01. FISIKA DAN PENGUKURAN

Besaran dan satuan

- Besaran / kuantitas :

  parameter untuk menyatakan suatu hal

  contoh : panjang, tinggi, kecepatan, gaya
- Satuan :

  ukuran dari suatu besaran

  contoh : m, m/s, detik

1.1. Standar panjang, massa, dan waktu

Dalam tahun 1960, panitia internasional membuat standar untuk kuantitas dasar ilmu pengetahuan yang disebut SI (Systeme International).

Satuan panjang = meter
Satuan massa = kilogram
Satuan waktu = detik

Satuan standar lain adalah untuk temperatur (kelvin), arus listrik (ampere), intensitas cahaya (candela), dan jumlah atom/senyawa (mol)

Detik (s, satuan dasar SI untuk waktu)

adalah lamanya 9 192 631 770 periode getaran atom Cesium-133.

Meter (m, satuan dasar untuk panjang)

adalah jarak perjalanan cahaya dalam vakum 1/299 792 458 detik

Kilogram (Kg, satuan dasar untuk berat)

massa silinder platinum-iridium yang dijaga di International Bureau of Weights and Measures di Sevres, Prancis.

Kelvin, symbol K, sama dengan 1/273,16 temperatur termodinamika pada titik tripel air

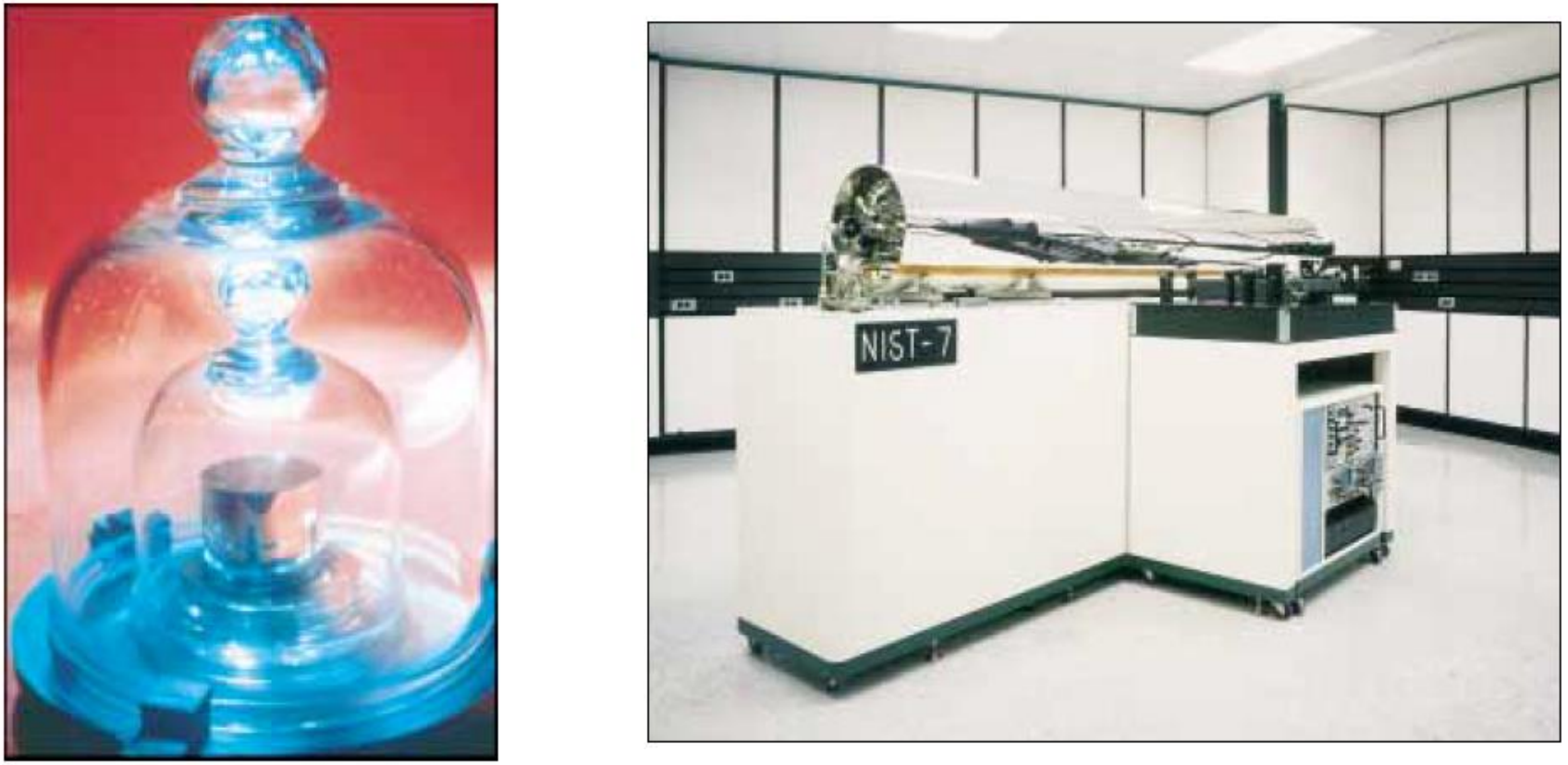

Figure 1.1 *(Top)* The National Standard Kilogram No. 20, an accurate copy of the International Standard Kilogram kept at Sèvres, France, is housed under a double bell jar in a vault at the National Institute of Standards and Technology (NIST). *(Bottom)* The primary frequency standard (an atomic clock) at the NIST. This device keeps time with an accuracy of about 3 millionths of a second per year. *(Courtesy of National Institute of Standards and Technology, U.S. Department of Commerce)*

Dalam perhitungan, sebaiknya satuan tetap diikutkan dengan keuntungan :

