Physics

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Lecturer

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Associate Prof. of Fluid Mechanics and Energy Resources in City of Scientific Research and Technological Applications (SRTAC)

Adjunct professor in Mechanical Engineering Department, PUA and AAST (Egypt)

Part-time Lecturer in university of leeds (UK)

Fellow of Academy of Scientific Research and Technology (ASRT) - Egypt

Member in Future Studies and Risk Management Council – ASRT – Egypt

President of Egyptian society of Water and Energy (EWE)

Member (Gold) in International Solar Energy Society (ISES)

Member in Egyptian Young Academy of Science and Technology (EYAS)

B.Sc. 2000 - Alexandria University

M.Sc. 2005 - Alexandria University

PhD. 2010 – University of Leeds, UK

Computational Fluid Dynamics in Industrial and Environmental applications

Research Interests

Computational Fluid Dynamics “CFD” in Industrial and Environmental applications

Projects : Solar power station (CSP), Solar GH self-sustained of Energy and water, Natural Gas Combustion Systems Technologies, Air flow in Urban Environment, Wind Turbine, Pipeline design and simulation, ...

Course Contents

- Dimensions and Units
- Principles of Thermodynamics
- Principles of Heat Transfer
- Principle of Electromagnetic

Units and Dimensions
الوحدات والأبعاد

Physical Quantity
الكمية الفيزيائية

Derived Quantity
كمية مشتقة

Fundamental Quantity
كمية أساسية

Physical Quantities
الكميات الفيزيائية

Derived Quantities كميات مشتقة		Fundamental Quantities كميات أساسية	
Velocity	السرعة	Length	١ ـ الطول
Acceleration	العجلة	Mass	٢ ـ الكتلة
Force	القوة	Time	٣ ـ الزمن
Energy Volume	الطاقة الحجم	Temperature	٤ ـ درجة الحرارة
Density Pressure	الكثافة الضغط	Electric current	٥ ـ التيار الكهربي

System of units أنظمة الوحدات

	Length الطول	Mass الكتلة	Time الزمن
CGS French	cm	gm	S
FPS British System	ft قدم	lb باوند Pound	S
SI Units (MKS)	m	Kg	S

Dimensions الأبعاد

It is a symbol of a physical quantity and it does not change by changing system of the units.

البعد هو رمز للكمية الفيزيائية ولا يتغير بتغير نظام الوحدات

Fundamental Quantities, Dimensions and their SI Units

Quantity	Dimension	SI Units
Length الطول	L	m (meter)
Mass الكتلة	M	Kg (kilogram)
Time الزمن	T	S (Second)
Temperature درجة الحرارة	K	K (Kelvin)
Electric current التيار الكهربى	A	A (Ampere)

الاستخدامات الأساسية لمعادلات الأبعاد

١) استنتاج أبعاد الكميات المشتقة

٢) الحكم علي صحة المعادلات الفيزيائية

٣) استنتاج بعض المعادلات الفيزيائية البسيطة

Dimensional Analysis

- Technique to check the correctness of an equation or to assist in deriving an equation

- Any relationship can be correct only if the dimensions on both sides of the equation are the same

١ ـ استنتاج أبعاد الكميات المشتقة

Dimensions of Derived Quantities

Dimension of Derived Quantities

أبعاد الكميات المشتقة

- $velocity : v = \frac{\ell}{t}$
- $$[v] = \left[\frac{L}{T}\right] = \left[L\ T^{-1}\right]$$
- $Acceleration:\ a = \frac{v}{t}$
- $$[a] = \left[\frac{L\ T^{-1}}{T}\right] = \left[L\ T^{-2}\right]$$
- $Force : F = m\,a$
- $$[F] = \left[M\ L\ T^{-2}\right]$$

