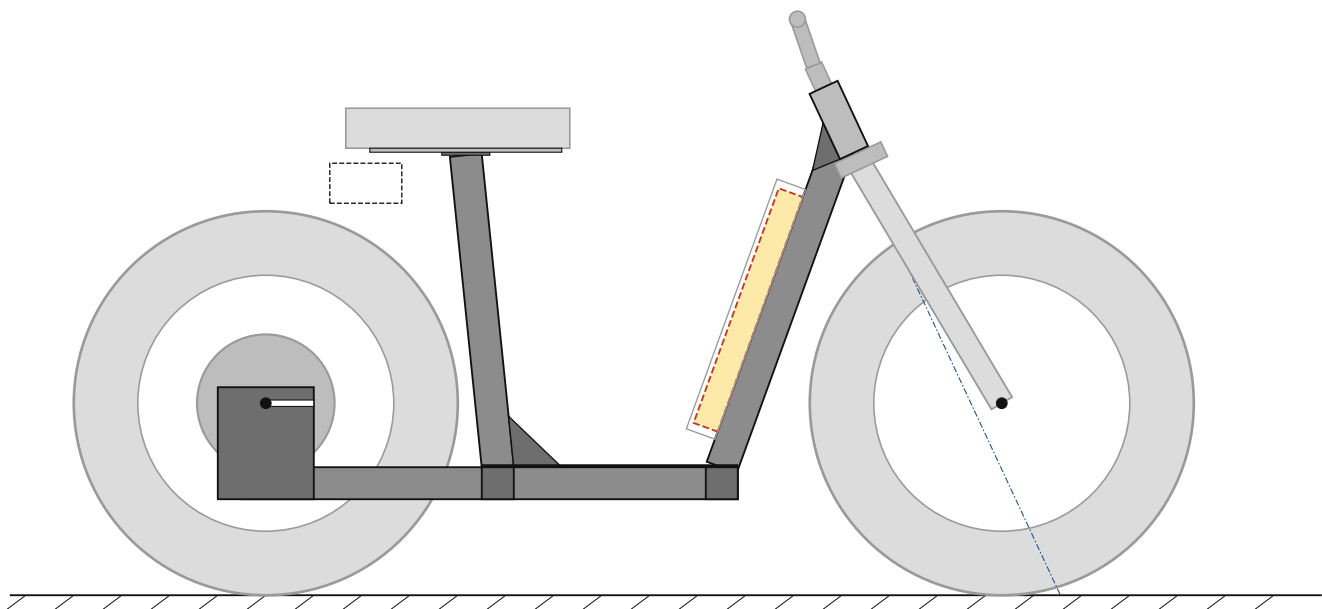


SCOOTER

BUILD BOOK

A 72 V step-through scooter with a hub motor. Six pieces of one tube, no chain, no jig.



Wheelbase	46"	Frame tube	2" x 2" x .120" square steel, about 10 ft, six pieces
Wheels	20 x 4.0 fat tires front and rear, about 24" tall	Head tube	44 mm, 25° back, EC44 headset
Floor / seat / bars	8" / 30-1/2" / about 36"	Motor	rear hub motor wheel, 72 V, 1000-1500 W, with its controller
Deck width	11-1/4" (set by the motor axle)	Battery	72 V, 15.6 x 5.9 x 1.6", on the back of the down tube
Weight, with battery	about 124 lb	Brakes	bicycle hydraulic discs, front and rear, from the kit you own
Rear weight, rider seated	69 %	Suspension	none in the frame. Soft fat tires at 12-18 psi

Revision A, made 2026-10-07 by the scripts in Scooter/book (book.py). Same page format as the Pulse Kart and OpenEMoto-CS build books. Every number comes from model.py; change a part there and the whole book redraws.

WARNING

NOT FINAL YET: the book assumes a 17-1/2" fork (axle to crown) and a 170 mm motor axle. Measure both when the parts arrive (page 1-04), put the numbers in model.py, and rerun book.py before you cut the cross tubes or the down tube. Pages that depend on them have a red banner at the bottom.

Print on US Letter at 100 % ("Actual size"). Page 2-05 is a 1:1 template: check its scale bar before you cut steel.
Every page has its part and page number in the bottom-right box, so pages can be pulled out and put back.

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How to use this book

Read the safety page. Buy the four parts on page 1-01 marked FIRST. When they arrive, do page 1-04: measure, write the numbers in, and have the book rerun. Then buy steel.

Part 2 is the frame. Page 2-01 is the one drawing that shows every tube, its cut length, and the order to tack (red numbers). The pages after it say how to cut, weld and check it with a bench, a tape and a square.

Parts 3 and 4 bolt the wheels, front end, seat, battery and wiring on. Part 5 puts it together and gets it ready to ride.

Coordinates

Positions: x = forward from the rear axle, y = up from the ground, z = toward the rider's left from the centerline. "c-c" = centerline to centerline. Left and right are the RIDER's left and right.

Still to measure or buy

item	status	where / note
Motor axle width	ASSUMED	170 mm (6-11/16"). Sets the rail spacing, 1-04
Axle flat width	ASSUMED	10 mm (3/8"). Sets the slot, 2-05
Fork axle-to-crown	ASSUMED	17-1/2". Sets the head tube position, 2-04
Fork offset	ASSUMED	1-3/4". Changes the trail a little
Controller max voltage	CHECK	must be 84 V or more, 1-01
Rider	ASSUMED	180 lb, sitting 11" ahead of the axle

What is decided

The frame shape, the one tube size, the wheelbase, the 20 x 4.0 wheels, the hub motor instead of the Kunray, the battery on the down tube, bicycle brakes both ends, rigid frame. The Kunray, its controller and the sprockets stay with the kart.

Read this first

This scooter has a 72 V battery, a motor in the rear wheel, and a frame you welded yourself. Each of those can hurt you. None of them will if you follow the rules below.

The battery (72 V DC)

- 72 V DC can stop your heart. Never touch both battery terminals at once. Keep one hand in your pocket when working on live wiring.
- Take off rings and watches before touching the battery. A ring across the terminals will weld to your finger.
- The battery has no "off". Unplug it (the big yellow connector) before you touch any wiring.
- The breaker is the fuse. It goes on the positive lead, as close to the battery as it will fit. No breaker, no ride.
- Charge on a concrete floor, away from anything that burns, never while you sleep. Use only the charger made for this battery.
- A swollen, hot or smelly battery goes outside, on the ground, now. No water on a lithium fire: sand, or let it burn out where it cannot spread.

Cutting, grinding, welding

- Welding helmet, leather gloves, long sleeves, no synthetic clothes. Flash burn hurts for days.
- Fumes: weld with air moving. Galvanized or painted steel gives off poison gas; grind it clean first.
- Grinder guard on. Cutting discs shatter. Safety glasses even with the helmet up.
- Hot steel looks like cold steel. Mark hot parts, or wait.
- Fire extinguisher and a bucket of water within reach. Sparks travel 15 ft and start fires an hour later. Check the shop before you leave.

