



AI-AUGMENTED ENGINEERING DYNAMICS: A CONVERSATIONAL APPROACH

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Observe



Idealize



Model



Solve / Analyze



Validate



Report

The engineering workflow you will use throughout this book

by Taner & Sebnem Onsay

CHAPTER - 2

PART 6 · ≈ 50 MIN

Choosing a Coordinate Description

The motion never changed. Only our description changed. How does an engineer decide which one to use — and how do you check yourself by using another?

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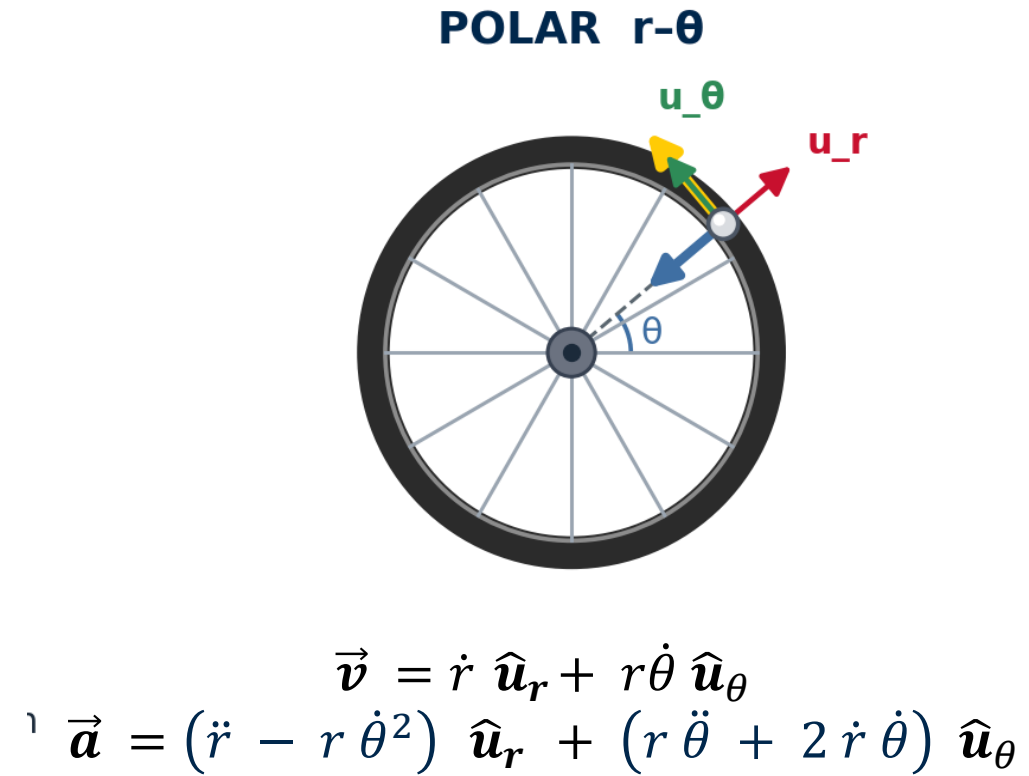
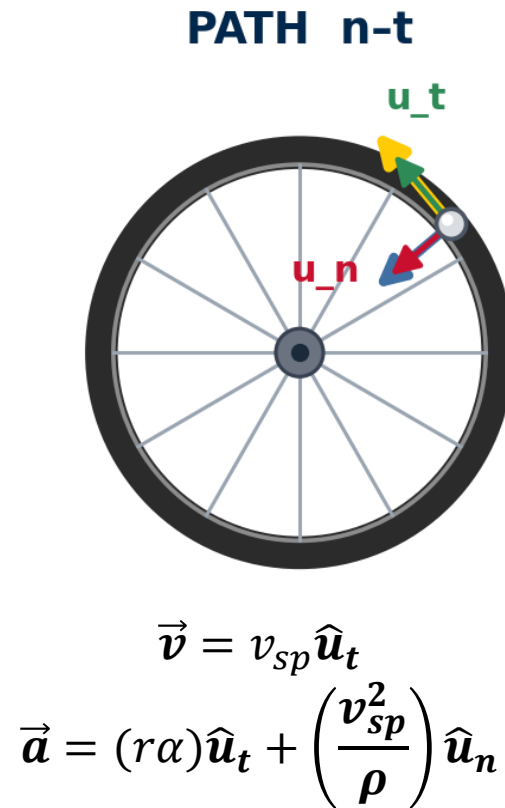
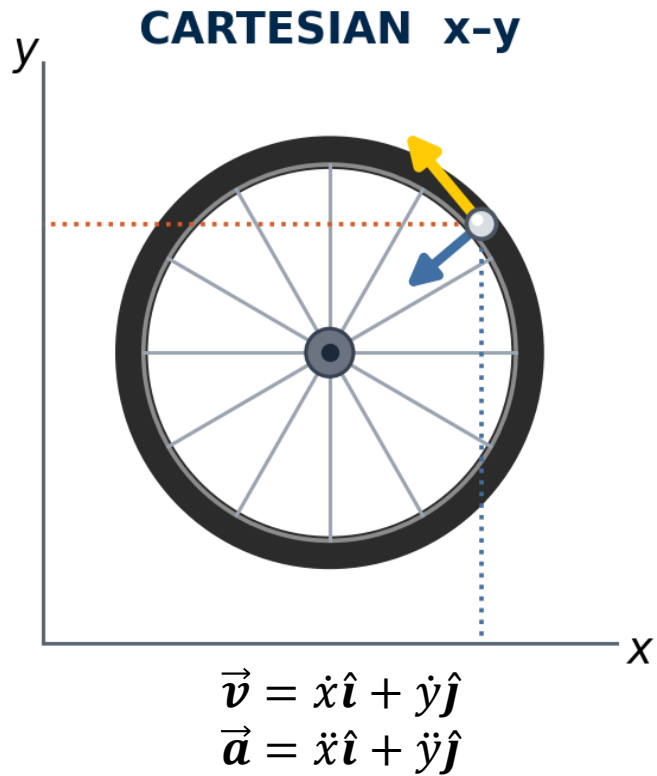
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One bead, three languages



