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Teknik Elektro - STEI ITB

Aspek-Aspek Rekayasa dan Metode Penyelesaian Masalah

KU1202 – Pengantar Rekayasa dan Desain

Luaran pertemuan pekan kedua

- Mahasiswa memahami bahwa dalam rekayasa diperlukan beberapa aturan (satuan, patent, copyright, trade secret, trade mark)
- Mahasiswa memahami pentingnya satuan dan konversi satuan
- Mahasiswa memahami pentingnya angka penting

Engineering Products

FIGURE 1.3 As an engineer you will apply physical and chemical laws and principles and mathematics to design various products and services.

Engineering Products

Product Categories

CES showcases companies including manufacturers, developers and suppliers of consumer technology hardware, content, technology delivery systems and more.

Exhibitors feature products from all facets of the consumer technology industry, including 5G connectivity, artificial intelligence, augmented and virtual reality, smart cities, sports, robotics and more.

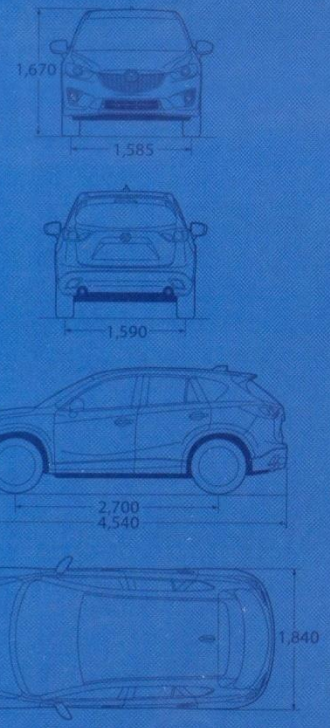
- 5G Technologies
- Accessibility
- Accessories
- AR/VR/XR
- Artificial Intelligence
- Audio Technologies
- Blockchain
- Car Audio
- Cloud Computing/Data
- Cybersecurity
- Digital Currency/Cryptocurrency
- Digital Health
- Digital Imaging and 3D Printing
- Drones
- Education

- Energy/Power
- Entertainment and Content
- Family and Lifestyle
- Fintech
- Fitness and Wearables
- Gaming and Esports
- High-Tech Retailing/E-Commerce
- Home Entertainment Hardware
- Home Office Hardware and Accessories
- Investing
- IoT/Sensors
- Marketing and Advertising
- Mobile Hardware and Accessories

- Privacy
- Quantum Computing
- Robotics
- Smart Cities and Resilience
- Smart Home and Appliances
- Sourcing and Manufacturing
- Sports Technology
- Startups
- Streaming
- Sustainability
- Travel and Tourism
- Vehicle Tech
- Video Technologies
- Wellness Technologies

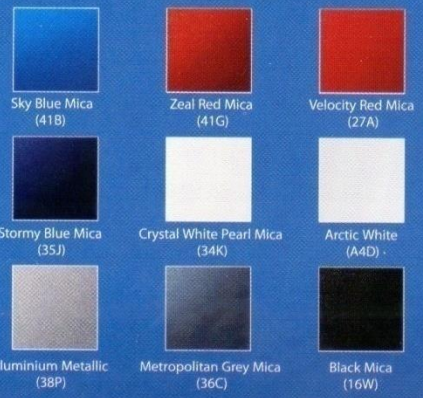
http://www.windsor.ie/new-cars/Mazda/CX-5.aspx