The finished scooter

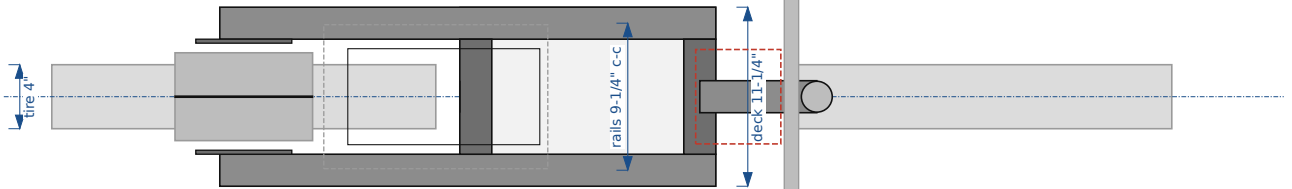
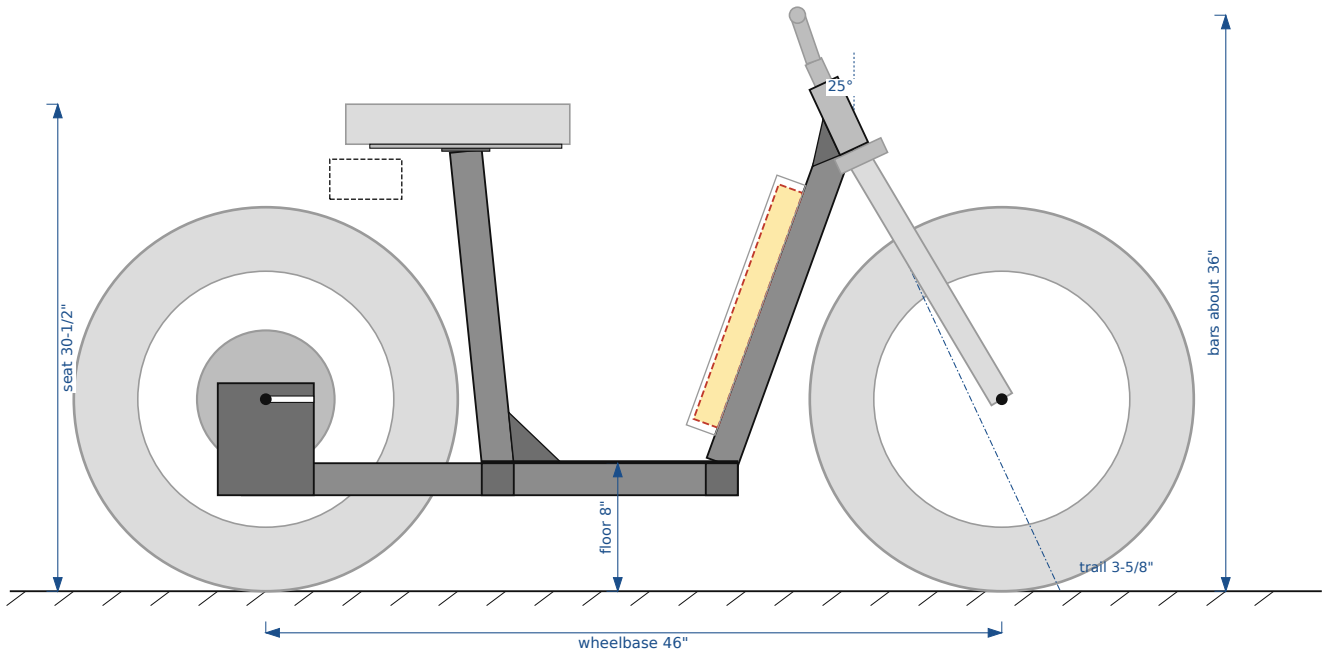
- Before the first ride, do every check in Part 5. The frame welds carry you; look at every one.
- The hub motor twists its axle hard. The torque arm is not optional.
- First ride: helmet, an empty lot, speed limit set to 15 mph on the display. Brakes first, then throttle.
- A scooter that pulls to one side, wobbles, or makes a new noise stops until you know why.
- Do the after-ride checks in Part 5. Bolts loosen on a new machine.

STOP

If you are not sure a weld is good, it is not. Grind it out and do it again. The head tube joint is the one that matters most: it is the only thing holding the front wheel on.

SIDE VIEW from the rider's left · front to the right

scale 1:12



Weight (estimate)

item	lb
Frame tube (2 x 2 x .120, about 10 ft)	30.3
Dropout plates, gussets, cap, straps	8.4
Floor, battery cover, seat plate	5.1
Battery (72 V)	20.0
Rear hub motor wheel with tire	25.0
Front wheel with tire	11.0
Fork, head tube, headset, stem, bar	9.3
Seat	4.0
Controller, display, throttle	3.0
Brakes, kickstand, breaker, wiring	7.5
Scooter, no rider	124
Rider (assumed)	180

Balance and the big picture

Center of gravity 18-13/16" ahead of the rear axle with nobody on it, 14-3/16" with a 180 lb rider: 69 % of the weight on the rear wheel, which is the one that drives. The battery on the down tube is what keeps the front from going light.

Names used in this book: the two RAILS run flat under the floor. Two CROSS TUBES sit between them. The DOWN TUBE rises from the front cross tube to the HEAD TUBE (the short round tube the fork turns in). The SEAT POST rises from the rear cross tube. Two DROPOUT PLATES at the back hold the motor axle.

Twelve welds in all. Three cuts are not square: the foot of the down tube, the foot of the seat post, and the top of the down tube, which is shaped with a grinder to hug the head tube.

NOT FINAL: fork assumed 17-1/2" axle-to-crown, motor axle assumed 170 mm. Measure both (page 1-04), rerun book.py, reprint before cutting.

SCOOTER BUILD BOOK

PART 0 · START HERE
REV A · 2026-10-07 · inches

The scooter at a glance

0-04

page 4 of 21

Already on hand (from the kart and e-moto projects)

item	notes	used in
72 V battery	15.6 x 5.9 x 1.6" slab (397 x 149 x 41 mm), BMS inside, about 20 lb	on the down tube, 3-03
Charger	for the 72 V pack, XT60 plug	plugs into the pack as now
Hydraulic bicycle brake kit	both levers, both calipers, both rotors. Note IS or post mount	front 3-02, rear 3-01
Twist throttle + grips	hall type. Works with the kit controller; else use the kit's throttle	3-02, 4-01
Kart leftovers	1/4" aluminum 12 x 6 (seat plate), 3/16" steel (gussets, cap), 1/16" aluminum (battery cover)	1-02
NOT used here	Kunray motor + controller, 84T and other sprockets, MTB fork, 1" square tube	stay with the kart

To buy (rough US prices, Oct 2026). FIRST = buy before anything else, then measure (1-04)

#	part	notes	approx.
1	FIRST Rear hub motor wheel kit, 20 x 4.0 rim, 72 V, 1000-1500 W, with controller, display and throttle	Amazon "20 inch fat tire rear hub motor kit 72V 1500W". Listing MUST say: controller works at 84 V; 6-bolt disc mount; axle 170 or 190 mm; display with speed limit	\$350
2	Rear tire 20 x 4.0 + inner tube	kits usually come without	\$45
3	Torque arm, bolt-on e-bike type, for the axle flats	left side. The motor twists its axle in the slots	\$12
4	FIRST Head tube, 44 mm straight, steel, 110-120 mm long	Paragon Machine Works "head tube 44", or eBay "44mm head tube 4130". About 1.9" outside	\$35
5	FIRST Fork, 20" fat bike, 1-1/8" straight threadless steerer, 9 x 135 mm QR, disc mount, clears a 4.0" tire	Rigid 20" fat forks are not sold: this is a spring fork (RST 20 Guide, or Amazon "20 inch fat bike fork 4.0 135mm disc"). Bolts in like a rigid one	\$100
6	Headset, external cups, EC44/28.6 top + EC44/30 bottom	for a straight 1-1/8" steerer in a 44 mm head tube	\$30
7	FIRST Front wheel 20 x 4.0, 9 x 135 QR, 6-bolt disc, 36 hole + tire and tube	Amazon "20x4.0 fat bike front wheel 135mm disc". Your front rotor and caliper fit	\$135
8	Stem, 1-1/8" threadless, 40-60 mm; riser handlebar, 22.2 mm at the grips	throttle, grips and brake levers clamp at 22.2 mm	\$40
9	Seat, scooter type with a flat bolt-on base		\$40
10	Side stand, moped or e-bike, clamp-on	clamps to the left rail	\$15
11	Main breaker 100 A + DIN rail; 6 AWG cable red + black with lugs; E-stop + start button	same three items as kart list #10, #11, #12	\$90
12	Hardware	#12 x 3/4" self-drilling screws (20); M6 x 20 + nylocs (6); M8 x 25 + nylocs (4); 5/16" x 1" bolts (2, seat plate); XT90 pair; IS-to-post adapter if your calipers are post mount	\$30

Parts 1-12: about \$920. Steel and sheet (page 1-02): about \$110. Total about \$1,030 before tax. The motor kit is a third of it. The kit also brings brake levers with cutoff switches; you will not use them.

