moto zero
by Transitions Lab

04

MODULE 4

Drivetrain and chassis

How engine torque is switched, multiplied and delivered to the rear tyre, and how the frame, steering, suspension, wheels and brakes turn that torque into controlled motion, with the inspection and repair procedures for each.



A technical course on how motorcycles work
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03 Fuel, ignition and electrical systems

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05 Electric motorcycles

Each chapter opens with learning objectives and closes with review questions and worked answers. Reference data comes from the K-Light 125 maintenance manual unless stated otherwise; always use the manual for the machine in front of you. Explorer exercises refer to the interactive anatomy explorer at transitionslab.org/motorcycle-anatomy.

CHAPTER 4.1

Primary drive and clutch

LEARNING OBJECTIVES

- Explain why a primary reduction sits between the crankshaft and the clutch, and calculate a primary ratio from tooth counts.
- Name every part of a wet multiplate clutch and trace the torque path and the release path through it.
- Calculate the torque capacity of a plate clutch from spring force, friction coefficient, mean radius and number of friction faces.
- Distinguish slipper, assist and centrifugal clutches and state where each is used.
- Diagnose slip, drag and judder from measurements of plates, springs and free play, and describe how a kick-start mechanism engages and disengages.

Primary drive

The crankshaft of a 125 cc single turns at 1,500 rpm at idle and up to about 10,000 rpm at full power, while the rear wheel of a motorcycle at 90 km/h turns at roughly 800 rpm. The total speed reduction of about 9:1 to 12:1 in top gear (and 25:1 to 30:1 in first) is split across three stages: the primary drive between crankshaft and clutch, the gearbox, and the final drive to the rear wheel. Splitting the reduction keeps each stage within a sensible size. Putting the first reduction ahead of the clutch means the clutch and gearbox mainshaft spin at only a quarter to a third of crankshaft speed, which reduces the centrifugal load on the clutch basket, the churning losses of the plates in oil, and the inertia that must be synchronised during a gear change.

Most singles and small twins use a **gear primary**: a small pinion on the right-hand end of the crankshaft meshes with a large gear riveted to the back of the clutch basket. Straight-cut (spur) teeth are cheap, carry no axial thrust and are used on most commuter engines; helical teeth run quieter but push the basket sideways, so they need a thrust face or bearing. Because the crank pinion and the basket gear are permanently meshed, any backlash produces a rattle at idle; some engines use a split "scissors" gear in which a spring-loaded half takes up the backlash. Large multi-cylinder engines with long crank-to-mainshaft centres often use a **chain primary**, either a duplex roller chain or an inverted-tooth (Hy-Vo) chain, with a tensioner; older British twins ran a duplex primary chain in an oil bath.

Between the primary gear and the clutch basket there is almost always a set of **cushion springs** (four to six short coil springs or rubber blocks in windows in the gear web). They let the gear rotate a few degrees relative to the basket, absorbing the torque pulses of a single-cylinder firing stroke and the shock of a snatched gear change. Worn cushion springs show as radial play between gear and basket and as a clonk when the throttle is opened and closed in gear.

```
i_p = z_basket / z_crank
n_clutch = n_crank / i_p
```

where i_p is the primary ratio, z the number of teeth and n the speed in rpm. A crank pinion of 20 teeth driving a 68-tooth basket gear gives i_p = 68/20 = 3.40, so at 9,000 rpm the clutch turns at 2,647 rpm. Torque rises in the same proportion (less about 1–2 % gear loss): the K-Light 125 peak of 8.9 N·m at 7,500 rpm becomes about 30

N·m at the clutch.

> ▤ REFERENCE DATA **K-Light 125 clutch data (K-Light 125 manual)**
>
> Clutch type: wet multi-plate friction type. Friction plate thickness 2.9–3.0 mm, service limit **2.6 mm**. Clutch spring free length 35.45–36.5 mm, service limit **34.2 mm**. Clutch centre locknut 50–60 N·m (four-claw socket QJ157-0110/G20 and holder QJ157-0111/G20). Clutch cable free play at the lever **10–15 mm**. Engine oil 1.1 ± 0.1 L at an oil change.

The wet multiplate clutch

The clutch lets the rider disconnect the engine from the gearbox to start from rest, change gear and stop without stalling, and it limits the torque that can reach the drivetrain during a shock. A motorcycle clutch must transmit full engine torque in a package small enough to fit inside the crankcase cover, so it uses many small friction faces in parallel rather than one large disc as in a car. Running the plates in engine oil (a **wet clutch**) carries heat away from the faces and makes engagement smooth, at the cost of some drag and a lower friction coefficient than a dry clutch.