DIMENSIONS



Unit: mm

COLORS



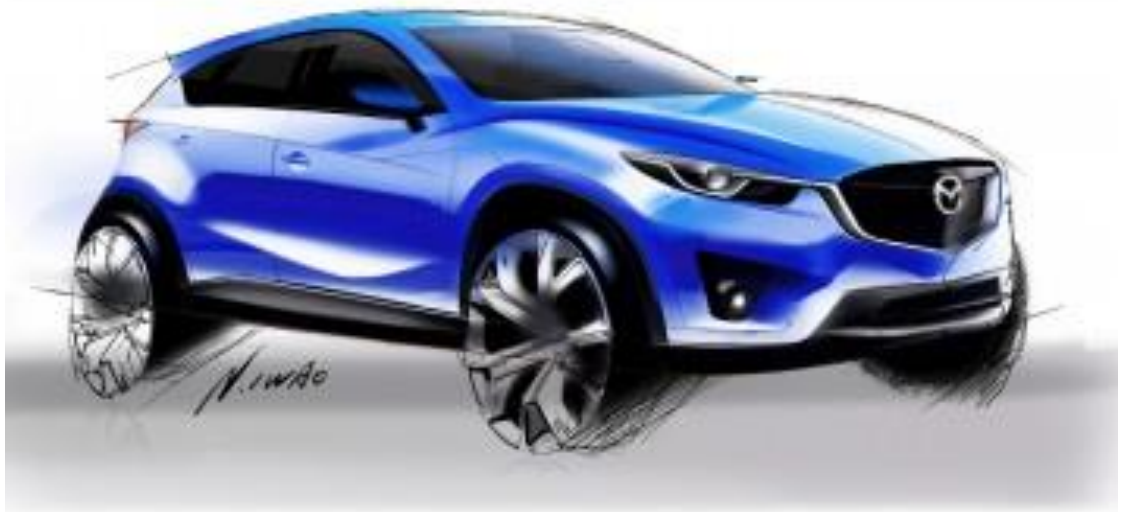
Not all colors are available at all times. Please ask your dealer for advise on color availability.

SPECIFICATIONS

Mazda CX-5		
Transmission	SKYACTIV-DRIVE 6-Speed Manual	SKYACTIV-DRIVE 6-Speed ACTIVEMATIC
Engine		
Type	SKYACTIV-G In-line 4-Cylinder DOHC, 16 Valves	
Displacement	1,997cc	
Bore and Stroke	83.5 x 91.2	
Compression Ratio	14 : 1	
Maximum Output	162hp @ 6,000rpm	
Maximum Torque	210Nm @ 4,000rpm	
Fuel Tank Capacity	56 Liters	
Emissions	Euro Stage 4	
Fuel System	Direct Injection	
Recommended Fuel	95RON or above	
Chassis		
Suspension	MacPherson Struts (front)	
	Multi-link beam (rear)	
Brakes	Ventilated Discs (front)	
	Discs (Rear)	
Tires	225/65R17	
Wheels	17X7J Aluminum wheels	
Dimensions		
Overall Length	4,540mm	
Overall Width	1,840mm	
Overall Height	1,670mm (without roof rails and antenna)	
Wheelbase	2,700mm	
Tread (front/rear)	1,585mm/1,590mm	
Min. Ground Clearance	215mm	
Luggage Capacity	490 Liters	
Min. Turning Radius	5.6m	
Curb Weight	1,375kg	1,405kg
Exterior		
Front Wipers	Time adjustable intermittent	
Headlamps	Halogen projector type	
Rear Wiper	Time adjustable intermittent	
Side turn lamps	Side mirror integrated	
Fog Lamps	Standard	
Antenna type	Shark fin	
Interior		
Steering wheel controls	audio and cruise control	
Entertainment	TFT multi-info display with CD, MP3, Aux in, Bluetooth voice control function	
Airconditioning System	Dual-Zone climate control	
Upholstery and door trim	Fabric	
Safety and Security		
Airbags	Driver + Passenger, side and curtain	
ABS	with EBD, BA, DSC, TCS	
Tire Pressure Monitoring System	Standard	
Seatbelts (front/rear)	3-pt ELR x2 with pretensioner and load limiter / 3-pt ELR & ALR x2 + 3pt ELR x1	
Immobilizer	Standard	
Burglar Alarm	Standard	
Keyless Entry System	Standard	