1. Mengurangi kemungkinan kesalahan yang terjadi selama perhitungan
2. Pendekatan logikal untuk persamaan daripada mengingat rumus
3. Interpretasi hasil pengukuran lebih mudah

TIDAK BOLEH menjumlahkan atau mengurangi kuantitas yang sama dengan satuan yang berbeda dengan dimensi yang berbeda

contoh 5 kg + 3 joule

tetapi jika satuan berbeda namun dimensi sama, maka BOLEH, dengan menyamakan satuan terlebih dahulu

contoh 10 lb + 5 g

BOLEH membagi dan mengalikan kuantitas yang berbeda, dengan satuan hasil juga ikut dibagi atau dikali

contoh 50 kg.m/detik

1.2. Analisa Dimensi

Simbol

Dimensi panjang = L

Dimensi massa = M

Dimensi waktu = T

Dimensi kuantitas fisik diberi tanda [ ]

Contoh

[v] = L/T

[A] = L^2

Units of Area, Volume, Velocity, Speed, and Acceleration

System	Area (L^2)	Volume (L^3)	Speed (L/T)	Acceleration (L/T^2)
SI	m^2	m^3	m/s	m/s^2
U.S. customary	ft^2	ft^3	ft/s	ft/s^2

example

Show that the expression $v = at$ is dimensionally correct, where v represents speed, a acceleration, and t an instant of time.

example

Suppose we are told that the acceleration *a* of a particle moving with uniform speed *v* in a circle of radius *r* is proportional to some power of *r,* say r^n, and some power of *v,* say v^m. Determine the values of *n* and *m* and write the simplest form of an equation for the acceleration.

$$a = kr^n v^m$$

EXAMPLE 1.4 The Density of a Cube

The mass of a solid cube is 856 g, and each edge has a length of 5.35 cm. Determine the density ρ of the cube in basic SI units.

1.3. Sistem Satuan

Sistem satuan Inggris

mil (mile), yar (yard), inci (inchi) untuk mengukur besaran panjang.