Cartesian: two shadows. n-t: speed vs direction. Polar: range vs bearing. Same v. Same a. The engineer chooses the language.



Three sets of components, one arrow: 2.59 m/s tangent to the wheel



Cartesian

$$\vec{v} = \dot{x}\hat{i} + \dot{y}\hat{j} = -R\omega \sin \theta \hat{i} + R\omega \cos \theta \hat{j}$$

$$= -1.67 \hat{i} + 1.98 \hat{j} \text{ m/s}$$

$$|\vec{v}| = \sqrt{(1.67^2 + 1.98^2)} = 2.59 \text{ m/s}$$

at 130° from x — which is the tangent direction at $\theta = 40^\circ$. Note: $40+90=130$



n-t

$$\vec{v} = v_{sp} \hat{u}_t = 2.59 \hat{u}_t \text{ m/s}$$

One number. The direction is built into the frame.



Polar

$$\vec{v} = \dot{r} \hat{u}_r + r\dot{\theta} \hat{u}_\theta = 0 \cdot \hat{u}_r + 2.59 \hat{u}_\theta \text{ m/s}$$

On a circle about O, $\hat{u}_\theta$ is in the same direction as $\hat{u}_t$. Same one number.

THE CHECK — ROTATE THE CARTESIAN PAIR INTO THE TANGENT DIRECTION

$$v_t = -v_x \sin \theta + v_y \cos \theta = 1.67(0.643) + 1.98(0.766) = 2.59 \text{ m/s}$$

$$v_n = -v_x \cos \theta - v_y \sin \theta = 1.28 - 1.27 \approx 0$$

Three descriptions, one velocity. If they ever disagree, the error is in the algebra, never in the physics.

