on the velocity of flow  $v$ , the density  $\rho$  of water, and the acceleration due to gravity  $g$ . Show that the mass,  $m$  varies to the sixth power of the velocity of flow.
- (2016) Define the term dimension of a physical quantity.
- (2016) Give two basic rules of dimensional analysis.
- (2016) The frequency,  $f$  of a vibrating string depends upon the force applied,  $F$ , the length,  $l$ , of the string and the mass per unit length,  $\mu$ . Using dimension show how  $f$  is related to  $F$ ,  $l$  and  $\mu$ .
- (2016) What is meant by least count of a measurement?
- (2017) Define the term dimensions of a physical quantity.
- (2017) Identify two uses of dimensional equations.
- (2017) What is the basic requirement for a physical relation to be correct?
- (2017) List two quantities whose dimension is  $[ML^2T^{-1}]$
- (2017) The frequency  $f$  of vibration of a stretched string depends on the tension  $F$ , the length  $l$  and the mass per unit length  $\mu$  of the string. Derive the formula relating the physical quantities by the method of dimensions.
- (2017) Use dimensional analysis to prove the correctness of the relation,  $\rho = \frac{3g}{4\pi R G}$  where by  $\rho$  = density of the earth,  $g$  = acceleration due to gravity,  $R$  = radius of the earth and  $G$  = gravitational constant.
- (2018) State the law of dimensional analysis.
- (2018) If the speed  $v$  of the transverse wave along a wire of tension,  $T$  and mass,  $m$  is given by,  $V = \sqrt{T/m}$ . Apply dimensional analysis to check whether the given expression is correct or not.
- (2019) Identify two basic rules of dimensional analysis.
- (2019) The frequency  $n$  of vibration of a stretched string is a function of its tension  $F$ , the length,  $l$  and mass per unit length  $m$ . Use the method of dimensions to derive the formula relating the stated physical quantities.

## 1.2 Errors

- (2000) What is an error? Mention two causes of systematic and two causes of random errors.
- (2000) The pressure  $P$  is calculated from the relation  $P = F/(\pi R^2)$  where  $F$  is the force and  $R$  the radius. If the percentage possible errors are +2% for  $F$  and +1% for  $R$ . Calculate the possible percentage error for  $P$ .
- (2007) What is systematic error?
- (2007) The smallest divisions for the voltmeter and ammeter are 0.1 V and 0.01 A respectively. If  $V = IR$ , find the relative error in the resistance  $R$ , when  $V = 2$  V and  $I = 0.1$  A.

- (2010) Define an error.
- (2010) In an experiment to determine the acceleration due to gravity  $g$  , a small ball bearing is timed while falling freely from rest through a measured vertical height. The following data were obtained: vertical height  $h = (600 \pm 1)$  mm, time taken  $t = (350 \pm 1)$  ms. Calculate the numerical value of  $g$  from the experimental data, clearly specify the errors.
- (2013) What is the difference between degree of accuracy and precision.
- (2013) In an experiment to determine Young's modulus of a wooden material the following measurements were recorded:
  - length  $l = 80.0 \pm 0.05$  cm
  - breadth  $b = 28.65 \pm 0.03$  mm
  - thickness  $t = 6.40 \pm 0.03$  mm and
  - slope  $G = 0.035 \pm 0.001$  cm/gm
  - Given that the Youngs modulus  $Y$  is given by:
  - $Y = (4/Gb)(l/t)^3$
  - Calculate the maximum percentage error in the value of  $Y$  .
- (2014) Distinguish random error from systematic error.
  - Give a practical example of random error and systematic error and briefly explain how they can be reduced or eliminated.
- (2014) Define the terms error and mistake.
- (2014) An experiment was done to find the acceleration due to gravity by using the formula:  $T = 2\pi\sqrt{l/g}$  , where all symbols carry their usual meaning. If the clock losses 3 seconds in 5 minutes, determine the error in measuring  $g$  given that,  $T = 2.22$  sec,  $l = 121.6$  cm,  $\Delta T_1 = 0.1$  sec, and  $\Delta l = \pm 0.05$  .
- (2014) The following measurements were taken by a student for the length of a piece of rod: 21.02 , 20.99 , 20.92 , 21.11 and 20.69 . Basing on error analysis find the true value at the length of a piece of rod and its associated error.
- (2015) What is meant by random errors?
  - Briefly explain two causes of random errors in measurements.
- (2015) The period  $T$  of oscillation of a body is said to be  $1.5 \pm 0.002$  s while its amplitude  $A$  is  $0.3 \pm 0.005$  m and the radius of gyration  $k$  is  $0.28 + 0.004$  m. If the acceleration due
  - to gravity  $g$  was found to be related to  $T$  ,  $A$  and  $k$  by the equation  $(gA)/(4\pi^2) = (A^2 + k^2)/T^2$  , find the:
  - Numerical value of  $g$  in four decimal places
  - Percentage error in  $g$  .
- (2016) The period of oscillation of a simple pendulum is given by  $T = 2\pi\sqrt{l/g}$  where by 100 vibrations were taken to measure 200 seconds. If the least count for the time and length of a pendulum of 1 m are 0.1 sec and 1 mm respectively, calculate the maximum percentage error in the measurement of  $g$  .

- (2017) Give the meaning of the following terms as used in error analysis:
  - Absolute error.
  - Relative error.
- (2017) The force  $F$  acting on an object of mass  $m$ , travelling at velocity  $v$  in a circle of radius  $r$  is given by:  $F = \frac{mv^2}{r}$  If the measurements are recorded as:  $m = (3.5 \pm 0.1)$  kg,  $V = (20 \pm 1)$  m/s,  $r = (12.5 \pm 0.5)$  m; find the maximum possible
  - Fractional error.
  - Percentage error in the measurement of force.
  - Show how you will record the reading of force,  $F$  in the question above.
- (2018) How can random and Systematic errors be minimized during an experiment?
- (2018) Estimate the precision to which the Youngs modulus,  $\gamma$  of the wire can be determined from the formula  $\gamma = (4Fl)/(\pi d^2 e)$ , given that the applied tension,  $F = 500$  N, the length of the loaded wire,  $l = 3$  m, the diameter of the wire,  $d = 1$  mm, the extension of the wire,  $e = 5$  mm and the errors associated with these quantities are 0.5 N, 2 mm, 0.01 mm and 0.1 mm respectively.
- (2019) What causes systematic errors in an experiment? Give four points.
- (2019) Estimate the numerical value of drag force  $D = 1/2C\rho AV^2$  with its associated error given that the measurements of the quantities  $C$ ,  $A$ ,  $\rho$  and  $v$  were recorded as  $(10 \pm 0.00)$  unit less,  $(5 \pm 0.2)$  cm<sup>2</sup>,  $(15 \pm 0.15)$  g/cm<sup>3</sup> and  $(3 \pm 0.5)$  cm/sec<sup>2</sup> respectively.