Sistem Internasional

meter, cm, untuk besaran panjang

Sistem Satuan Internasional

Physical Quantity	Name of Unit	Symbol for Unit*	Definition of Unit
	Basic SI Units		
Length	metre, meter	m	
Mass	kilogramme, kilogram	kg	
Time	second	s	
Temperature	kelvin	K	
Amount of substance	mole	mol	
	Derived SI Units		
Energy	joule	J	$kg \cdot m^2 \cdot s^{-2}$
Force	newton	N	$kg \cdot m \cdot s^{-2} \rightarrow J \cdot m^{-1}$
Power	watt	W	$kg \cdot m^2 \cdot s^{-3} \rightarrow J \cdot s^{-1}$
Density	kilogram per cubic meter		$kg \cdot m^{-3}$
Velocity	meter per second		$m \cdot s^{-1}$
Acceleration	meter per second squared		$m \cdot s^{-2}$
Pressure	newton per square meter, pascal		$N \cdot m^{-2}$, Pa
Heat Capacity	joule per (kilogram · kelvin)		$J \cdot kg^{-1} \cdot K^{-1}$
	Alternative Units		
Time	minute, hour, day, year	min, h, d, y	
Temperature	degree Celsius	°C	
Volume	litre, liter (dm^3)	L	
Mass	tonne, ton (Mg), gram	t, g	

Sistem engineering Inggris/Amerika

Physical Quantity	Name of Unit	Symbol
	Basic Units	
Length	feet	ft
Mass	pound (mass)	lb_m
Force	pound (force)	lb_f
Time	second, hour	s, hr
Temperature	degree Rankine	°R
	Derived Units	
Energy	British thermal unit, foot pound (force)	Btu, $(ft)(lb_f)$
Power	horsepower	hp
Density	pound (mass) per cubic foot	lb_m/ft^3
Velocity	feet per second	ft/s
Acceleration	feet per second squared	ft/s^2
Pressure	pound (force) per square inch	$lb_f/in.^2$
Heat capacity	Btu per pound (mass) per degree F	$Btu/(lb_m)(°F)$

Awalan Metrik

TABLE 1.4 Prefixes for SI Units

Power	Prefix	Abbreviation
10^{-24}	yocto	y
10^{-21}	zepto	z
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{1}	deka	da
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z
10^{24}	yotta	Y

1.4. Konversi Satuan

(Billy E. Barnes/Stock Boston).

(Paul Silverman/Fundamental Photographs)

1.4. Konversi Satuan

Contoh :

1.Jika sebuah pesawat dapat berjalan dengan kecepatan dua kali kecepatan suara (asumsi kecepatan suara 1100 ft/detik), berapa kecepatannya dalam mil/jam?

2.Ubah 400 in^3/hari menjadi cm^3/menit

3.Ubahlah satuan debit air 1000 L/jam ke dalam cuft/menit !

1 kg = 2,21 lb = 6,02 x 10^{26} μ
1 kg = 6,022 x 10^{23} u
1 kg = 6,852 x 10^{-2} slug
1 kg = 2,20462 lb_m
1 u = 1,6606 x 10^{-27} kg
1 u = 931,50 MeV/c^2
1 slug = 14,5 kg

Massa Jenis

(1 g/cm^3)g = 62,4 lb/ft^3
1 kg/m^3 = 0,06243 lb_m/ft^3

Panjang

1 km = 0,6215 mil
1 mil = 1,609 km
1 inci = 2,54 cm
1 ft = 12 inci
1 ft = 30,48 cm
1 ft = 0,3048 m
1 yard = 3 ft
1 yard = 91,44 cm
1 m = 1,0936 yard
1 m = 3,2808 ft
1 m = 39,37 inci
1 Å = 0,1 nm

Luas

1 m^2 = 10^4 cm^2
1 m^2 = 10,7639 ft^2
1 km^2 = 0,3861 mil^2
1 km^2 = 247,1 are
1 mil^2 = 640 are
1 mil^2 = 2,590 km^2
1 are = 43.560 ft^2
1 ft^2 = 9,29 x 10^{-2} m^2

1 mil/jam = 0,4470 m/s
1 mil/jam = 1,609 km/jam
1 mil/jam = 1,467 ft/sekon
1 knot = 1,151 mil/jam
1 knot = 0,5144 m/s

Volum

1 m^3 = 1.000.000 cm^3
1 m^3 = 35,3134 ft^3
1 L = 1000 cm^3
1 L = 10^{-3} m^3
1 L = 61 $inci^3$
1 gal = 3,786 L
1 gal = 4 qt
1 gal = 8 pt
1 gal = 128 oz
1 gal = 231 $inci^3$
1 $inci^3$ = 16,39 cm^3
1 ft^3 = 1728 $inci^3$
1 ft^3 = 28,32 L
1 ft^3 = 2,832 x 10^4 cm^3