Dimension of Derived Quantities

أبعاد الكميات المشتقة

- $[v] = [L\ T^{-1}]$ $\quad [a] = [L\ T^{-2}]$
- $[F] = [M\ L\ T^{-2}]$
- $Work, Energy : W = F\ x$
- $[W] = [M\ L\ T^{-2}\ \ L] = [M\ L^2\ T^{-2}]$
- $Power : P = \dfrac{W}{t}$
- $[P] = \left[\dfrac{M\ L^2\ T^{-2}}{T}\right] = [M\ L^2\ T^{-3}]$

Dimension of Derived Quantities

أبعاد الكميات المشتقة

Density (ρ) الكثافة

$a)$ $[\rho] = [m^{-1}\, L^3]$

$b)$ $[\rho] = [M^{-1}\, L^3]$

$c)$ $[\rho] = [M\ \ell^{-3}]$

$d)$ $[\rho] = [ML^{-3}]$

$$Density : \rho = \frac{m}{V}$$

$$m : \ mass$$

$$Volume : V = \ell^3$$

$$[V] = [L^3]$$

$$Density : \rho = \frac{m}{V}$$

$$[\rho] = \left[\frac{M}{L^3}\right] = [ML^{-3}]$$

Dimension of Derived Quantities

أبعاد الكميات المشتقة

- $[v] = [L\ T^{-1}]$
- $[a] = [L\ T^{-2}]$
- $[F] = [M\ L\ T^{-2}]$
- $[W] = [M\ L^2\ T^{-2}]$
- $[P] = [M\ L^2\ T^{-3}]$

- $Pressure : p = \frac{F}{A}$
- $[p] = \left[\frac{M\ L\ T^{-2}}{L^2}\right]$
- $[p] = [M\ L^{-1}\ T^{-2}]$
- $Volume : V = \ell^3$
- $[V] = [L^3]$
- $Density : \rho = \frac{m}{V}$
- $[\rho] = \left[\frac{M}{L^3}\right] = [ML^{-3}]$

Dimension of Derived Quantities

أبعاد الكميات المشتقة

- $[v] = [L\ T^{-1}]$
- $[a] = [L\ T^{-2}]$
- $[F] = [M\ L\ T^{-2}]$
- $[W] = [M\ L^2\ T^{-2}]$
- $[P] = [M\ L^2\ T^{-3}]$
- $[p] = [M\ L^{-1}\ T^{-2}]$
- $[V] = [L^3]$
- $[\rho] = [ML^{-3}]$

- $Surface\ tenstion: S$
- $S = F/\ell$
- $[S] = \left[\frac{M\ L\ T^{-2}}{L}\right]$
- $[S] = [M\ T^{-2}]$
- **Electric current :I**
- $[I] = [A]$
- $Area\ of\ circle$
- $A = \pi r^2$
- $[A] = [L^2]$

أبعاد كميات المشتقة ووحداتها في النظام العالمي

Dimension of Derived Quantities

Physical Quantity	Dimensions	SI Units
$a = v/t$	$[L\ T^{-2}]$	m/S^2
$F = m\,a$	$[M\,L\ T^{-2}]$	$Kg\,m/S^2 = N$
$W = F\ x$	$[M\,L^2\,T^{-2}]$	$N\,m = J$
$P = W/t$	$[M\,L^2\,T^{-3}]$	$J/S = W$
$p = F/A$	$[M\,L^{-1}\ T^{-2}]$	$N/m^2 = Pa$
$S = F/\ell$	$[M\,T^{-2}]$	N/m

G : Universal gravitational constant

ثابت الجذب العالمي

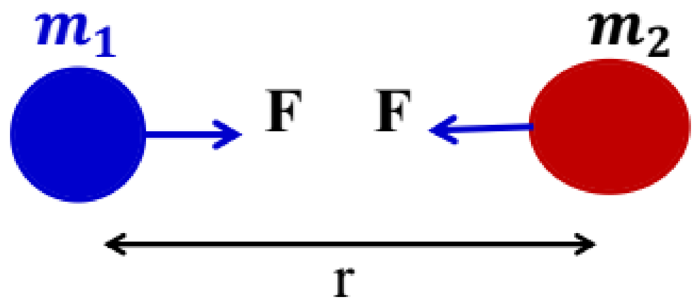
$$F = G\,\frac{m_1 \quad m_2}{r^2}$$

Derive the dimension and SI units of G

- استنتج ابعاد *ثابت الجذب العالمي* G ووحداته في النظام الدولي.
- حيث mass (m_1, m_2)
- كتلة الجسم الأول وكتلة الجسم الثانى
- Distance r المسافة بين الجسمين
- Force F قوة التجاذب المادى بين الجسمين