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Inward 20.3 m/s^2 and backward 0.22 m/s^2 — in every language



n-t

$$a_t = r\alpha = -0.22 \text{ m/s}^2 \text{ (backward)}$$

$$a_n = r\omega^2 = 20.3 \text{ m/s}^2 \text{ (inward)}$$

$$|a| = 20.3 \text{ m/s}^2$$



Polar

$$a_r = -r\omega^2 = -20.3 \frac{\text{m}}{\text{s}^2}$$

(-) sign means inward since $\hat{u}_r$ is outward

$$a_\theta = r\alpha = -0.22 \text{ m/s}^2$$

$$|a| = 20.3 \text{ m/s}^2$$



Cartesian ($\theta = 40^\circ$)

$$\vec{a} = -15.4 \hat{i} - 13.2 \hat{j} \text{ m/s}^2$$

$|a| = 20.3 \text{ m/s}^2$ — but which part is braking and which is turning? You would have to project to find out.

Same magnitude, same arrow. Cartesian tells you WHERE it points; n-t and polar tell you WHY. That difference is the reason we have three descriptions.



Ask yourself

If a Tracker export gave you only (t, x, y) for the braking bead, which description would you compute in first — and which would you convert to in order to read a_t ? (Cartesian first, because that is the data; n-t second, because that is the question.)

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Model



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What do I know? What am I asked? What did the instrument measure?



Choose CARTESIAN when...

the components are measured or prescribed independently (Tracker data, GPS, a projectile with $a_x = 0$ and $a_y = -g$), or the geometry is naturally rectangular.



Choose n-t when...

the PATH is known and the question is about speed change vs direction change: ramps, tracks, curves, the wheel — and any comfort or grip limit stated as an acceleration.



Choose POLAR when...

the motion is naturally seen FROM A POINT (range and bearing) or prescribed along a rotating line: antennas, booms, turntables, slotted arms, pendulums with a stretching cord.

THE CAUTION

The guide is a starting point. The engineer decides — and states why.

Many real problems use two descriptions: compute in the instrument's language, answer in the question's language, validate in the third.

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Idealize

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Report



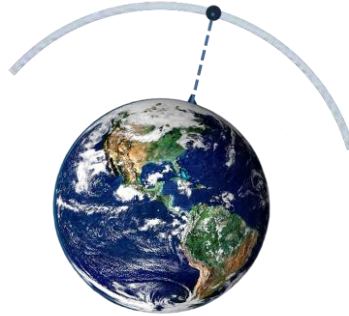
Six situations. One sentence of justification each.

1



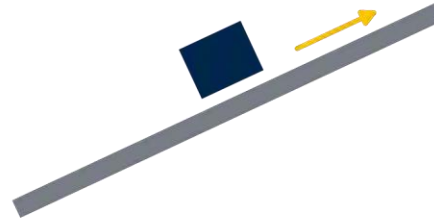
car on a mapped mountain road

2



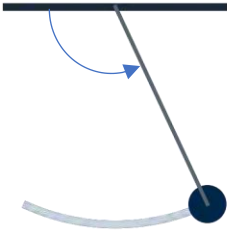
satellite tracked from a ground station

3



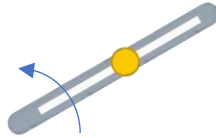
package on a straight inclined conveyor

4



pendulum bob on a fixed-length cord

5



pin sliding in a rotating slotted arm

6



ball thrown across a gym

1

Car on a mapped mountain road

2

Satellite from a ground station

3

Package on a straight incline

4

Pendulum bob on a fixed cord

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Pin in a rotating slotted arm

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Ball thrown across a gym

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The label matters less than the sentence after it

1 n-t

Path known from the map; the question is a_n against a comfort limit and how hard to brake. **Would change to Cartesian** if the data were GPS points to be differentiated.

2 Polar

The station measures range and bearing. **Would change to Cartesian** if the question were the ground track or a rendezvous with another object.

3 Cartesian (along the incline)

Straight path: one axis along the belt, constant acceleration — Chapter 1 in disguise. **Would change to n-t** if the conveyor curved.

4 n-t or polar — they coincide

On a circle centered at the pivot, $\hat{u}_n = -\hat{u}_r$ and $\hat{u}_t = \hat{u}_\theta$. **They separate** if the cord stretches or is reeled in (then $\dot{r} \neq 0$ and polar is the only natural choice).