Gaya

1 N = 0,2248 lb
1 N = 0,2248 lb_f
1 N = 10^5 dyne
1 lb = 4,4482 N
(1 kg)g = 2,2046 lb
1 lb = 4,45 N

Tekanan

1 Pascal = 1 N/m^2
1 Pascal = 1 kg/m.s^2Hg
1 atm = 101,325 kPa
1 atm = 1,01325 bar

1 torr = 133,32 Pa
1 lb/$inci^2$ = 6,895 kPa
1 N/m^2 = 1,45038 x 10^{-4} lb_f/$inci^2$

Energi, Kalor

1 kWh = 3,6 MJ
1 kal = 4,1840 J
1 kJ = 0,94783 Btu
1 J = 10^7 erg
1 J = 1 Watt/s
1 L.atm = 101,325 J
1 L.atm = 24,217 kal
1 ft.lb_f = 1,356 J
1 ft.lb = 1,286 x 10^{-3} Btu
1 Btu = 778 ft.lb
1 Btu = 252 kal
1 Btu = 1054,35 J
1 Btu = 1,05504 kJ
1 eV = 1,602 x 10^{-19} J
1 eV = 1,60 x 10^{-12} erg

Daya

1 W = 1,341 x 10^{-3} HP
1 W = 0,7376 ft.lb/s
1 HP = 764 W
1 HP = 745,7 W
1 HP = 550 ft.lb/s

Thermal Conductivity (*k*)

1 W/m.°C = 0,5778 Btu/jam.ft.°F
1 Btu/jam.ft.°F = 1,7307 W/m.°C
1 W/m.K = 6,938 Btu.inci/jam.ft^2.°F
1 Btu.inci/jam.ft^2.°F = 0,1441 W/m.K

1 Btu/jam.ft^2 = 3,154 W/ m^2

Fluks Kalor per Panjang Satuan (*q/L*)

1 W/m = 1,0403 Btu/jam.ft
1 Btu/jam.ft = 0,9613 W/m

Pembangkitan Kalor per Volum Satuan (*q*)

1 W/m^3 = 0,096623 Btu/jam.ft^3
1 Btu/jam.ft^3 = 10,35 W/m^3

Suhu/Temperatur

$C = \frac{5}{4} R$ $F = \frac{9}{4} R + 32$
$C = \frac{5}{9} (F - 32)$ $F = \frac{9}{5} C + 32$
$R = \frac{4}{5} C$ $K = C + 273$
$R = \frac{4}{9} (F - 32)$

Kalor Spesifik (*c*)

1 kJ/kg.°C = 0,23884 Btu/lb_m.°F
1 Btu/lb_m.°F = 4,1869 kJ/kg.°C

Koefisien Perpindahan Kalor Konveksi (*h*)

1 W/m^2.°C = 0,1761 Btu/jam.ft^2.°F
1 Btu/jam.ft^2.°F = 5,6782 W/m^2.°C

Viskositas Dinamik (*μ*)

1 kg/m.s = 0,672 lb_m/ft.s
1 kg/m.s = 2419,2 lb_m/ft.jam
1 lb_m/ft.s = 1,4881 kg/m.s

Viskositas Kinematik dan Difusivitas Termal (*v,α*)

1 m^2/s = 10,3679 ft^2/s
1 ft^2/s = 0,092903 m^2/s

Contoh Tabel Konversi

Length	*1 in.	:	25.4 mm
	*1 ft	:	0.3048 m
	*1 yd	:	0.9144 m
	1 mile	:	1.6093 km
	*1 Å(angstrom)	:	10^{-10} m
Time	*1 min	:	60 s
	*1 h	:	3.6 ks
	*1 day	:	86.4 ks
	1 year	:	31.5 Ms
Area	*1 $in.^2$	:	645.16 mm^2
	1 ft^2	:	0.092903 m^2
	1 yd^2	:	0.83613 m^2
	1 acre	:	4046.9 m^2
	1 $mile^2$	:	2.590 km^2
Volume	1 $in.^3$	:	16.387 cm^3
	1 ft^3	:	0.02832 m^3
	1 yd^3	:	0.76453 m^3
	1 UK gal	:	4546.1 cm^3
	1 US gal	:	3785.4 cm^3
Mass	1 oz	:	28.352 g
	*1 lb	:	0.45359237 kg
	1 cwt	:	50.8023 kg
	1 ton	:	1016.06 kg
Force	1 pdl	:	0.13826 N
	1 lbf	:	4.4482 N
	1 kgf	:	9.8067 N
	1 tonf	:	9.9640 kN
	*1 dyn	:	10^{-5} N