G : Universal gravitational constant

ثابت الجذب العالمي



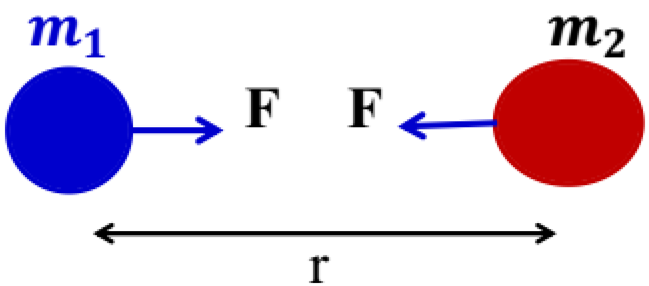
$$G = \frac{F \; r^2}{m_1 \; m_2}$$

$$[G] = \frac{[M\,L\;T^{-2}\;\;L^2]}{[M^2]}$$

$$[G] = [M^{-1}\,L^3\,T^{-2}]$$

G : Universal gravitational constant

ثابت الجذب العالمي



الوحدات

$$G = \frac{F\ r^2}{m_1\ m_2} \qquad \left(N\ m^2/kg^2\right)$$

$$[G] = \left[M^{-1}\ L^3\ T^{-2}\right] \qquad \left(kg^{-1}\ m^3\ S^{-2}\right)$$

Temperature gradient
الانحدار الحراري

Temperature gradient : The variation of temperature with position

الانحدار الحراري : تغير درجة الحرارة مع المسافة

$$\frac{dT}{dx}$$

ابعاد الانحدار الحراري

$$\left[\frac{dT}{dX}\right] = \left[K \quad L^{-1}\right]$$

الوحدات : (K/m)

Velocity Gradient
انحدار السرعة

- **Velocity gradient :** The variation of velocity with position

- انحدار السرعة : تغير السرعة مع المسافة

$$\frac{dv}{dX}$$

ابعاد الانحدار السرعة

$$\left[\frac{dv}{dX}\right] = \left[\frac{L\,T^{-1}}{L}\right] = [T^{-1}]$$

الوحدات : (S^{-1})

Pressure Gradient
انحدار الضغط

- **Pressure gradient** : The variation of Pressure with position
- انحدار الضغط : تغير الضغط مع المسافة

$$\frac{d\,p}{d\,X}$$

ابعاد الضغط $[p] = \left[\frac{M\,L\,T^{-2}}{L^{2}}\right]$

ابعاد الانحدار الضغط

$$\left[\frac{d\,p}{d\,X}\right] = \left[\frac{M\,L^{-1}\;T^{-2}}{L}\right] = \left[M\,L^{-2}\;T^{-2}\right]$$

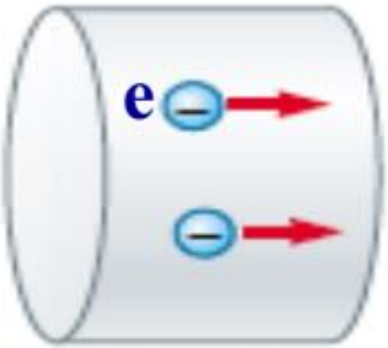
الوحدات : $\left(kg\;\; m^{-2}\,S^{-2}\right)$ or (Pa/m)

Dimension of Derived Quantities
أبعاد الكميات المشتقة

- **Q: Electric Charge**
  الشحنة الكهربية

$$I = \frac{Q}{t}$$

$$Q = I\,t$$



e : **charge of electron**
شحنة الاكترون

Dimension of Q ?