Scooter BOM (raw stock)

stock	how much	what for	about
2" x 2" x .120" (11 ga) mild steel square tube, A513 or A500	12 ft (one stick, or 2 x 6 ft)	everything: 2 rails, 2 cross tubes, down tube, seat post. 121" of cuts, about 23" left	\$55
1/4" mild steel plate	7" x 14"	the two dropout plates, 6 x 7 each (2-05)	\$25
1/8" x 1" mild steel flat bar	4 ft	two 19" battery straps (3-03). Steel because it bends without cracking	\$8
1/8" 5052 aluminum sheet	12" x 24"	the floor, 11-1/4" x 16 (3-03). The rest is spare	\$20
3/16" mild steel plate	kart leftover (need 6" x 9")	2 head tube gussets 3 x 3, seat post gusset 3 x 3, seat post cap 3 x 3	—
1/16" 5052 aluminum sheet	kart leftover (need 17" x 10-1/2")	battery cover. If short: 12" x 24" sheet, about \$12	—
1/4" aluminum plate	kart leftover, 12" x 6" piece	seat plate (3-03)	—

Rough cost of stock: about \$110. Ask for mild steel square tube, not galvanized (poison fumes when welded). Hot-rolled plate is fine; grind the scale off where you weld.

Substitute BOM (if the first choice is not in stock)

first choice	substitute	note
2 x 2 x .120 square tube	2 x 2 x .083 (14 ga) square tube, 12 ft	6 lb lighter. Burns through easier when welding. Not thinner than .083, not smaller than 2"
1/4" steel plate 7 x 14	1/4" x 7" flat bar, 14"	or 1/4" x 6" flat bar: plates become 6 x 6, slot moves down 1" (still 1" from the top edge)
1/8 x 1 steel flat bar	1" x 1/8" 3003 aluminum flat bar	NOT 6061: it cracks when bent around the pack
1/8" 5052 aluminum	1/8" 6061-T6 aluminum, or 12 ga (.105") mild steel sheet	steel floor is 6 lb heavier
1/16" 5052 aluminum	.063" 3003-H14 aluminum	NOT 6061: cracks when bent
3/16" steel plate	1/4" steel plate	fine for the gussets and the cap

How the one stick of tube is cut (12 ft = 144")

rail 31	rail 31	down tube blank 24	seat post blank 21	7-3/16	7-3/16	22" left
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Cut the rails first, then the two blanks, then the cross tubes. Cut the cross tubes LAST, after the motor arrives and you know the axle width (1-04): they are axle width + 1/2".

Tools you need

job	tools
Cutting	chop saw or bandsaw for the tube; angle grinder with cut-off, grinding and flap discs; hacksaw; drill with 3/8" and 1/4" bits
Shaping the down tube end	angle grinder, half-round file, a felt pen for scribing. No hole saw needed
Marking	tape, steel rule, square, scratch awl, center punch, chalk line, a sheet of plywood for the full-size drawing
Welding	MIG, .030" ER70S-6 wire, 75/25 gas. Arc (7018) is fine for the plates
Holding	two or three welding clamps, a couple of magnets, a flat bench or a flat sheet of ply on the floor
Checking	a 4 ft straightedge, string, a level, an angle finder (the \$10 magnetic kind)
Bicycle	headset cup press (or a threaded rod + washers), hacksaw guide for the steerer, 4/5/6 mm hex keys, torque wrench to 40 ft-lb
Electrical	multimeter, crimper for 6 AWG lugs, heat-shrink, cable ties

Welding settings that work

what	setting	how
2 x 2 x .120 tube (all of the frame)	MIG, .030" wire, 19-20 V, about 190 ipm	weld 1" at a time, move to the opposite side, repeat
1/4" dropout plates	MIG, 20-21 V, about 210 ipm; or arc 7018 3/32" at 90-100 A	two passes if the first looks thin. Weld all the way round
3/16" gussets and cap	MIG, 18-19 V, about 170 ipm	short stitches, let it cool
Head tube (1.9" round, about .090 wall)	MIG, 17-18 V, about 150 ipm	the head tube is thinner than the down tube: aim the wire at the down tube side

Test every setting on scrap of the same tube first: a good bead is flat, wets in at both edges, and shows a little color on the inside of the tube. Grind every joint bright before you weld it, 1/2" each side.

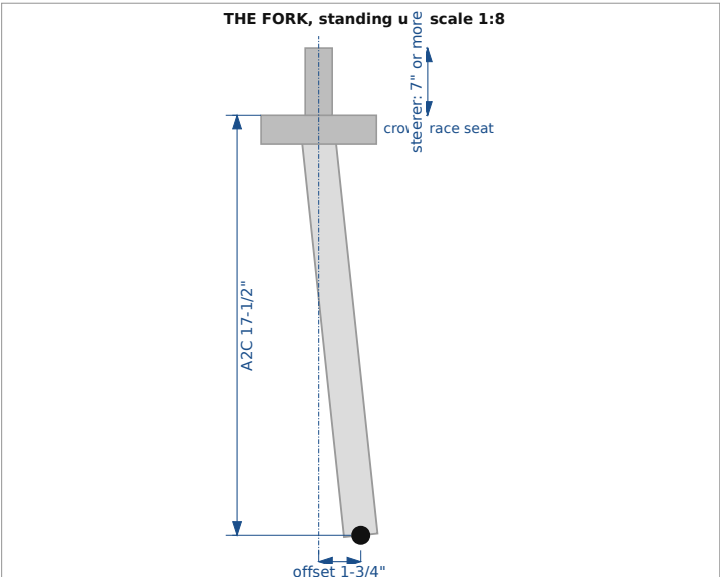
Words used in this book

word	meaning
rail	one of the two long tubes under the floor. Left and right
cross tube	a short tube between the rails. There are two: rear (under the seat post) and front (under the down tube)
down tube	the tube that rises from the front cross tube to the head tube
head tube	the short round tube the fork turns in. 44 mm inside
headset	the two bearing cups that press into the head tube, with the bearings
steerer	the long tube on top of the fork that goes through the head tube. 1-1/8" here
dropout plate	the flat plate at the back of each rail with the slot the motor axle sits in
torque arm	a bolt-on arm that grips the motor axle flats so the motor cannot spin its axle in the slot
IS mount	the bicycle standard for a disc caliper: two bolts 51 mm apart, parallel to the axle
tack	a small weld, 1/4" long, to hold parts while you check them. Easy to grind off
weld out	do the full welds after everything is tacked and checked

Write the real numbers here, then put them in model.py and rerun book.py

The book is drawn with the numbers in the "assumed" column. Two of them move steel: the motor axle width sets how far apart the rails go, and the fork length sets where the head tube sits. Cut nothing until these are measured.

measure	assumed	name in model.py	used on	measured
motor axle, shoulder to shoulder (the width the frame must be)	170 mm = 6-11/16"	OLD	2-01, 2-02: cross tube length	
motor axle flats, width across the flats	10 mm = 3/8"	SLOT_W	2-05: slot width	
tire height, inflated, on the rim	24"	R_WHEEL (half)	2-01: axle height, floor gap	
which side the motor wire comes out	left	—	3-01, 4-01: controller side	
fork: axle center to the crown race seat (where the lower bearing sits)	17-1/2"	FORK_A2C	2-01, 2-04: head tube position	
fork offset: axle ahead of the steerer centerline	1-3/4"	FORK_OFF	0-04: trail	
fork steerer length above the crown race	need 7" or more	—	3-02: steerer cut	
controller: maximum battery voltage on the label	84 V or more	—	4-01	
battery, re-check	15.6 x 5.9 x 1.6"	BAT_L, BAT_W, BAT_T	3-03: straps and cover	
rider weight, and where you sit	180 lb at x = 11"	RIDER_LB, RIDER_X	0-04: balance	