FIGURE 4.1 X-ray view of a horizontal single-cylinder commuter engine with the clutch cover rendered transparent. The small primary drive gear on the crankshaft meshes with the large driven gear riveted to the clutch basket; inside the basket the friction plates (brown) alternate with the steel plates, and four coil springs clamp the stack through the pressure plate. Pulling the lever pushes the lift rod and release bearing outward, compressing the springs and letting the plates separate.

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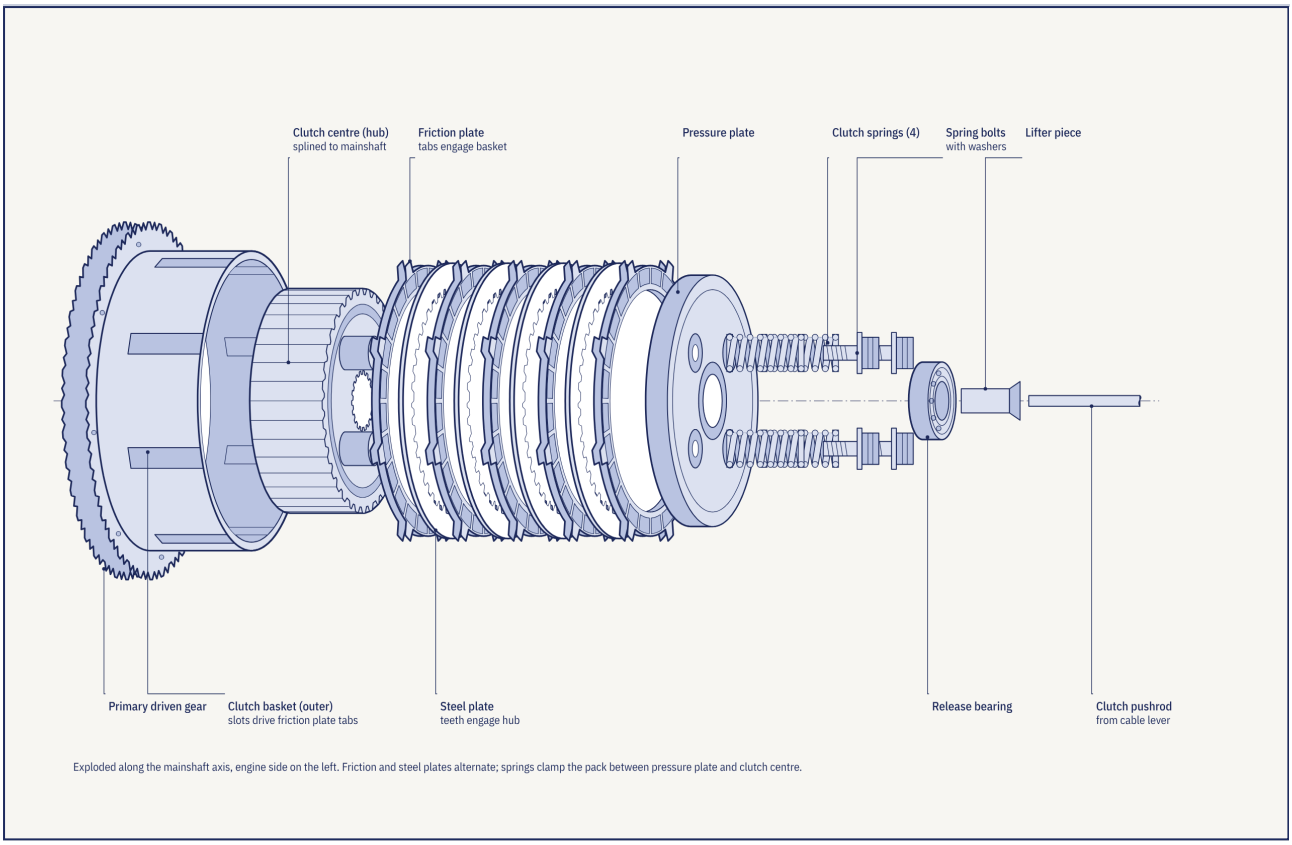


FIGURE 4.2 Wet multiplate clutch exploded: clutch basket with primary driven gear and cushion springs, alternating friction and steel plates, clutch hub, pressure plate, coil springs and bolts, release bearing and pushrod mechanism.