Q: Electric Charge

الشحنة الكهربية

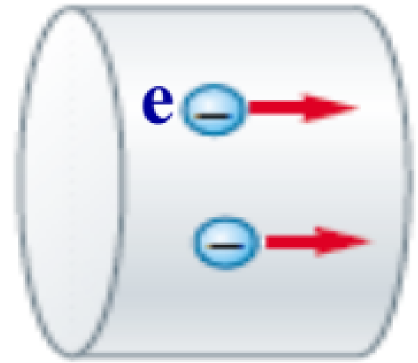
$$Q = I\,t$$

a) $[Q] = [A \;\; s]$

b) $[Q] = [A \;\; T]$

c) $[Q] = [A \;\; t\,]$

d) $[Q] = [\,I \;\; s]$



e : charge of electron

شحنة الالكترون

استنتج ابعاد الجهد الكهربي

Derive dimension of electric potential

$V = I\,R$ ✗

$$\left.\begin{aligned} V &= \frac{W}{Q} = \frac{work}{charge} \\ Power\,(P) &= V\,I \\ Energy\,(E) &= V\,I\,t \end{aligned}\right\} \checkmark$$

ابعاد الجهد الكهربي

Dimension of electric potential

$$[V] = \left[M\,L^2\ T^{-3}\ A^{-1}\right]$$

uints الوحدات

$$\left(Kg\ m^2\,S^{-3}\,A^{-1}\right) = volt$$

استنتج ابعاد المقاومة الكهربية

Derive dimension of electric Resistance

$$V = I\,R$$

$$R = \frac{V}{I}$$

$$[V] = \left[M\,L^{2}\ T^{-3}\ A^{-1}\right]$$

$$[R] = \left[M\,L^{2}\ T^{-3}\ A^{-2}\right]$$

DIMENSIONS AND UNITS

- Any physical quantity can be characterized by dimensions.
- The magnitudes assigned to the dimensions are called units.
- Some basic dimensions such as mass M, length L, time T, and temperature K, electrical Current A are selected as primary or fundamental dimensions, while others such as velocity V, energy E, and volume V are expressed in terms of the primary dimensions and are called secondary dimensions, or derived dimensions.
- Metric SI system:.
- English system

TABLE 1–1

The seven fundamental (or primary) dimensions and their units in SI

Dimension	Unit
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	ampere (A)
Amount of light	candela (cd)
Amount of matter	mole (mol)

TABLE 1–2

Standard prefixes in SI units

Multiple	Prefix
10^{12}	tera, T
10^{9}	giga, G
10^{6}	mega, M
10^{3}	kilo, k
10^{2}	hecto, h
10^{1}	deka, da
10^{-1}	deci, d
10^{-2}	centi, c
10^{-3}	milli, m
10^{-6}	micro, μ
10^{-9}	nano, n
10^{-12}	pico, p

Primary Dimensions in Standard International System (SI) and British Gravitational System (BG)

Primary dimension	SI unit	BG unit	Conversion factor
Mass $\{M\}$	Kilogram (kg)	Slug	1 slug = 14.5939 kg
Length $\{L\}$	Meter (m)	Foot (ft)	1 ft = 0.3048 m
Time $\{T\}$	Second (s)	Second (s)	1 s = 1 s
Temperature $\{\Theta\}$	Kelvin (K)	Rankine (°R)	1 K = 1.8°R

Table1.1 provides a list of dimensions for a number of common physical quantities.