UP-ROEL
E-123 2,4

Artistic design concept



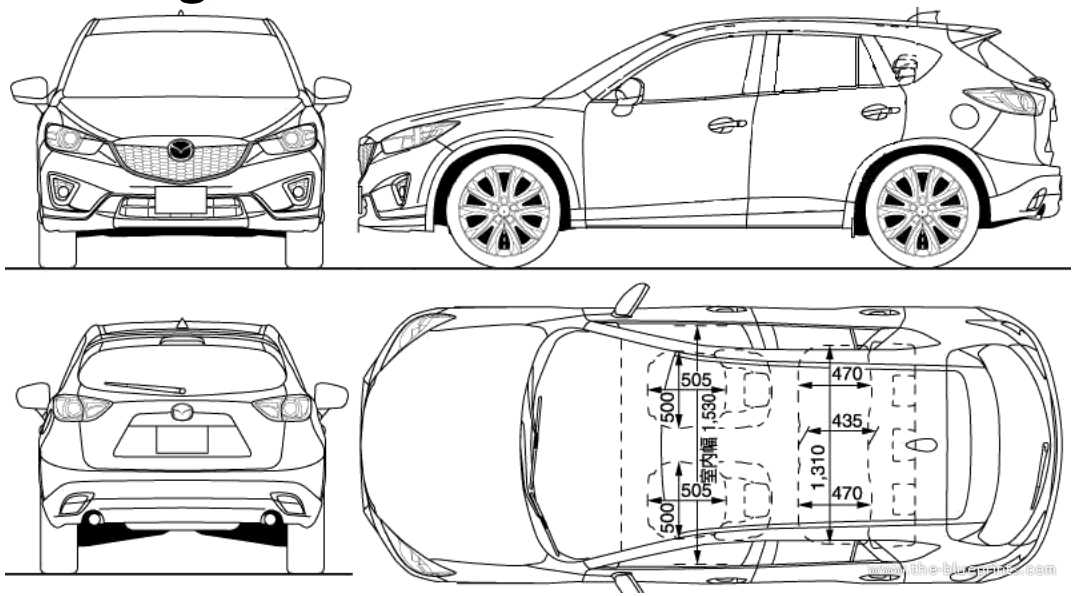
'KODO - Soul of Motion‘ (2010)

www.mazda.com.au/design/kodo-design-language

World.honda.com/design/designers-talk/civic/concept

Beberapa Aturan dalam Rekayasa

- Standard :
  - ISO : International Standardization Office (www.iso.org)
  - ASME : American Society of Mechanical Engineers (www.asme.org)
  - ASTM : American Society for Testing and Materials (www.astm.org)
  - IEEE : Institute of Electrical and Electronics Engineers (www.ieee.org)



Beberapa Aturan dalam Rekayasa

- Intellectual Property Right (IPR)
  - Trade Mark (ekspresi dan/atau lambang yang mengidentifikasi suatu produk)
    - www.trademarksnet.com/Trademark
    - Contoh : SKYACTIVE® , Apple, iPod, iPad, etc
  - Patent (hak eksklusif penemu untuk memanfaatkan temuannya - berkaitan dengan benda fisik) : www.uspto.org
    - Contoh : Sky Active technology, (engine+transmission+chassis+body) 150 patents
      - High compressive ration 14:1 (gasoline engine)
      - 4-2-1 exhaust system, cavity piston etc
  - Copyright (hak eksklusif penemu untuk memanfaatkan temuannya- berkaitan dengan benda non fisik)
    - Contoh : musik, tulisan, dll
  - Industrial design right (melindungi desain visual dari sebuah benda khusus tertentu)
  - Trade dress (melindungi dari produk lain yang menyerupai)
  - Trade secret (informasi produk yang dirahasiakan)

Kantor HAKI Indonesia : Dirjen HAKI, Kemenkumham : wwww.dgip.go.id

Elemen Kunci Analisis Rekayasa

- Harga numerik (numerical value)
- Variabel (Variable)
- Dimensi (Dimension)
- Satuan (Units)
- Angka penting (Significant figure)