The parts, in the order the torque passes through them, are:

- **Clutch basket (outer, housing)**: a cup, usually aluminium, with axial slots around its rim. It is driven by the primary gear and turns freely on a bush or needle bearing on the gearbox mainshaft.
- **Friction plates (drive plates)**: aluminium or steel cores bonded with a cork, paper-based or sintered friction material, with tabs on the outside that engage the basket slots. A 125 cc engine typically has four or five; a 1,000 cc sports engine eight to ten.
- **Steel plates (driven plates)**: plain pressed steel discs with internal teeth that engage splines on the clutch hub, interleaved between the friction plates.
- **Clutch hub (centre, inner)**: splined to the gearbox mainshaft and held by a locknut with a tab washer or staked collar. The K-Light 125 manual calls this the "center bearing bracket".
- **Pressure plate**: clamps the plate stack against a flange on the hub. Four to six coil springs, held by bolts through the pressure plate into hub bosses, or a single diaphragm (Belleville) spring, provide the clamping force.
- **Release mechanism**: lifts the pressure plate away from the stack against the springs. On most singles the cable turns a lever on the right-hand crankcase cover whose cam or quick-thread pushes on a release bearing in the centre of the pressure plate (an outside push mechanism); on many larger engines a pushrod runs through the hollow mainshaft from a lever or slave cylinder on the left-hand side.

With the lever released, the springs squeeze the stack so that the friction plates (turning with the basket) and the steel plates (turning with the hub) lock together by friction, and torque flows from basket to hub to mainshaft. Pulling the lever compresses the springs and lets the stack open by a total of about 0.5–1.0 mm; the plates then slide past each other in a film of oil and the engine runs while the mainshaft can stop.

Cable versus hydraulic release

A **cable release** is light, cheap and easy to replace at the roadside, but cable friction rises as the inner wire corrodes or the outer is routed in tight bends, and the free play changes as the plates wear and as the engine (and so the cable) warms. Free play is set at the lever (10–15 mm on the K-Light 125) with the in-line adjuster, using the lower adjuster at the crankcase when the upper one runs out of thread. Too little free play holds the release bearing against the pressure plate and causes slip; too much prevents full release and causes drag.

A **hydraulic release** uses a master cylinder on the handlebar and a slave cylinder at the engine, linked by a hose. Because the slave piston sits on the pushrod with the fluid taking up the clearance, plate wear is compensated automatically and there is no free play to set. The fluid is normally DOT 4 brake fluid (some makers, for example many Magura-equipped European bikes, specify mineral oil, which must never be mixed with glycol fluids), and the system is bled exactly like a brake (Job sheet 4.7.2).

Slipper and assist clutches

A downshift at high road speed asks the rear wheel to drive the engine through the gearbox. If the engine cannot accelerate quickly enough, the back-torque can lock or hop the rear tyre. A **slipper clutch (back-torque limiter)** places a set of ramps between the hub and the pressure plate. Under drive torque the ramps are inactive or, in an **assist** design, they pull the pressure plate further into the stack, so lighter springs can be fitted for the same capacity and the lever effort falls by roughly a quarter to a third. Under back-torque the ramps ride up and push the pressure plate outwards, partially releasing the stack so that it slips at a set torque. Combined assist and slipper ("A&S") clutches are now common on mid-size road bikes and are fitted to some 125 cc and 150 cc sports models.

Centrifugal clutches

Step-through motorcycles such as the Honda Super Cub use an **automatic centrifugal clutch** on the crankshaft: weighted shoes or a ball-and-ramp plate engage the plate stack as engine speed rises above idle, and a linkage from the gear pedal also releases the clutch while the pedal is moved, so the rider never needs a lever. Twist-and-go scooters place a dry **centrifugal shoe clutch** on the driven pulley of the CVT (Chapter 4.3): three shoes, held in by springs, swing outwards and contact the inside of a steel bell as engine speed rises, typically engaging between about 2,800 and 4,000 rpm depending on the spring rate. Mopeds and small trail bikes for children use similar dry shoe clutches on the crankshaft.

Torque capacity

The torque a plate clutch can transmit before it slips is the friction force on each face multiplied by its effective radius and by the number of faces in contact.

```
T = μ × F × r_m × n
r_m ≈ (r_o + r_i) / 2
```

where T is the slip torque (N·m), μ the coefficient of friction (about 0.10–0.15 for wet paper or cork against steel in motorcycle oil, about 0.3–0.4 dry), F the total spring force on the pressure plate (N), r_m the mean friction radius (m) using the uniform-wear approximation, r_o and r_i the outer and inner radii of the friction lining, and n the number of friction faces. Each friction plate has two faces, so five friction plates give n = 10.