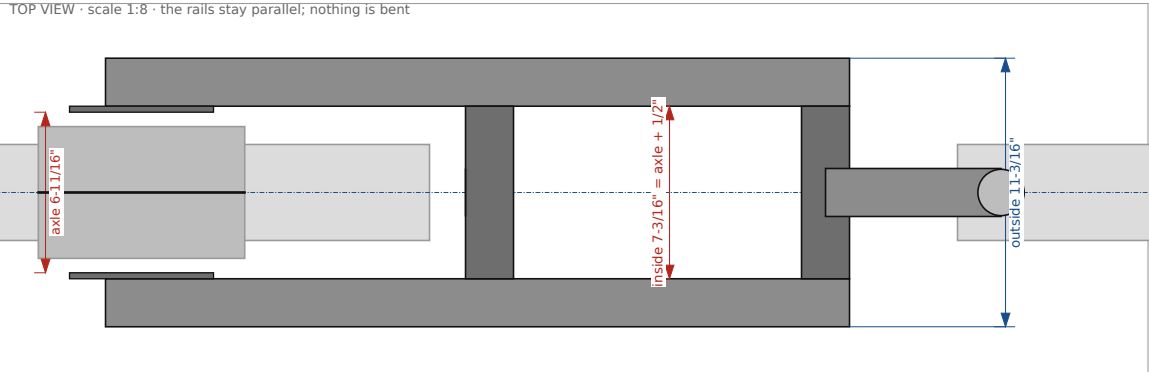
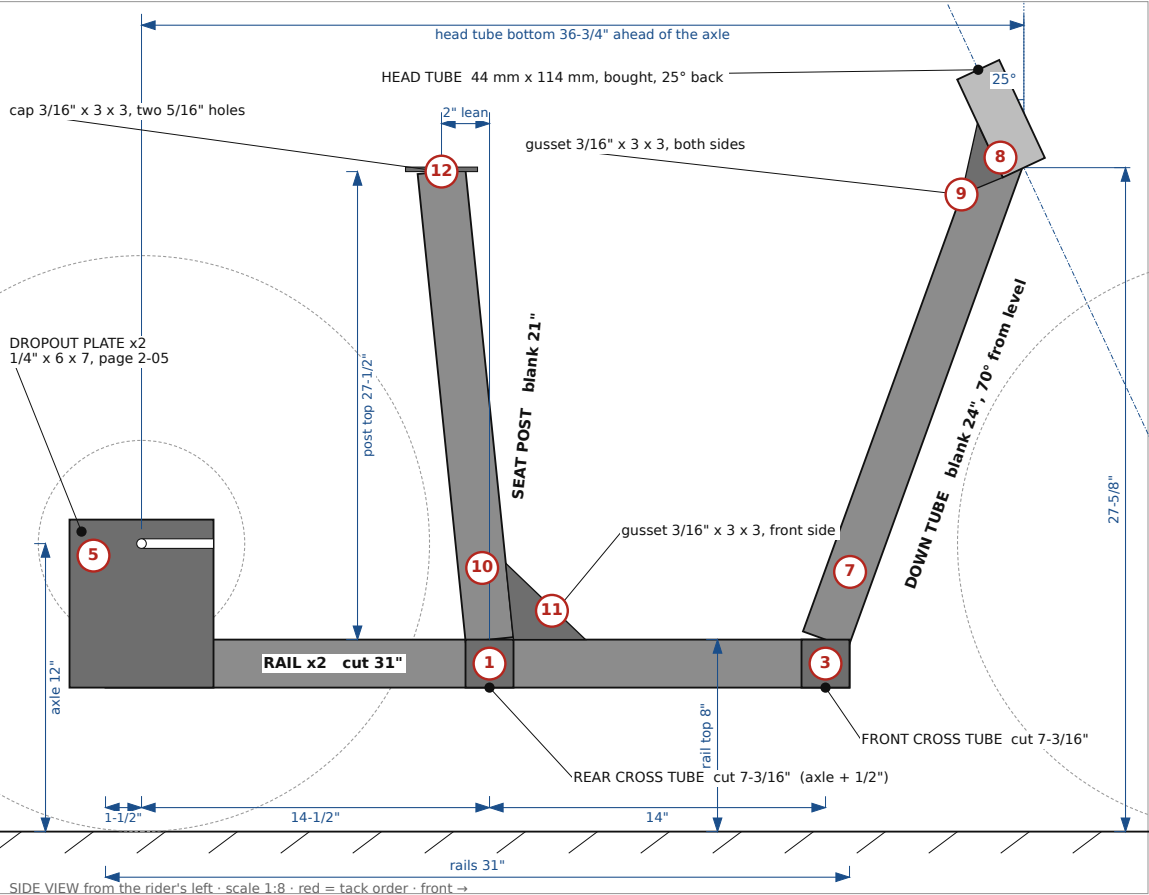


How to measure the fork

Stand the fork on its axle on the bench. Measure straight up from the axle center to the flat shoulder at the top of the crown where the lower bearing race sits. That is A2C. Lay a straightedge along the steerer and measure from it to the axle center: that is the offset. Both to the nearest 1/16".

Measure the motor axle with calipers across the flats (the slot width) and from shoulder to shoulder with a tape (the frame width). 170 mm and 190 mm are the two common sizes.

If A2C is within 1/2" of the assumed number you can build from this printing; the head tube just moves a little along the down tube. If the axle width differs at all, the cross tubes change: rerun the book.



point	x	y	note
rear axle	0	12"	in the dropout plate slots
rail, back end	-1-1/2"	6" to 8"	plates reach 1-1/2" past it
rear cross tube	14-1/2"	same	seat post stands on it
seat post top	12-1/2"	27-1/2"	cap plate, then seat plate
front cross tube	28-1/2"	same	down tube stands on it
rail, front end	29-1/2"	same	flush with the front cross tube
head tube bottom	36-3/4"	27-5/8"	from the fork: MEASURE
head tube top	34-7/8"	31-3/4"	25° back from vertical
front axle	46"	12"	wheelbase

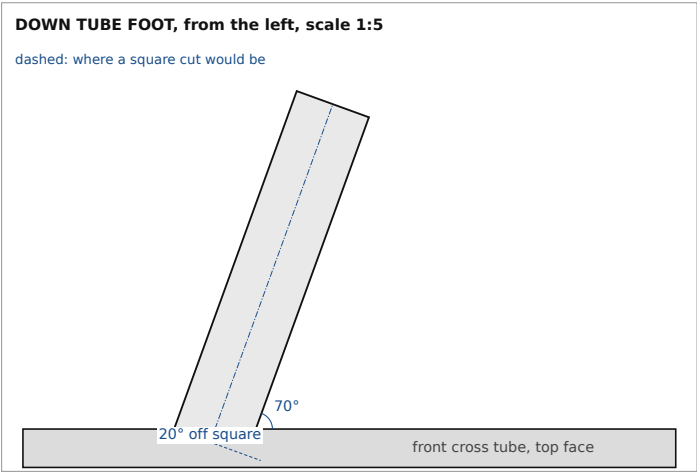
piece (2 x 2 x .120)	cut	ends
rail x2	31"	square both ends
cross tube x2	7-3/16"	square. = axle + 1/2"
down tube	24" blank	foot 20° off square; top shaped to the head tube, 45° between them
seat post	21" blank	foot 6° off square; top square
head tube	44 mm x 115	bought. Sits 1-1/2" of its length onto the down tube

Red numbers are the order to tack (page 2-03). Blank lengths are what to cut before shaping the ends (2-02). x and y: inches forward of the rear axle, inches above the ground. Both rails and both cross tubes lie flat on the bench; only the down tube, head tube and seat post stand up.