TABLE 1.1

Dimensions Associated with Common Physical Quantities

	MLT System		*MLT* System
Acceleration	LT^{-2}	Moment of inertia (mass)	ML^2
Angle	$M^0L^0T^0$	Momentum	MLT^{-1}
Angular acceleration	T^{-2}	Power	ML^2T^{-3}
Angular velocity	T^{-1}	Pressure	$ML^{-1}T^{-2}$
Area	L^2	Specific heat	$L^2T^{-2}\Theta^{-1}$
Density	ML^{-3}	Specific weight	$ML^{-2}T^{-2}$
Energy	ML^2T^{-2}	Strain	$M^0L^0T^0$
Force	MLT^{-2}	Stress	$ML^{-1}T^{-2}$
Frequency	T^{-1}	Surface tension	MT^{-2}
Heat	ML^2T^{-2}	Temperature	Θ
Length	L	Time	T
Mass	M	Torque	ML^2T^{-2}
Modulus of elasticity	$ML^{-1}T^{-2}$	Velocity	LT^{-1}
Moment of a force	ML^2T^{-2}	Viscosity (dynamic)	$ML^{-1}T^{-1}$
Moment of inertia (area)	L^4	Viscosity (kinematic)	L^2T^{-1}

■ **TABLE 1.3**

Conversion Factors from BG and EE Units to SI Units[a]

	To Convert from	to	Multiply by
Acceleration	ft/s^2	m/s^2	3.048 E − 1
Area	ft^2	m^2	9.290 E − 2
Density	lbm/ft^3	kg/m^3	1.602 E + 1
	$slugs/ft^3$	kg/m^3	5.154 E + 2
Energy	Btu	J	1.055 E + 3
	ft · lb	J	1.356
Force	lb	N	4.448
Length	ft	m	3.048 E − 1
	in.	m	2.540 E − 2
	mile	m	1.609 E + 3
Mass	lbm	kg	4.536 E − 1
	slug	kg	1.459 E + 1
Power	ft · lb/s	W	1.356
	hp	W	7.457 E + 2
Pressure	in. Hg (60 °F)	N/m^2	3.377 E + 3
	lb/ft^2 (psf)	N/m^2	4.788 E + 1
	$lb/in.^2$ (psi)	N/m^2	6.895 E + 3
Specific weight	lb/ft^3	N/m^3	1.571 E + 2
Temperature	°F	°C	$T_C = (5/9)(T_F - 32°)$
	°R	K	5.556 E − 1
Velocity	ft/s	m/s	3.048 E − 1
	mi/hr (mph)	m/s	4.470 E − 1
Viscosity (dynamic)	$lb \cdot s/ft^2$	$N \cdot s/m^2$	4.788 E + 1
Viscosity (kinematic)	ft^2/s	m^2/s	9.290 E − 2
Volume flowrate	ft^3/s	m^3/s	2.832 E − 2
	gal/min (gpm)	m^3/s	6.309 E − 5

TABLE 1.4
Conversion Factors from SI Units to BG and EE Units[a]

	To Convert from	to	Multiply by
Acceleration	m/s^2	ft/s^2	3.281
Area	m^2	ft^2	1.076 E + 1
Density	kg/m^3	lbm/ft^3	6.243 E − 2
	kg/m^3	$slugs/ft^3$	1.940 E − 3
Energy	J	Btu	9.478 E − 4
	J	ft · lb	7.376 E − 1
Force	N	lb	2.248 E − 1
Length	m	ft	3.281
	m	in.	3.937 E + 1
	m	mile	6.214 E − 4
Mass	kg	lbm	2.205
	kg	slug	6.852 E − 2
Power	W	ft · lb/s	7.376 E − 1
	W	hp	1.341 E − 3
Pressure	N/m^2	in. Hg (60 °F)	2.961 E − 4
	N/m^2	lb/ft^2 (psf)	2.089 E − 2
	N/m^2	$lb/in.^2$ (psi)	1.450 E − 4
Specific weight	N/m^3	lb/ft^3	6.366 E − 3
Temperature	°C	°F	$T_F = 1.8\,T_C + 32°$
	K	°R	1.800
Velocity	m/s	ft/s	3.281
	m/s	mi/hr (mph)	2.237
Viscosity (dynamic)	$N \cdot s/m^2$	$lb \cdot s/ft^2$	2.089 E − 2
Viscosity (kinematic)	m^2/s	ft^2/s	1.076 E + 1
Volume flowrate	m^3/s	ft^3/s	3.531 E + 1
	m^3/s	gal/min (gpm)	1.585 E + 4