- How heavy is the manual version ?
  - Curb weight = 1375 kg

Variabel (mass) Harga numerik satuan

- How long is the wheel base ?
  - Length = 2700 mm

Variabel, Besaran dan Satuan

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Tires	225/65R17	
Wheels	17X7J Aluminum wheels	
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Overall Height	1,670mm (without roof rails and antenna)	
Wheelbase	2,700mm	
Tread (front/rear)	1,585mm/1,590mm	
Min. Ground Clearance	215mm	
Luggage Capacity	490 Liters	
Min. Turning Radius	5.6m	
Curb Weight	1,375kg	1,405kg

- Apa beda ‘satuan’ dengan ‘dimensi’ ?
  - kg = massa [M]

satuan dimensi

  - m = panjang [L]
  - s = waktu [T]
  - N = kg. m/s^2 [M.L.T^{-2}]
- Satuan :
  - cara mengkuantifikasi konsep dimensi
  - Kesepakatan, dapat berbeda-beda sesuai kebiasaan
- Dimensi :
  - Ukuran dasar yang dapat diukur langsung
  - Contoh : massa, panjang, waktu

SI (Le Système International d'Unités)

- Satuan dasar : m, kg, s, K, mol, A

Table 2.2 Some Derived SI Units

Quantity	Name	Symbol	Formula	Fundamental Units
Frequency	hertz	Hz	1/s	s^{-1}
Force	newton	N	$kg \cdot m/s^2$	$m \cdot kg \cdot s^{-2}$
Energy	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
Power	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
Electric charge	coulomb	C	$A \cdot s$	$A \cdot s$
Electric potential	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
Electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
Electric capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$

Dari Kosky et al

SI (Le Système International d'Unités)

Quantity	Symbol	Unit	Unit symbol	Dimensions
Length	l	meter	m	$[L]$
Mass	m	kilogram	kg	$[M]$
Time	t	second	s	$[T]$
Area	A	square meter	m^2	$[L^2]$
Volume	V	cubic meter	m^3	$[L^3]$
Velocity	v	meter per second	m/s	$[LT^{-1}]$
Acceleration	a	meter per second per second	m/s^2	$[LT^{-2}]$
Force	F	newton	N	$[MLT^{-2}]$
Pressure	p	newton per square meter	N/m^2	$[ML^{-1}T^{-2}]$
Work	W	joule	J	$[ML^2T^{-2}]$
Power	P	watt	W	$[ML^2T^{-3}]$
Electric current	I	ampere	A	$[I]$
Electric charge	Q	coulomb	C	$[IT]$
Emf	V	volt	V	$[ML^2T^{-3}I^{-1}]$
Electric field strength	ξ	volt per meter	V/m	$[MLT^{-3}I^{-1}]$
Resistance	R	ohm	Ω	$[ML^2T^{-3}I^{-2}]$
Capacitance	C	farad	F	$[M^{-1}L^{-2}T^4I^2]$
Inductance	L	henry	H	$[ML^2T^{-2}I^{-2}]$
Magnetic field strength	H	ampere per meter	A/m	$[IL^{-1}]$
Magnetic flux	Φ	weber	Wb	$[ML^2T^{-2}I^{-1}]$
Magnetic flux density	B	tesla	T	$[MT^{-2}I^{-1}]$

SI (Le Système International d'Unités)