What to cut

piece	qty	stock	cut	ends / size	note
rail	2	2 x 2 x .120 tube	31"	square both ends	rear axle ends up 1-1/2" from the back end
cross tube	2	2 x 2 x .120 tube	7-3/16"	square both ends	= axle width + 1/2" (6-11/16" + 1/2"). Both the same.
down tube	1	2 x 2 x .120 tube	24"	foot: 20° off square. Top: shaped to the head tube (45° between them)	blank; about 22-3/4" long point when finished
seat post	1	2 x 2 x .120 tube	21"	foot: 6° off square. Top: square	blank; about 19-5/8" finished
dropout plate	2	1/4" plate	—	6 x 7, slot 3/8" wide, 3" long	page 2-05 is the 1:1 template. One left, one right (flip it over)
head tube gusset	2	3/16" plate (kart leftover)	—	3 x 3, cut corner to corner	one each side of the joint
seat post gusset	1	3/16" plate (kart leftover)	—	3 x 3, cut corner to corner	front side of the post
seat post cap	1	3/16" plate (kart leftover)	—	3 x 3, two 5/16" holes	the aluminum seat plate bolts to it
seat plate	1	1/4" aluminum (kart leftover)	—	12 x 6, 4 seat holes + 2 cap holes	bolted, not welded (aluminum)
floor	1	1/8" aluminum	—	11-1/4" x 16	10 self-drilling screws
battery strap	2	1/8 x 1 steel flat bar	19"	bend around the pack and the down tube	one M6 bolt closes it
battery cover	1	1/16" aluminum (kart leftover)	—	17 x 10-1/2 blank, bent into a U	6-1/2" top, 2" sides

Tube lengths are long point to long point. Cut the two blanks 1" long and trim to fit on the frame: it is easy to take more off. Write the name on each piece with a paint pen the moment it is cut.



Mark the foot with an angle finder set to 20°, or lay out the long side 3/4" longer than the short side across the 2" face. The seat post foot is the same idea at 6°.

Shaping the top of the down tube

The down tube meets the round head tube at 45°. There is no hole saw step. Cut the blank square at 45° (the long side toward the front). Stand it on the tacked cross tube, hold the head tube against it at the 25° lean, and scribe where the round tube touches. Grind to the line with a flap disc. Offer it up again. Repeat until the gap is under 1/16" all round. Three or four tries is normal.

The head tube should sit about 1-1/2" of its length onto the down tube, so the gusset has something to grab. Where the down tube is cut away is where the two side gussets go (2-04).

The seat post

Foot cut at 6° so the post leans back 2" over its height. Top cut square. The 3 x 3 cap plate is welded on top, two 5/16" holes drilled for the seat plate bolts.

The plates

Page 2-05 is the 1:1 template. Glue it to the 1/4" plate, center-punch, drill 3/8" at the inner end of the slot, cut the slot sides with a cut-off wheel, file to the axle flats. Cut both plates identical. The caliper holes come later, marked through the caliper with the wheel in (3-01).

NOT FINAL: fork assumed 17-1/2" axle-to-crown, motor axle assumed 170 mm. Measure both (page 1-04), rerun book.py, reprint before cutting.

- Chalk the axle line ($x = 0$) and the two rail centerlines $y = \pm 4\text{-}5/8$ on the bench. Tack numbers [n] match page 2-01. Tack, measure, then weld out.

STEP 1 The ladder: two rails and two cross tubes [1] [2] [3] [4]

- Lay both rails on the chalk lines, 9-3/16" c-c, back ends on the same line. Set the rear cross tube between them centered at $x = 14\text{-}1/2$ " and the front cross tube at $x = 28\text{-}1/2$ ", flush with the rail tops and the front ends.
- Inside distance between the rails = 7-3/16" at BOTH ends. Both diagonals of the rectangle equal within 1/16". Tack [1] to [4].
- Re-check. Weld out: 1" at a time, opposite corners, so it does not pull.

STEP 2 The dropout plates [5] [6] (the wheel is the jig)

- Put both plates on the motor axle, nuts finger tight, slots facing the same way.
- Slide the wheel in from behind, plates against the inside faces of the rails, plate bottoms flush with the rail bottoms, axle 1-1/2" ahead of the rail ends. The plate sticks up 5" above the rail.
- Check: the wheel is centered between the rails (equal gap each side) and stands plumb (level across the tread, with the ladder level).
- Tack each plate at its top and bottom edge [5] [6]. Pull the wheel. Weld out all round where the plate meets the rail: along the top edge of the rail, along the bottom edge, and down the back end.

STEP 3 The down tube [7]

- Stand the down tube on the middle of the front cross tube, 20° end down, leaning forward at 70° from level (angle finder on its face). Centered: 2-5/8" from each rail. Tack front and back [7]. Do not weld out yet.

STEP 4 The head tube [8] [9] (the one that matters: page 2-04)

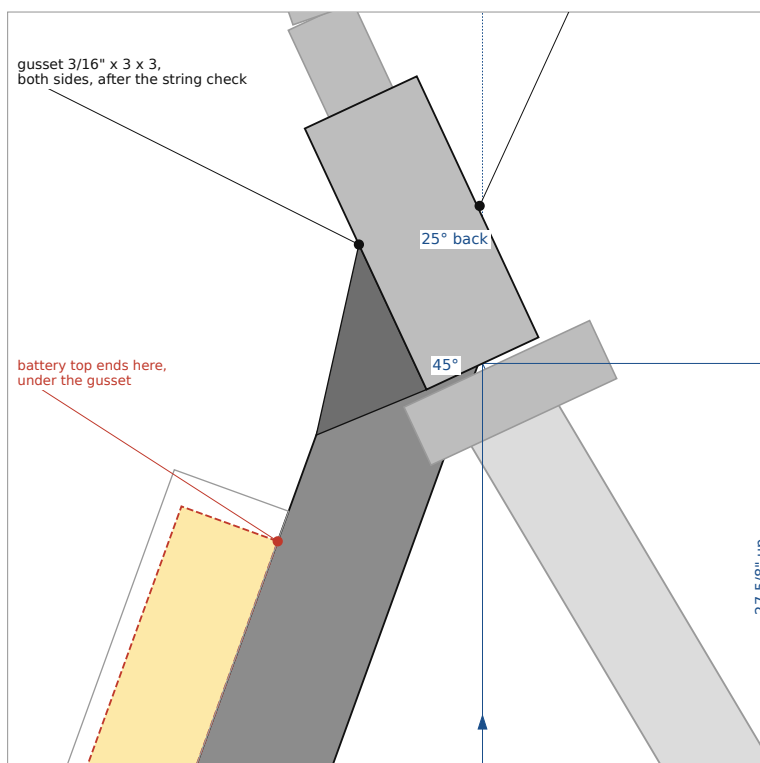
- Shape the top of the down tube (2-02). Set the head tube on it: 25° back from vertical seen from the side, dead plumb seen from the front. Tack top and bottom [8].
- Press the headset cups in, drop the fork and front wheel in, set both wheels on the floor and do the STRING CHECK (2-04). If the front wheel is off the line, break the tacks and move it. Only then weld the head tube out, then the down tube foot, then the two gussets [9].

STEP 5 The seat post [10] [11] [12]

- Stand it on the middle of the rear cross tube, 6° end down, top 2" behind the foot. Plumb seen from behind. Tack [10], check, weld out. Gusset on the front side [11]. Cap plate on top [12], then drill it for the seat plate.

WARNING

Weld the head tube only after the string check. Everything else on this frame can be fixed with a grinder and a second try; a crooked head tube means cutting the down tube off.



The down tube runs at 70° from level, the head tube leans 25° back from vertical: 45° between them. Head tube bottom at $x = 36\text{-}3/4"$, $y = 27\text{-}5/8"$ with the assumed fork.

NOTE

If the measured fork is more than 1/2" different from 17-1/2", rerun the book first: the head tube moves along the down tube and the blank length changes.

Setting the angle

Side to side: an angle finder on the head tube must read 25° from vertical with the ladder dead level (put the level across both rails first and shim the bench). Front to back: a plumb line or a long level held against the head tube must read vertical. Check both again after each tack: tacks pull.

The string check

- With the head tube tacked, press the headset cups in and drop the fork, front wheel, stem and bar in.
- Put both wheels on the floor. Point the front wheel straight ahead so the bar is square to the frame.
- Stretch a string from the floor behind the rear wheel, over the middle of the rear tire's tread, along the frame centerline, to the floor ahead of the front wheel. Pull it tight and low.
- The front tire must sit on the string along its whole length, and the bar must be level.
- Front tire off the string by more than 1/4" at the ground: the head tube leans sideways. Break the tacks, move it, tack again.
- Bar not level with the wheel on the string: the fork is just turned in the head tube. Loosen the stem and square it.