Contoh Tabel Konversi

Temperature difference	*1 deg F (deg R)	:	$\frac{5}{9}$ deg C (deg K)
Energy (work, heat)	1 ft lbf	:	1.3558 J
	1 ft pdl	:	0.04214 J
	*1 cal (internat. table)	:	4.1868 J
	1 erg	:	10^{-7} J
	1 Btu	:	1.05506 kJ
	1 hp h	:	2.6845 MJ
	*1 kW h	:	3.6 MJ
	1 therm	:	105.51 MJ
	1 thermie	:	4.1855 MJ
Calorific value (volumetric)	1 Btu/ft^3	:	37.259 kJ/m^3
Velocity	1 ft/s	:	0.3048 m/s
	1 mile/h	:	0.44704 m/s
Volumetric flow	1 ft^3/s	:	0.028316 m^3/s
	1 ft^3/h	:	7.8658 cm^3/s
	1 UK gal/h	:	1.2628 cm^3/s
	1 US gal/h	:	1.0515 cm^3/s
Mass flow	1 lb/h	:	0.12600 g/s
	1 ton/h	:	0.28224 kg/s
Mass per unit area	1 lb/in.^{2}	:	703.07 kg/m^2
	1 lb/ft^2	:	4.8824 kg/m^2
	1 ton/sq mile	:	392.30 kg/km^2
Density	1 lb/in^3	:	27.680 g/cm^3
	1 lb/ft^3	:	16.019 kg/m^3
	1 lb/UK gal	:	99.776 kg/m^3
	1 lb/US gal	:	119.83 kg/m^3

Pressure	1 lbf/in.^{2}	:	6.8948 kN/m^2
	1 tonf/in.^{2}	:	15.444 MN/m^2
	1 lbf/ft^2	:	47.880 N/m^2
	*1 standard atm	:	101.325 kN/m^2
	*1 atm (1 kgf/cm^2)	:	98.0665 kN/m^2
	*1 bar	:	10^5 N/m^2
	1 ft water	:	2.9891 kN/m^2
	1 in. water	:	249.09 N/m^2
	1 in. Hg	:	3.3864 kN/m^2
	1 mmHg (1 torr)	:	133.32 N/m^2
Power (heat flow)	1 hp (British)	:	745.70 W
	1 hp (metric)	:	735.50 W
	1 erg/s	:	10^{-7} W
	1 ft lbf/s	:	1.3558 W
	1 Btu/h	:	0.29307 W
	1 ton of refrigeration	:	3516.9 W
Moment of inertia	1 lb ft^2	:	0.042140 kg m^2
Momentum	1 lb ft/s	:	0.13826 kg m/s
Angular momentum	1 lb ft^2/s	:	0.042140 kg m^2/s
Viscosity, dynamic	*1 P (Poise)	:	0.1 N* s/m^2
	1 lb/ft h	:	0.41338 mN s/m^2
	1 lb/ft s	:	1.4882 N s/m^2
Viscosity, kinematic	*1 S (Stokes)	:	10^{-4} m^2/s
	1 ft^2/h	:	0.25806 cm^2/s
Surface energy (surface tension)	1 erg/cm^2 (1 dyn/cm)	:	10^{-3} J/m^2 (10^{-3} N/m)
Mass flux density	1 lb/h ft^2	:	1.3562 g/s m^2
Heat flux density	1 Btu/h ft^2	:	3.1546 W/m^2
	*1 kcal/h m^2	:	1.163 W/m^2
Heat transfer coefficient	1 Btu/h ft^2 F	:	5.6783 W/m^2 K
Specific enthalpy (latent heat, etc.)	*1 Btu/lb	:	2.326 kJ/kg
Specific heat capacity	*1 Btu/lb °F	:	4.1868 kJ/kg K
Thermal conductivity	1 Btu/h ft °F	:	1.7307 W/m K
	1 kcal/h m °C	:	1.163 W/m K