5 Polar

r along the arm, θ the arm's angle; the pin slides while the arm turns, so $2\dot{r}\dot{\theta}$ is real. **Would change to n-t** if the slot were curved and only the pin's speed along it mattered.

6 Cartesian

$a_x = 0$, $a_y = -g$: the projectile model. **Would change to n-t** if the question were the curvature of the flight path **at the apex** ($a_n = g$ there, since $a_n = \frac{v_{sp}^2}{\rho}$, $\rho = \frac{v_x^2}{g}$).

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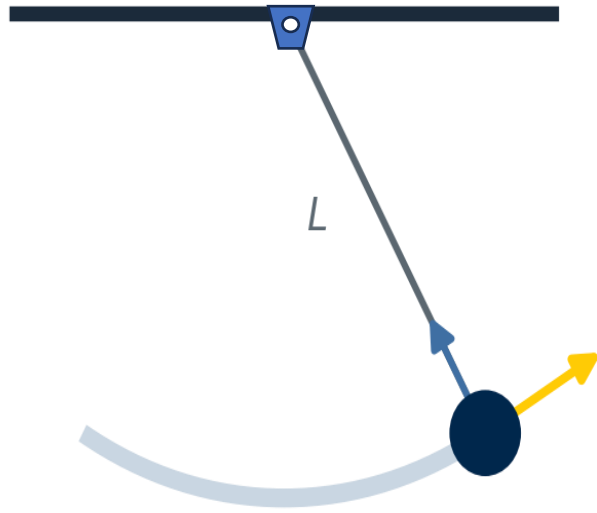
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n-t and polar give the same components here. When would they not?



$\hat{u}_n = -\hat{u}_r$ on a circle centered at the pivot

FIXED CORD, ORIGIN AT THE PIVOT

$$r = L: a_r = -L\dot{\theta}^2, \quad a_\theta = L\ddot{\theta}$$

$$n-t: a_n = L\dot{\theta}^2 = v^2/L, \quad a_t = L\ddot{\theta}$$

Identical vectors: $\hat{u}_n = -\hat{u}_r$, $\hat{u}_t = \hat{u}_\theta$.
Pick either; say which.



Now reel the cord in while it swings

r decreases. Polar keeps working: $\dot{r}$, $\ddot{r}$ and $2\dot{r}\dot{\theta}$ appear. n-t would need the radius of curvature of a spiral at every instant. The choice is no longer a coin toss.



Where this goes

Chapter 3: the cord tension must supply a_n .
Chapter 10: for small θ , $\ddot{\theta} = -(g/L)\theta$ — the pendulum becomes the first vibration model.



Right answer, wrong language: the same 5.5 m/s^2 costs three times the algebra

CONVERT THE n - t ANSWER AT B^+ (HEADING 50°)

$$\hat{u}_t = (\cos 50^\circ, \sin 50^\circ) = (0.643, 0.766); \hat{u}_n = (-0.766, 0.643)$$

$$\vec{a} = a_t \hat{u}_t + a_n \hat{u}_n = -0.96 \hat{u}_t + 5.4 \hat{u}_n$$

$$\vec{a} = (-4.75, 2.74) \text{ m/s}^2, \quad |a| = 5.49 \text{ m/s}^2 \checkmark$$

Same magnitude as Part 4. But from $(-4.75, 2.74)$ alone you cannot tell that only 0.96 of it is braking — you would project back onto the heading to find out.

Starting in x - y from the map would have meant: parametrize both arcs, compute $\ddot{x}$, $\ddot{y}$, then ρ from the curvature formula, then project. Three times the algebra for the same 5.49.



Validation by alternate description

Two independent routes, one number. This is the Part 4 VALIDATE step we promised — and it is how you catch a sign error in a_n .



The lesson

The wrong description does not give a wrong answer. It gives the right answer slowly, and hides the meaning.



The instrument chose the description. The validation used the other one.