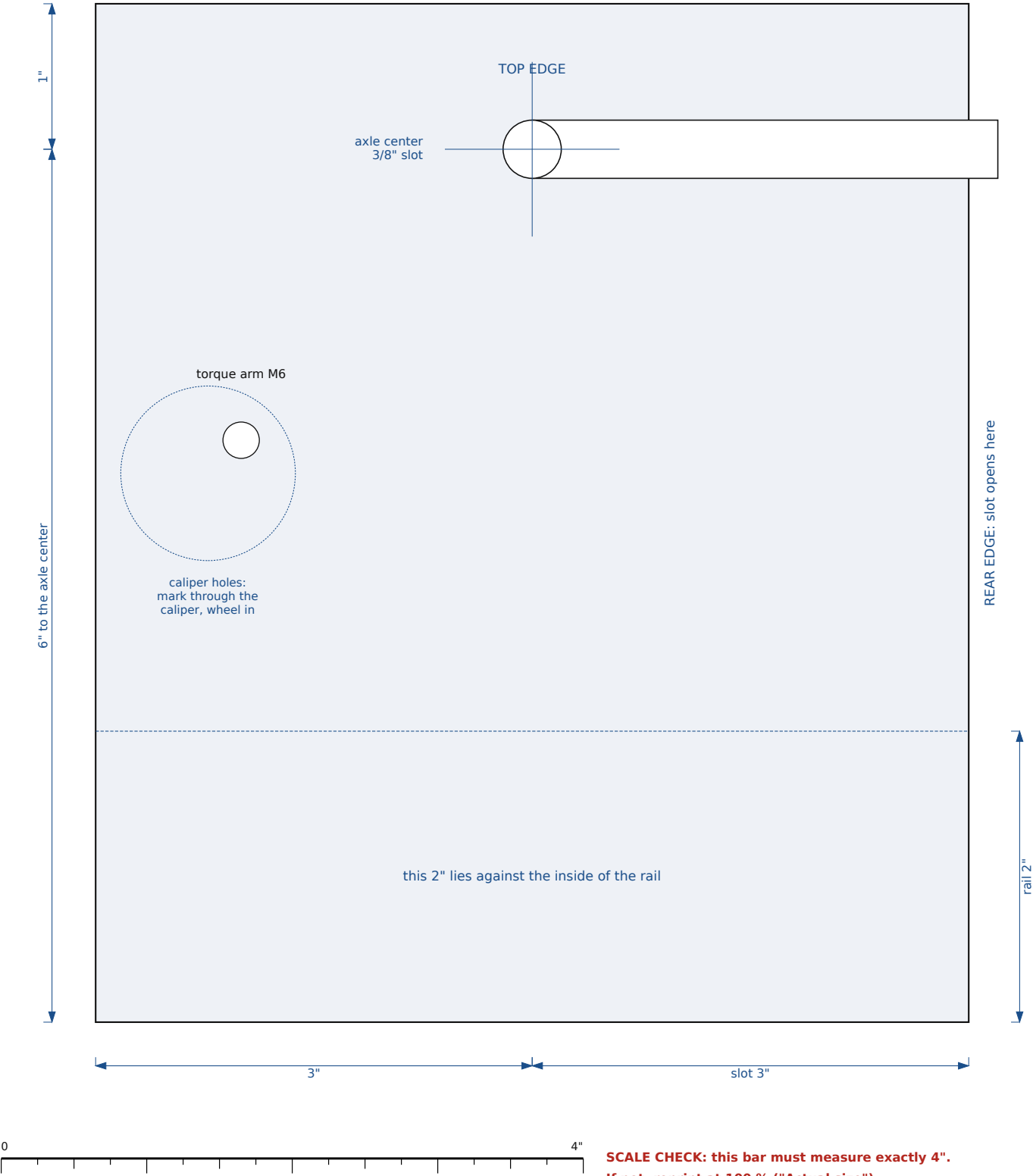
Then

Pull the fork out (heat ruins bearings). Weld the head tube all round in four short runs, opposite sides, letting it cool between. Weld the down tube foot. Fit and weld the two gussets, one each side, to the down tube face and the head tube. Repeat the string check once more when it is cold.

NOT FINAL: fork assumed 17-1/2" axle-to-crown, motor axle assumed 170 mm. Measure both (page 1-04), rerun book.py, reprint before cutting.

DROPOUT PLATE · 1/4" steel, 6 x 7 · make two, identical · 1:1

Check the scale bar at the bottom with a ruler. Glue to the plate. Center-punch the slot end and the torque arm hole. Drill 3/8" at the slot end, cut the slot sides, file to the axle flats. The bottom 2" of the plate lies against the inside of the rail (dashed line). The slot opens to the rear. Caliper holes: not here. Mark them through the caliper with the wheel and rotor in (3-01), on the LEFT plate only.



Before anything bolts on, measure the bare frame against this table

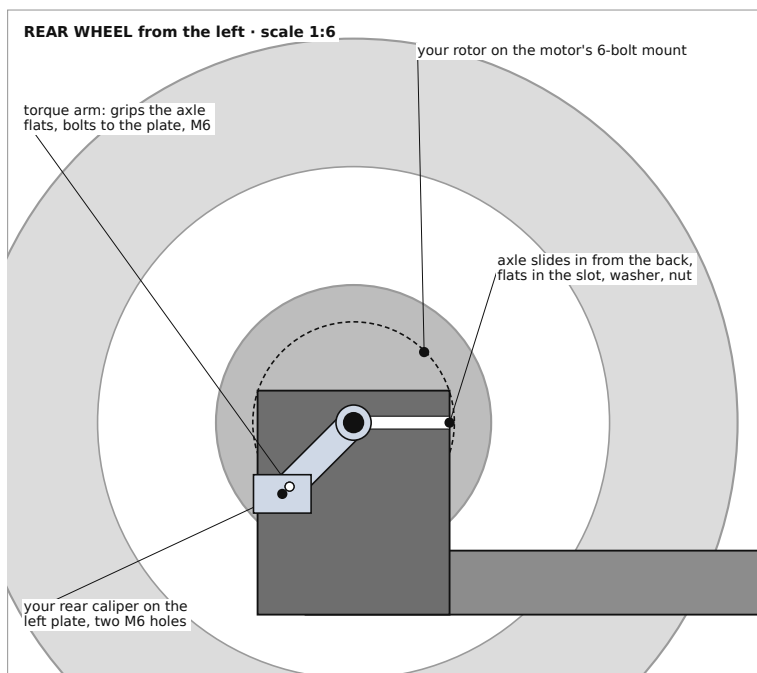
measure	should be	tolerance	why
rails, inside, at the back	7-3/16"	± 1/16"	the motor axle must drop in with no spring
rails, inside, at the front	7-3/16"	± 1/16"	same
rectangle diagonals (rail corner to opposite rail corner)	32-3/8" both	equal ± 1/16"	square ladder
rail back end to axle slot center	1-1/2"	± 1/8"	both sides the same
axle slot center above the rail bottom	6"	± 1/16"	both sides the same, or the wheel leans
head tube lean, side view, from vertical	25°	± 1°	angle finder, frame level
head tube lean, front view	0°	± 1/2°	the string check (2-04)
head tube bottom, ahead of the axle / above the ground	36-3/4" / 27-5/8"	± 1/4"	with the assumed fork
down tube from level	70°	± 1°	
seat post top, ahead of the axle / above the ground	12-1/2" / 27-1/2"	± 1/4"	cap plate level
frame sits flat	all four rail corners touch	—	on a flat floor, no rock

Look at every weld

- ☐ Every joint welded all the way round where it can be reached. No tack left as a weld.
- ☐ No undercut (a groove along the edge of the bead) on the head tube. If there is, add a pass.
- ☐ No crater at the end of a run. Fill the ends.
- ☐ Gussets: welded on both the down tube face and the head tube, both sides.
- ☐ Dropout plates: three edges welded, top, bottom and back. The slot edges are clean and the axle flats slide in snug.
- ☐ Spatter knocked off the rail tops where the floor sits.

Then

Grind nothing flush on the head tube or the plates: the bead is the strength. Flush-grind only where the floor and the seat plate must sit flat. Prime or paint now, before the wiring goes on. Mask the head tube bore and the slots.