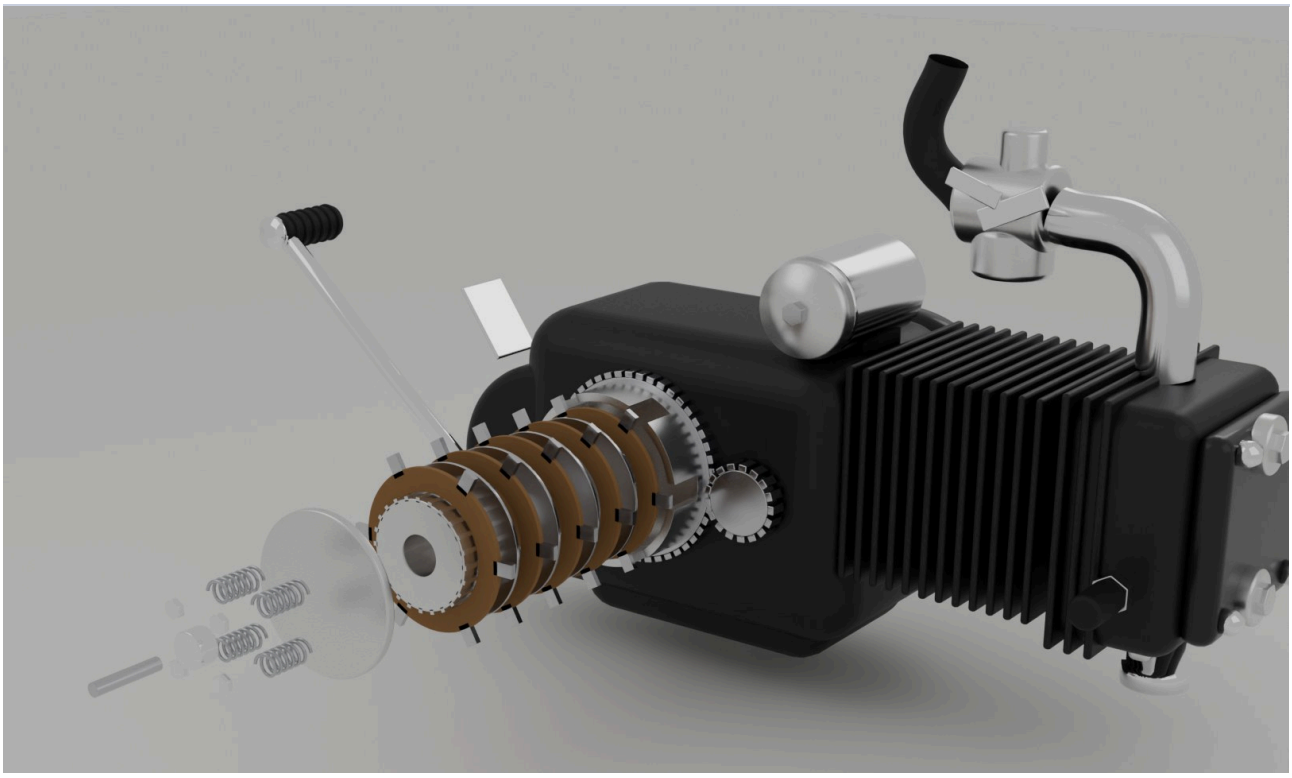


FIGURE 4.3 The same clutch exploded along the mainshaft, in assembly order from the crankcase outward: driven gear and basket with its six slots, friction and steel plates, splined hub, pressure plate, the four springs and their bolts, the release bearing and lift rod, and finally the clutch cover. The friction plates lock to the basket by their outer tabs and turn with the engine; the steel plates lock to the hub by their inner teeth and turn with the gearbox.

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Worked example: a 125 cc clutch has five friction plates with linings from r_i = 35 mm to r_o = 50 mm (r_m = 42.5 mm), four springs each exerting 240 N at installed height (F = 960 N) and μ = 0.13.

$$T = 0.13 \times 960 \times 0.0425 \times 10 \approx 53 \text{ N·m}$$

The clutch must carry engine torque multiplied by the primary ratio: 8.9 × 3.40 ≈ 30 N·m for the K-Light 125. The capacity margin of 53/30 ≈ 1.75 covers firing-stroke torque peaks, which on a single can be several times the mean, and the loss of spring force as springs fatigue. The same equation explains every slip fault: worn linings reduce spring installed length and so F; short springs reduce F; glazed linings or the wrong oil reduce μ.

> SAFETY **Oil and the wet clutch**
>
> Automotive oils labelled "Energy Conserving" or with friction modifiers (molybdenum, some esters) lower μ and cause clutch slip. Use oil meeting **JASO MA or MA2**; JASO MB is for scooters with dry clutches and must **not** be used in a wet clutch. A clutch that slips after an oil change is checked by changing back to a JASO MA oil before dismantling anything.