Encoder on a wheel or rail

measures distance along the path $\rightarrow$ n-t is natural ($s, v = \dot{s}$).



GPS · motion capture · Tracker

deliver $x(t), y(t) \rightarrow$ Cartesian first, then convert to answer the question.



Radar · tracking antenna · rangefinder

deliver $r(t), \theta(t) \rightarrow$ polar first; validate in Cartesian when the flight is simple.



Automotive radar

reports the RELATIVE velocity of the car ahead — a fourth kind of description, Part 7.

The instrument often makes the first choice for you. The second choice — which language to ANSWER and VALIDATE in — is always yours.

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It is a rotation through one angle. Nothing more.

FRAME ROTATED BY φ (ANGLE OF $\mathbf{u}_t$ FROM THE x -AXIS;
 $\mathbf{u}_n$ TO ITS LEFT)

$$\begin{aligned} a_t &= a_x \cos \varphi + a_y \sin \varphi \\ a_n &= -a_x \sin \varphi + a_y \cos \varphi \end{aligned} \quad \Rightarrow \quad \begin{bmatrix} a_t \\ a_n \end{bmatrix} = \begin{bmatrix} \cos \varphi & \sin \varphi \\ -\sin \varphi & \cos \varphi \end{bmatrix} \begin{bmatrix} a_x \\ a_y \end{bmatrix}$$

Same two lines for $\vec{v}$, and for polar with φ the line-of-sight angle ($\hat{\mathbf{u}}_r, \hat{\mathbf{u}}_\theta$). If $\hat{\mathbf{u}}_n$ is to the right of $\hat{\mathbf{u}}_t$, flip the sign of a_n .



Check with the braking bead

$$\begin{aligned} \vec{a} &= (-15.4, -13.2) \text{ m/s}^2 \text{ at } \theta = 40^\circ, \text{ so } \phi = 130^\circ. \\ a_t &= -15.4 \cos 130^\circ - 13.2 \sin 130^\circ = -0.22 \text{ m/s}^2 \checkmark \\ a_n &= 15.4 \sin 130^\circ - 13.2 \cos 130^\circ = 20.3 \text{ m/s}^2 \checkmark \end{aligned}$$

Draw the two frames on top of each other before you write the equations. The angle φ is read from the sketch — most sign errors are sketch errors.



Give an AI your coordinate choice. Then grade its critique.



THE PROMPT

"Here is a situation [describe it] and the coordinate system I chose [name it, with my one-sentence reason]. Critique my choice. Propose the alternative you would use. Then tell me what information I would need that I do not have."

1

Did it apply the three questions?

Known · asked · measured. If not, its critique is decoration.

2

Did it invent information?

"Assume the path is circular" — was that given? Added assumptions change the problem.

3

Did you change your mind?

One sentence: "I kept / changed my choice because ..." — that is the deliverable.

AI can assist reasoning. It does not choose the engineering model. The model, the assumptions, the interpretation, the validation and the final result remain yours.



AI AS CODING COMPANION

"Write one Python function that prints x , y , v and a in Cartesian, n - t and polar side by side at a given t ." All three $|a|$ must agree to the last digit — if not, the code is wrong, not the physics.

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Part 6 — what you can now explain and do



You can now EXPLAIN

- That Cartesian, n-t and polar are three descriptions of ONE motion, and that the vectors v and a are identical in all three
- The natural domain of each description — and the one piece of information that would flip the choice
- Why the instrument often makes the first choice, and why the second choice (answer and validate) is yours
- Why the "wrong" description gives the right answer slowly and hides the meaning



You can now DO

- Choose a description for an unfamiliar situation and justify it in one or two sentences
- Rotate components between two frames at an instant and use it to validate a result by an alternate description
- Solve one motion two ways and reconcile term by term ($a_t \leftrightarrow r\ddot{\theta}$, $a_n \leftrightarrow r\dot{\theta}^2$)
- Grade an AI's critique of your modeling choice against the three questions

Next — Part 7: what if motions are connected by a cable, or observed from something that is itself moving? Two more descriptions — constraints and relative motion — and a bridge to Chapter 3.