Fitting the wheel

- Tire on the rim, tube in, 15 psi. Rotor on the 6-bolt mount, 5 ft-lb, star pattern.
- Slide the axle into both slots from behind, flats lined up with the slots. The wire comes out on the left (check 1-04).
- Torque arm on the left: its slot over the axle flats, then the plate washer and the nut. Mark where its bolt hole lands on the dropout plate, pull the wheel, drill 1/4", put it back.
- Axle nuts: 35 ft-lb (about 48 Nm), both sides. Then the torque arm bolt, nyloc, 5 ft-lb.
- Spin it. It must run true and not touch the rails or the floor. The gap to each rail should be equal.

The rear brake

- Your rotor is about 6-1/2" across. With the wheel in, hold the caliper over the rotor edge at the lower-back of the plate, pads centered on the rotor, body clear of the spokes. Post-mount caliper: use the IS-to-post adapter.
- Mark the two mounting holes through the caliper (IS: 51 mm apart, bolts parallel to the axle). Pull the wheel, drill 1/4", wheel back in.
- Bolt the caliper on loosely, squeeze the lever hard, tighten the bolts while squeezing: the pads center themselves. 6 ft-lb.
- Lever on the bar, hose along the left rail, cable-tied every 8". Bleed if the lever is soft.

WARNING

The torque arm is not optional. A 1500 W hub motor can spin its axle in a plain slot and tear the wire out.

The stack, bottom to top

part	what	how
crown race	pressed onto the fork crown (EC44/30 lower race, 30 mm)	tap down with a piece of pipe over the steerer until it seats all round
lower cup	EC44 external cup, pressed into the bottom of the head tube	headset press, or threaded rod with big washers. Square, not cocked
upper cup	EC44/28.6 external cup, pressed into the top	same
bearings	one in each cup, grease them	the sealed cartridge kind just drops in
fork in	steerer up through the head tube	from below
compression ring + dust cover	onto the steerer, onto the upper bearing	comes with the headset
spacers	10 mm or so	so the stem can preload the bearings
stem	1-1/8" clamp, 40-60 mm long	bolts LOOSE for now
star nut or expander	inside the steerer, 15 mm down	the top cap bolt pulls on it
top cap	tighten until there is no play when you rock the fork, and it still turns freely	about 2 ft-lb: light
stem bolts	tighten with the stem square to the wheel	4 ft-lb (5-6 Nm)

Cutting the steerer

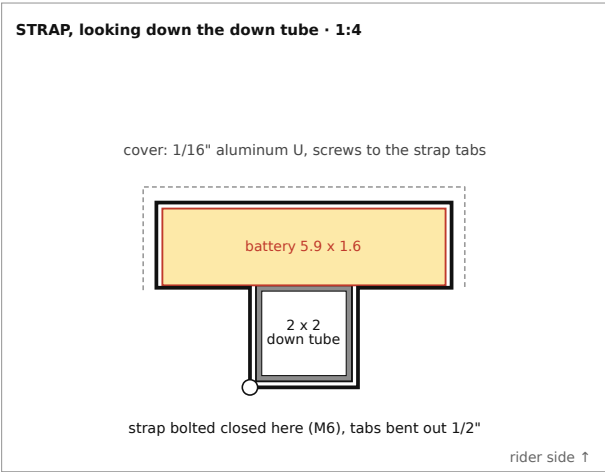
Assemble everything dry with an uncut steerer first. Mark the steerer 1/8" BELOW the top of the stem. Pull it, cut square with a hacksaw in a guide, file the burr inside and out. Steerer needed above the crown race: head tube 4-1/2" + cups about 5/8" + spacers 3/8" + stem 1-5/8" = about 7". Most forks have 9" or more.

The handlebar and what hangs on it

- Riser bar in the stem clamp, centered, rolled so the grips point a little back toward you. Clamp 4 ft-lb.
- Right side: your twist throttle first (inboard), then the front brake lever. Left side: the rear brake lever, the display next to it, then the grip.
- Front caliper onto the fork's disc mount (post mount or IS; use the adapter if they differ). Rotor on the hub. Center the pads as on 3-01.
- Front wheel in the fork dropouts, quick release closed hard enough to leave a mark on your palm. Rotor between the pads.
- Hoses and wires: down the right side of the head tube, along the down tube under the battery cover, under the floor to the controller. Leave enough slack at the head tube for full lock both ways.

NOTE

Rigid 20" fat forks are not sold, so this is a spring fork. It fits exactly like a rigid one. If you ever want the frame rigid, any 20" fork with a 1-1/8" straight steerer and 135 mm dropouts drops into the same head tube.



Two straps, 1/8" x 1" steel, 19" each, bent around the pack and the tube together. No tabs on the frame, no welds.

The floor and the stand

- 1/8" aluminum, 11-1/4" x 16, on the rails and both cross tubes, flush with the front. Ten #12 self-drilling screws: four down each rail, one into each cross tube. Round the corners.
- Run the motor wire and the brake hose under it along the left rail before it goes on. Cable-tie them to the rail.
- Side stand clamps to the left rail about 20" ahead of the axle. Check the scooter leans but does not tip with the battery in.

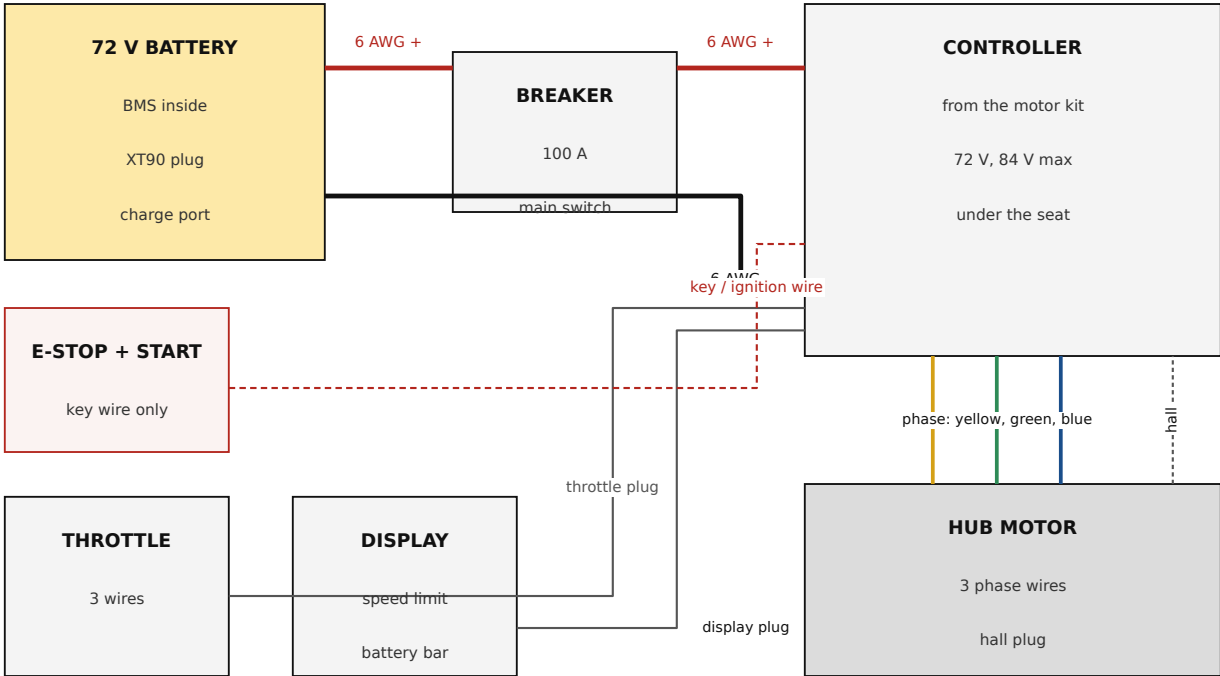
The battery

- It lies on the back (rider side) of the down tube, starting 2" up from the foot. Wires toward the top. A strip of 1/4" rubber or foam between pack and tube.
- Bend the two straps around pack and tube at 1/3 and 2/3 of the pack length. Bend the two free ends out 1/2" and bolt them together with one M6. Snug, not crushing.
- The cover is a U of 1/16" aluminum over the pack, 6-1/2" top and 2" sides, 17" long, screwed to the strap tabs with #12 screws. Leave the top open for the wires. Edge it with rubber trim.
- Main breaker and E-stop: on the left side of the down tube below the battery, where your left hand reaches from the seat. XT90 plug between pack and breaker so the pack lifts off with the two strap bolts.