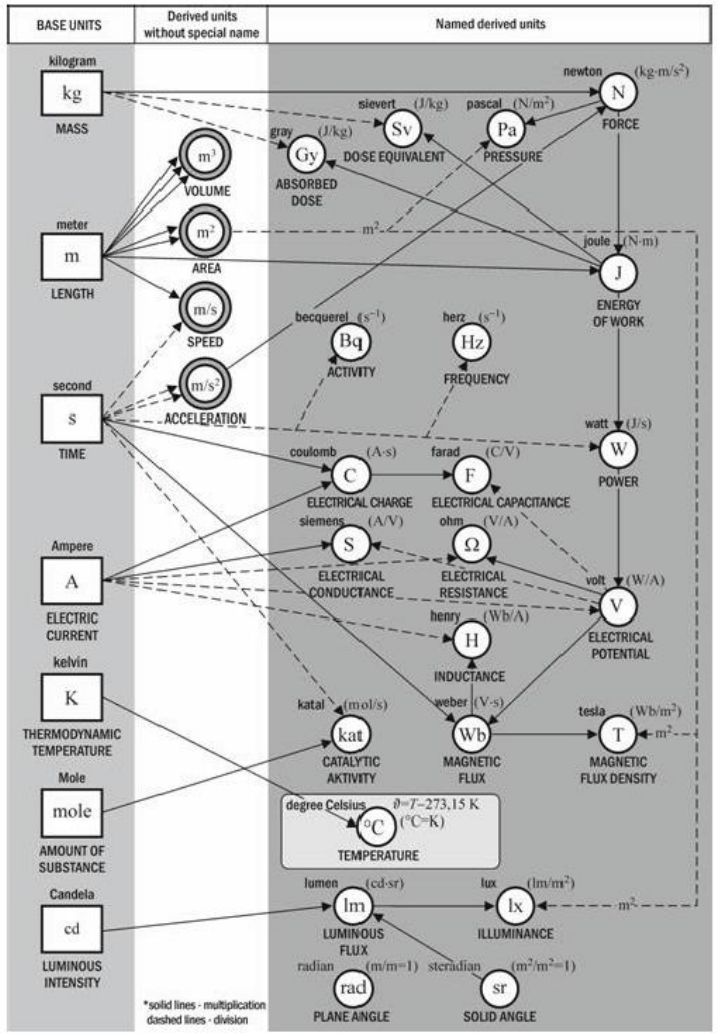


Figure 1.2 SI system – the relationship of base and derived units

Table 1.2 Representation of SI units, Symbols, and Dimensions

Quantity	*Symbol*	*Units*	*Unit Symbol*	*Dimensions*
Fundamental Units				
Mass	*m*	kilogram	kg	[*M*]
Length	*l*	metre	m	[*L*]
Time	*t*	second	s	[*T*]
Electric current	*I*	ampere	A	[*I*]
Thermodynamic temperature	*T*	kelvin	K	[Θ]
Luminous intensity		candela	cd	
Supplementary Units				
Solid angle	Ω	steradian	sr	$[L^2]^\circ$
Plane angle	α, β, γ	radian	rad	$[L]^\circ$
Derived Units				
Area	*A*	square metre	m^2	$[L^2]$
Volume	*V*	cubic metre	m^3	$[L^3]$
Frequency	*f*	hertz	Hz	$[T^{-1}]$
Density	ρ	kilogram per cubic metre	kg/m^3	$[L^{-3}M]$
Velocity	*u*	metre per second	m/s	$[LT^{-1}]$
Angular velocity	ω	radian per second	rad/s	$[L^\circ T]$
Acceleration	*a*	metre per second squared	m/s^2	$[LT^{-2}]$
Angular acceleration	α	radian per second squared	rad/s^2	$[L^\circ T^{-2}]$
Force	*F*	newton	$N(kgm/s^2)$	$[LMT^{-2}]$
Pressure, Stress	*p*	newton per square metre	N/m^2	$[L^{-1}MT^{-2}]$
Work, Energy	*W*	joule	J(N m)	$[L^2MT^{-2}]$
Power	*P*	watt	W(J/s)	$[L^2MT^{-3}]$
Quantity of electricity	*Q*	coulomb	C(A s)	[*TI*]
Potential difference, Electromotive force	*V*	volt	V(W/A)	$[L^2MT^{-3}I^{-1}]$
Electric resistance	*R*	ohm	Ω(V/A)	$[L^2MT^{-3}I^{-2}]$
Electric capacitance	*C*	farad	F(As/V)	$[L^{-2}M^{-1}T^4I^2]$
Electric field strength	*E*, ε	volt per metre	V/m	$[LMT^{-3}I^{-1}]$
Magnetic field strength	*H*	ampere per metre	A/m	$[L^{-1}I]$
Magnetic flux	Φ	weber	Wb(v s)	$[L^2MT^{-2}I^{-1}]$
Magnetic flux density	*B*	tesla	$T(Wb/m^2)$	$[MT^{-2}I^{-1}]$
Inductance	*L*	henry	H(Vs/A)	$[L^2MT^{-2}I^2]$
Magnetomotive force	*U*	ampere	A	[*I*]
Luminous flux		lumen	lm(cd sr)	
Luminance		candela per square metre	cd/m^2	
Illumination		lux	$lx(lm/m^2)$	