TABLE 1.5

Approximate Physical Properties of Some Common Liquids (BG Units)

Liquid	Temperature (°F)	Density, ρ (slugs/ft³)	Specific Weight, γ (lb/ft³)	Dynamic Viscosity, μ (lb · s/ft²)	Kinematic Viscosity, ν (ft²/s)	Surface Tension,[a] σ (lb/ft)	Vapor Pressure, p_v [lb/in.² (abs)]	Bulk Modulus,[b] E_v (lb/in.²)
Carbon tetrachloride	68	3.09	99.5	2.00 E − 5	6.47 E − 6	1.84 E − 3	1.9 E + 0	1.91 E + 5
Ethyl alcohol	68	1.53	49.3	2.49 E − 5	1.63 E − 5	1.56 E − 3	8.5 E − 1	1.54 E + 5
Gasoline[c]	60	1.32	42.5	6.5 E − 6	4.9 E − 6	1.5 E − 3	8.0 E + 0	1.9 E + 5
Glycerin	68	2.44	78.6	3.13 E − 2	1.28 E − 2	4.34 E − 3	2.0 E − 6	6.56 E + 5
Mercury	68	26.3	847	3.28 E − 5	1.25 E − 6	3.19 E − 2	2.3 E − 5	4.14 E + 6
SAE 30 oil[c]	60	1.77	57.0	8.0 E − 3	4.5 E − 3	2.5 E − 3	—	2.2 E + 5
Seawater	60	1.99	64.0	2.51 E − 5	1.26 E − 5	5.03 E − 3	2.26 E − 1	3.39 E + 5
Water	60	1.94	62.4	2.34 E − 5	1.21 E − 5	5.03 E − 3	2.26 E − 1	3.12 E + 5

TABLE 1.6

Approximate Physical Properties of Some Common Liquids (SI Units)

Liquid	Temperature (°C)	Density, ρ (kg/m³)	Specific Weight, γ (kN/m³)	Dynamic Viscosity, μ (N · s/m²)	Kinematic Viscosity, ν (m²/s)	Surface Tension,[a] σ (N/m)	Vapor Pressure, p_v [N/m² (abs)]	Bulk Modulus,[b] E_v (N/m²)
Carbon tetrachloride	20	1,590	15.6	9.58 E − 4	6.03 E − 7	2.69 E − 2	1.3 E + 4	1.31 E + 9
Ethyl alcohol	20	789	7.74	1.19 E − 3	1.51 E − 6	2.28 E − 2	5.9 E + 3	1.06 E + 9
Gasoline[c]	15.6	680	6.67	3.1 E − 4	4.6 E − 7	2.2 E − 2	5.5 E + 4	1.3 E + 9
Glycerin	20	1,260	12.4	1.50 E + 0	1.19 E − 3	6.33 E − 2	1.4 E − 2	4.52 E + 9
Mercury	20	13,600	133	1.57 E − 3	1.15 E − 7	4.66 E − 1	1.6 E − 1	2.85 E + 10
SAE 30 oil[c]	15.6	912	8.95	3.8 E − 1	4.2 E − 4	3.6 E − 2	—	1.5 E + 9
Seawater	15.6	1,030	10.1	1.20 E − 3	1.17 E − 6	7.34 E − 2	1.77 E + 3	2.34 E + 9
Water	15.6	999	9.80	1.12 E − 3	1.12 E − 6	7.34 E − 2	1.77 E + 3	2.15 E + 9

TABLE B.2

Physical Properties of Water (SI Units)[a]