The seat

- Cap plate welded on the post (2-03), two 5/16" holes. Aluminum seat plate 12 x 6 bolted to it, 5/16" bolts, nylocs, centered on the post.
- Seat on the plate, four M8, 15 ft-lb. Seat front about 5" ahead of the axle, so you sit over the rear wheel.
- Controller: cable-tie or strap it to the back of the seat post, under the seat, fins up. Nothing touches the tire.

Big wires: 6 AWG with crimped lugs. Thin wires and plugs come with the kit and only fit one way.



Big wires (6 AWG, crimped lugs, heat-shrink)

from	to	wire	note
battery + (red)	breaker, line side	6 AWG	XT90 at the pack so it unplugs
breaker, load side	controller B+ (thick red)	6 AWG	the kit controller has bare leads or an XT60/XT90: match it
battery - (black)	controller B- (thick black)	6 AWG	direct

Thin wires (come with the kit; the plugs only fit their own socket)

from	to	note
motor phase wires (3, thick: yellow, green, blue)	controller, same colors	bullet connectors. If it stutters, see 4-02
motor hall plug (5 or 6 pins)	controller hall socket	one plug, keyed
throttle (3 wires: red 5 V, black ground, signal)	controller throttle socket	your twist throttle or the kit's. Same three wires
display	controller display socket	waterproof round plug
key / ignition wire (thin, usually red or orange)	through the E-stop and start button	this is the only switch. Never put the E-stop on the 6 AWG
brake cutoff levers from the kit	not used	your hydraulic levers have no switch. The controller does not need them

Charger: plugs into the pack's own charge port, as it does now. Never through the controller.

WARNING

Check the controller label before you connect anything: it must say 72 V and accept at least 84 V. A 48-60 V controller dies the moment a full pack is plugged in.

First power-up (rear wheel off the ground)

- ☐ Breaker OFF. Rings off. Meter across the controller B+ / B-: no short. Plug in the pack.
- ☐ Breaker ON. Press start: the display lights, no smoke, no fault code.
- ☐ Press the E-stop: the display must go dark. Reset, start: it must come back.
- ☐ On the display, set: wheel size 20", speed limit 15 mph, low-voltage cutoff 60 V (3.0 V per cell x 20).
- ☐ Throttle a hair: the wheel turns FORWARD, smoothly, quietly. If not, see the right column.
- ☐ Run it up slowly to full. Let go: it coasts down with no grinding.
- ☐ Both brakes: the wheel must stop from a spin with a third of the lever travel left.
- ☐ Feel the controller and the motor after a minute: warm is fine, too hot to hold is not.

If the wheel stutters, runs backward, or screams

- The three phase wires and the three hall wires can be plugged in 36 ways and only a few are right. The kit is usually right color-to-color. If not:
- Runs backward but smooth: swap any two phase wires AND the same two hall wires (the hall wires have the same colors inside the plug).
 - Stutters or jerks: swap two phase wires only. Try the three pairs. If none is smooth, swap two hall wires and try the three phase pairs again.
 - Screams and draws current but does not turn: wrong combination. Stop, do not hold the throttle; try the next one.
 - Write the working combination on a label on the controller.

Display settings worth knowing

setting	value	why
wheel size	20"	speedometer reads right
speed limit	15 mph first, then 25-30	the only "gearing" on a hub motor
low-voltage cutoff	60 V	protects the pack. The BMS is the backstop
assist / power level	lowest for the first ride	softer throttle
throttle mode	twist, from a stop	not pedal-assist

WARNING

Wheel in the air for all of this. A hub motor at full throttle on the bench will walk off the stand.

In this order

- 1. Frame welded and checked (2-06), painted, head tube bore and slots masked and clean.
- 2. Headset cups pressed, fork in, stem and bar on, steerer cut (3-02). Front wheel and brake.
- 3. Rear wheel in with the torque arm (3-01). Rear caliper holes marked, drilled, caliper on. Both brakes bled and working by hand.
- 4. Seat plate and seat on the post. Controller strapped under the seat.
- 5. Motor wire and rear brake hose along the left rail. Floor on.
- 6. Battery on the down tube, straps, breaker and E-stop, cover. Big wires crimped (4-01).
- 7. Thin wires plugged in. First power-up with the wheel in the air (4-02).
- 8. Stand on. Tire pressure 15 psi. Every bolt below checked and paint-marked.

Torque (dry threads)

fastener	torque	note
rear axle nuts (hub motor, usually M14)	35 ft-lb (48 Nm)	both sides. Torque arm fitted first
torque arm bolt M6	5 ft-lb	nyloc
front quick release	hand: closes with a firm push	lever ends up pointing back along the fork
rotor bolts M5 / T25	5 ft-lb (6 Nm)	star pattern, blue threadlocker
caliper bolts M6	6 ft-lb (8 Nm)	tightened with the lever squeezed
headset top cap	2 ft-lb	just enough: no play, turns freely
stem bolts, bar clamp	4 ft-lb (5-6 Nm)	stem square to the wheel first
brake levers, throttle, display clamps	2 ft-lb	they should rotate in a crash rather than snap
seat plate to cap, 5/16"	15 ft-lb	nylocs
seat bolts M8	15 ft-lb	
battery strap bolts M6	5 ft-lb	snug. Do not crush the pack
floor and cover screws #12	snug	stop when the head seats
6 AWG lug bolts (breaker, controller)	8 ft-lb	star washer, cover the terminal
side stand clamp	15 ft-lb	

Paint-pen a line across every nut and onto the part under it. A moved line shows at a glance.

Before the first ride

- ☐ Speed limit on the display: 15 mph.
- ☐ Rear axle nuts and torque arm tight. Front quick release closed.
- ☐ Both brakes lock the wheel pushed by hand. Levers do not reach the bar.
- ☐ Headset: lift the front, rock it, no clunk. Bar turns lock to lock, hoses not tight at full lock.
- ☐ Tires 15 psi. Nothing touches either tire.
- ☐ Battery straps tight, cover on, breaker reachable from the seat.
- ☐ Every paint mark in place.
- ☐ Helmet. Empty flat pavement.

The first ride

- Roll it, no power. It should track straight hands-off at a walking push. If it pulls, the head tube or the rear wheel is off: check the string again before riding.
- Power on. Walking pace, brakes, stop. Then 15 mph, brake hard three or four times to bed the pads.
- Slow weave: no wobble, no clunk. Ride 10 minutes, then do the after-ride checks before raising the limit.
- Raise the limit to 20, ride again, check again. Then 25-30. A head shake at speed means stop and check the headset preload and the wheel.

After the first ride, and again at 50 miles

- ☐ every paint mark
- ☐ axle nuts, torque arm
- ☐ headset play
- ☐ every weld, especially the head tube and the plates
- ☐ brake pads centered, hoses not rubbing
- ☐ battery straps, connector warm?
- ☐ tire pressure
- ☐ floor screws

Record sheet: measure and write it here

item	book / assumed	measured
motor axle width / flats	6-11/16" / 3/8" assumed	
fork axle-to-crown / offset	17-1/2" / 1-3/4" assumed	
head tube bottom x / y, as built	36-3/4" / 27-5/8"	
head tube lean, as built	25°	
rails inside, as built	7-3/16"	
controller make / max volts / amps	72 V kit, 84 V, ? A	
working phase + hall combination	colors matched	
scooter weight, finished	124 lb estimate	
top speed at the limit you chose		
range on a full charge		
tire pressure that rides best	15 psi start	

NOTE

If a measurement differs from the book, put it in model.py and rerun book.py so the next printing matches the scooter you have.