Satuan dalam praktek

- MKS (Metric system, meter-kilogram-second)
- Old English (British) (FPS, feet-pounds-second)
- US Customary Unit (FPS)

Pa (Pascal)
psi (pound per square inch)
rpm (rotation per minute)
in (inch)
ft (feet)
kgf (kilogram force)

mile statut mile
nm nautical mile
kts knots
lb (pound mass/force ??)
gal US gallon
Barrel US barrel

Gaya dalam berbagai Sistem Satuan

- SI :

$$F = m\,a$$

- MKS, British, US :

$$F = m\,\frac{a}{g_c}$$

$$g_c = |g|\,\frac{kg \cdot m}{kgf \cdot s^2} \qquad |g| = 9{,}81$$

$$g_c = |g|\,\frac{lbm \cdot ft}{lbf \cdot s^2} \qquad |g| = 32{,}174$$

  - MKS
  - British, US :

Konversi Satuan

Dimensi	SI	MKS	US
Panjang	m	m	1 ft = 12 in = 0,3048 m
Massa	kg	kgm	1 lbm = 0,4536 kg
Percepatan gravitasi	9,81 m/s2	9,81 m/s^2	32,174 ft/s^2
gaya	N = kg m/s^2	1 kgf = 9,81 N	1 lbf = 4.448 N
tekanan	Pa = N/m^2	kgf/cm^2 = 98.0665 kPa	1 psi = 1 lbf/in^2 = 6,895 kPa

SENSE OF NUMBERS

Panjang : 1 m , 10 ft , 42 in, …
Kecepatan : 1 m/s , 50 kmh , 200 kts , …
Gaya : 1 N, 20 lbf, …
Tekanan : 30 psi, …

Konversi Satuan

MODEL	City (mpg)	Combined (mpg)	Highway (mpg)
2WD 4cyl, 2.0L, Automatic (S6), reg gasoline	26	29	32
2WD 4cyl, 2.0L, Manual 6-spd, reg gasoline	26	29	35
4WD 4cyl, 2.0L, Automatic (S6), reg gasoline	25	28	31

Berapa dalam km per liter ? (1US gallon = 3,785 liter)

Soal Latihan

1. Tekanan bejana, p = 350 psi = ...kgf/cm^2 = ... MPa
2. Bahan bejana, $\sigma_{allowable}$ = σ_{boleh} = 15000 psi = 15 ksi = ... kgf/mm^2 = ... MPa
3. Spesifikasi bahan, St.37, S_u = 37 kgf/mm^2 = ... ksi
4. Berat jenis baja, γ = 7,8 kgf/dm^3 = ... lbf/in^3
5. Modulus elastis baja, E = 200 GPa = ... psi
6. Nilai kalor (HHV: higher heating value) LNG 10000 kcal/m^3 = ... kWh/m^3 = ... MM Btu/ft^3

- Panjang kendaraan = 4541,237 mm
- Diplacement = 1997,441 cm^3
- How many of those digits really matter?
  - How many of those digits actually contribute toward achieving the purpose of engineering (to design useful objects and systems and to understand, predict, and control their function in useful ways) ?