Temperature (°C)	Density, ρ (kg/m^3)	Specific Weight[b], γ (kN/m^3)	Dynamic Viscosity, μ ($N \cdot s/m^2$)	Kinematic Viscosity, ν (m^2/s)	Surface Tension[c], σ (N/m)	Vapor Pressure, p_v [N/m^2(abs)]
0	999.9	9.806	1.787 E − 3	1.787 E − 6	7.56 E − 2	6.105 E + 2
5	1000.0	9.807	1.519 E − 3	1.519 E − 6	7.49 E − 2	8.722 E + 2
10	999.7	9.804	1.307 E − 3	1.307 E − 6	7.42 E − 2	1.228 E + 3
20	998.2	9.789	1.002 E − 3	1.004 E − 6	7.28 E − 2	2.338 E + 3
30	995.7	9.765	7.975 E − 4	8.009 E − 7	7.12 E − 2	4.243 E + 3
40	992.2	9.731	6.529 E − 4	6.580 E − 7	6.96 E − 2	7.376 E + 3
50	988.1	9.690	5.468 E − 4	5.534 E − 7	6.79 E − 2	1.233 E + 4
60	983.2	9.642	4.665 E − 4	4.745 E − 7	6.62 E − 2	1.992 E + 4
70	977.8	9.589	4.042 E − 4	4.134 E − 7	6.44 E − 2	3.116 E + 4
80	971.8	9.530	3.547 E − 4	3.650 E − 7	6.26 E − 2	4.734 E + 4
90	965.3	9.467	3.147 E − 4	3.260 E − 7	6.08 E − 2	7.010 E + 4
100	958.4	9.399	2.818 E − 4	2.940 E − 7	5.89 E − 2	1.013 E + 5

Units to remember

- ft = 12 in
- ft = 0.304 m
- in = 0.0254 m

Mass and Weight

Weight and mass are different.

- The unit of *force, called Newton (N), it is defined from Newton's second law as:*

  Force = mass X acceleration

  $$1\text{N} = (1\ \text{kg})(1\ \text{m/s}^2)$$

  ✓ Standard gravity in “SI” units is 9.81m/s^2 so that a 1-kg mass weighs 9.81 N under standard gravity.

- For English system

  the units for Force (weight) is lb or lbf

  the units for mass is lbm

  ✓ Standard gravity in “English system” units is $32.17\ \text{ft/s}^2$ so that a 1-lbm mass weighs 32.17 lb under standard gravity.

Work and Power

- The unit of *work in "SI" units is the joule(J), which is the work done when the point of application of a 1-N force is displaced through a 1-m distance in the direction of a force. Thus,*

  Work = Force X distance

  1 J = 1N.m

- The unit of *power is the watt (W) defined as a joule per second. Thus,*

  Power = Force X velocity

  1W = 1 J/s = 1 N.m/s

  Power = Torque X Angular Velocity

- Sometimes horse power (hp) is used as the unit for the power to convert (hp) into watt (W) multiply by 746

- **Dimensional Homogeneity : All equations must be dimensionally homogeneous.**

Example 1: A useful theoretical equation for computing the relation between pressure, velocity, and altitude in a steady flow of a nearly inviscid, nearly incompressible fluid with negligible heat transfer and shaft work is:

$$p_0 = p + \tfrac{1}{2}\rho V^2 + \rho g Z$$

where p_0 = stagnation pressure
p = pressure in moving fluid
V = velocity
ρ = density
Z = altitude
g = gravitational acceleration

- *Show that Eq. (1) satisfies the principle of dimensional homogeneity, which states that all* additive terms in a physical equation must have the same dimensions.

Solution

We can express Eq. (1) dimensionally, using braces by entering the dimensions of each term from Table 1.2:

$$\{ML^{-1}T^{-2}\} = \{ML^{-1}T^{-2}\} + \{ML^{-3}\}\{L^2T^{-2}\} + \{ML^{-3}\}\{LT^{-2}\}\{L\}$$

$$= \{ML^{-1}T^{-2}\} \text{ for all terms} \qquad \textit{Ans. (a)}$$

Example 2

During a study of a certain flow system, the following equation relating p_1 and p_2 at two points was developed:

$$p_2 = p_1 + \frac{flV}{\mathrm{Dg}}$$

In this equation V is a velocity, l the distance between the two points, D a diameter, g the acceleration of gravity, and f a dimensionless coefficient. Is this equation dimensionally consistent?