Angka Penting

- Contoh :
  - 254,2 = ... angka penting
  - 100 = ... angka penting
  - 254,2 + 100 = ...
  - 100 / 254,2 = ...
- Berapa konsumsi bahan bakar (km/lt) sebuah kendaraan yang menempuh 42 km dan menghabiskan 4,3 lt bahan bakar ?
- Berapa konsumsi bahan bakar (km/lt) sebuah kendaraan yang menempuh 42,21 km dan menghabiskan 4,3 lt bahan bakar ?

Angka Penting

- Jumlah angka penting dalam sebuah bilangan
  - Lebih mudah dinyatakan dalam angka saintifik : A x10^n
  - 543,23 = 5,4323 x 10^2 => 5 angka penting
  - 120 = 1,2 x 10^2 (2 angka penting) atau 1,20 x 10^2 (3 ap)
  - 0,00221 = 2,21 x 10^{-3} (3 angka penting)
- Operasi Aritmetika
  - Penjumlahan/pengurangan
    - Hasil operasi mengikuti jumlah angka desimal terkecil.
  - Perkalian/pembagian
    - Hasil operasi mengikuti jumlah angka penting terkecil.
  - Pembulatan
    - Pembulatan ke bawah : jika angka desimal yang dibulatkan <5
    - Pembulatan ke atas : jika angka desimal yang dibulatkan >=5

The “NEED-KNOW-HOW-SOLVE” Method

Suatu metoda penyelesaian masalah

Langkah penyelesaian masalah:

- Need : apa yang harus dijawab
- Know : apa yang diketahui
- How : memodelkan dan menjelaskan proses penyelesaian
- Solve : melakukan perhitungan untuk mencari jawaban
- (Check) : men-cek kembali jawaban (jika diperlukan)

Langkah Need-know-how-solve membantu Anda dalam :

- Mengatasi masalah kompleks dengan langkah sistematis
- Menghindari menyelesaikan masalah yang salah
- Merumuskan proses penyelesaian masalah
- Membuat nilai lebih baik, meski jawaban akhirnya tidak tepat

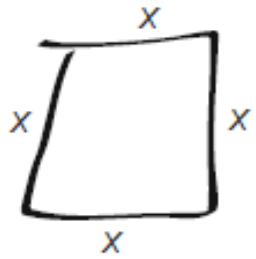
Need-Know-How-Solve-(Check)

- Langkah ini terlihat berlebihan untuk masalah sederhana
- Tetapi bagi mahasiswa tingkat akhir, metoda ini memiliki keuntungan tambahan dalam menganalisis bila terdapat kesalahan perhitungan yang menyebabkan jawaban tidak tepat/tidak sesuai.
- Terdapat "**Audit Trail**", dimana suatu error dapat dilacak hingga sumbernya

Contoh 1

Example 3.1

A Texan wants to purchase the largest fenced-in square ranch she can afford. She has exactly $320,000. available for the purchase. Fencing costs exactly $10,000. a mile, and land costs exactly $100,000. a square mile. How large a ranch, as measured by the length of one side of a square, can she buy?



Need: The length of a side of the largest square of land the Texan can buy.

Know: Fencing costs $10,000. a mile, and land costs $100,000. a square mile. Our Texan has $320,000. to invest.

How: Let the unknown length = x miles. It may not be immediately obvious how to write an equation to find x. So sketch the ranch.

From the crude picture (and that is generally all you need), it is immediately obvious that the length of the fence surrounding the ranch is 4x, and the area of the ranch is x^2.

So the cost of the ranch is:

$$\text{Length of fence [miles]} \times 10{,}000.\ [\$/\text{mile}] + \text{area of ranch [square miles]} \times 100{,}000.\ [\$/\text{sq. mi}] = \text{total cost of ranch} = \$320{,}000.$$

or

$$4x\ [\text{miles}] \times 10{,}000.\ [\$/\text{mile}] + x^2\ [\text{sq. mile}] \times 100{,}000.\ [\$/\text{sq. mi}] = \$320{,}000.$$

Solve: $(4x) \times (10{,}000.) + x^2 \times (100{,}000.) = 320{,}000.$

Therefore, $10x^2 + 4x - 32 = 0$, which is a quadratic equation whose solutions are:

$x = +1.6$ and $x = -2.0$ (to just two significant figures, which is typical of land measurement)

Menyelesaikan masalah rekayasa

- Menentukan variabel yang digunakan
- Penggunaan satuan yang konsisten
- Menyatakan jawaban dalam jumlah angka penting yang sesuai

- Tetapi, apa yang menjamin bahwa kita telah mendapat jawaban terhadap apa yang dicari? Atau
- Hasil yang diperoleh merefleksikan kinerja sesungguhnya sistem pada dunia nyata?

- **Kebenaran jawaban bergantung dari kebenaran metoda dan asumsi yang digunakan dalam mencari solusi**

Menyelesaikan masalah rekayasa

- Semakin sistematis metoda yang digunakan, semakin jauh terhindar dari kesalahan (error)
- Penggunaan metoda yang eksplisit akan memberikan “audit trail” bagi customer kita (termasuk rekan kerja dan atasan)

- Gunakan metoda “the NEED-KNOW-HOW-SOLVE”

Contoh 2

Example 3.2

Consider the following problem: How many barbershops are there in the city of Schenectady (population about 60,000 people)? Your first reaction may be "I haven't got a clue." (You may want to try the need–know–how–solve method on this problem for yourself before looking at what follows.)

Need: The number of barbershops.

Know: There are about 60,000 people in the city of Schenectady, of whom about half are male. Assume the average male gets about 10 haircuts a year. A barber can probably do one haircut every half hour, or about 16 in the course of an eight-hour day. There are about three barbers in a typical barbershop.

How: The number of haircuts given by the barbers must be equal to the number of haircuts received by the customers. So if we calculate the number of haircuts per day received by all those 30,000 males, we can find the number of barbers needed to give those haircuts. Then we can calculate the number of shops needed to hold those barbers. Assume that barbershops are open 300 days per year.

Solve: 30,000 males require about 10 [haircuts/male-year] × 30,000 [males] = 300,000 haircuts/year.

On a per-day basis, this is about 300,000 [haircuts/year] × [one year/300 days] = 1000 haircuts/day.

This requires 1000 [haircuts/day] × [1 barber-day/16 haircuts] = 62.5 barbers. At three barbers per shop, this means 62.5 barbers × [1 shop/3 barbers] = 20.8 shops.

So the solution is **20 barbershops** (since surely not more than one of the digits in the calculation above is significant).

Looking in a recent yellow pages directory and counting the number of barbershops in Schenectady gives the result 23 barber shops. So we are within about 10 percent, which is a fortuitously good answer, given the roughness of our estimates and the many likely sources of error. Notice also in this problem how the method of carrying the units in square brackets [..] helps your analysis of the problem and directs your thinking.

Contoh 3

Example 3.3

A 2.00 m steel wire is suspended from a hook in the ceiling with a mass of 10.0 kg that is tied to its lower end; the wire stretches by 15.0 mm under this load. If this same mass is used to stretch a 4.00 m piece of the same steel wire, how much will it stretch?

Need: Stretch = ____ mm for a 4.00 m piece of wire.
Know: 10.0 kg mass will stretch a 2.00 m wire by 15.0 mm.
How: We need to deduce a possible law for extending a wire under load. Without experimentation we cannot know if our "theoretical law" is correct, but a mixture of common sense and dimensional analysis can yield a plausible relationship.
Solve: A longer wire should stretch further than a shorter one if otherwise equivalent. A larger mass presumably will also stretch the wire further.

A *plausible* model is thus the extension x is proportional to the unstretched length of wire L (all other things such as the stretching force and the wire's cross section being equal).

Then $x \propto L$ and the ratio between the two cases is $\frac{x_2}{x_1} = \frac{L_2}{L_1}$.

Therefore the new extension $\mathbf{x_2} = 15.0 \times 4.00/2.00$ [mm][m/m] = **30.0 mm.**