Slip, drag, judder and wear

Slip shows as engine speed rising without a matching rise in road speed, most noticeably in top gear at wide throttle. Causes in order of likelihood are insufficient free play, wrong oil, worn friction plates, weak springs and, on a cable clutch, a binding release lever. **Drag** is incomplete release: the bike creeps in gear with the lever pulled, neutral is hard to find at rest, and first gear engages with a loud clunk. Causes are excessive free play, a stretched cable, warped steel plates, swollen friction material, notched basket slots that stop the plates sliding apart, or cold, thick oil. **Judder** (grab) during take-off comes from glazed or contaminated linings, warped plates, a notched basket or loose engine mounts.

Steel plates rarely wear in thickness but distort from heat. Each is checked for warp on a surface plate with a feeler gauge; a typical service limit is **0.10–0.20 mm**, so any plate that admits a feeler of that size at any point is replaced. Friction plates are measured across the lining with a vernier at several points (K-Light 125 limit **2.6 mm** from 2.9–3.0 mm new); MAVCC Unit XIII notes that the wear on a single plate is small, but multiplied by eight or ten faces it is enough to shorten the spring installed height noticeably. Springs are measured for free length and replaced as a set if any one is below the limit, because uneven force tilts the pressure plate and causes judder. Basket slots and hub splines are inspected for notches worn by the plate tabs: light notches can be dressed with a file, deep notches mean a new basket.

Symptom	Likely cause	Check	Remedy
Engine revs rise, speed does not (slip)	No free play; worn plates; weak springs; wrong oil	Free play at lever; plate thickness; spring free length; oil grade	Adjust to 10–15 mm; replace plates or springs as a set; JASO MA oil
Bike creeps with lever pulled (drag)	Excess free play; warped steels; notched basket	Free play; warp on surface plate; slot condition	Adjust; replace plates; dress or replace basket
Judder on take-off	Glazed or oily linings; warped plates; loose engine mount	Lining surface; warp; mount bolts	Replace plates; torque mounts
Heavy lever	Dry or kinked cable; release mechanism seized	Disconnect cable and operate lever alone	Lubricate or replace cable; reroute without tight bends
Clonk on throttle opening	Worn cushion springs; loose hub nut	Rotational play between primary gear and basket; hub nut torque	Replace basket assembly; retorque and lock nut

The kickstart mechanism

Many small motorcycles keep a kickstarter as a backup to the electric starter; the K-Light 125 has both. The kick lever is splined to a **kickstart shaft** carrying a **ratchet** on a helical spline and a free-turning **kick gear** that meshes with a gear on the gearbox (usually the mainshaft first gear or an idler that drives the clutch basket). At rest, a tab on the ratchet rests against a **guide (stopper) plate** fixed to the crankcase, which holds the ratchet away from the kick gear. When the lever is pressed, the shaft turns, the tab leaves the stopper and a light **ratchet spring** pushes the ratchet along the helix until its face teeth engage the kick gear, so the shaft drives the gearbox and, through the engaged clutch, the crankshaft. When the engine fires and overruns the gear, the angled ratchet teeth ride over each other; at the end of the stroke a strong **return spring** brings the shaft back, the tab rides up the stopper and the ratchet is pulled clear. A **primary kickstart**, which drives the clutch basket directly, can start the engine in any gear with the clutch pulled; a non-primary type needs neutral. Faults are a lever that slips under load (worn ratchet teeth or a weak ratchet spring), a lever that does not return (broken or unhooked return spring) and grinding during riding (stopper worn so the ratchet does not fully disengage). The K-Light 125 manual directs checks of both springs and of the fit of the shaft spline in the ratchet.

EXPLORER EXERCISE · transitionslab.org/motorcycle-anatomy **Find the clutch in the exploded diagram**

Open the exploded diagram at transitionslab.org/motorcycle-anatomy and select "Engine (cylinder head, cylinder, crankcase)". Locate the right-hand crankcase cover behind which the clutch sits, then use the RPM slider to see how crankshaft speed compares with the speed of a clutch geared down by 3.4:1.

REVIEW QUESTIONS

1. List the three stages of speed reduction between crankshaft and rear wheel and give one reason the first reduction is placed ahead of the clutch.
2. A crank pinion has 17 teeth and the basket gear 72 teeth. Calculate the primary ratio and the clutch speed at 8,000 rpm.
3. Name the clutch parts that are splined to (a) the basket and (b) the hub.
4. A clutch has six friction plates (lining r_i = 38 mm, r_o = 55 mm), five springs at 280 N each, and μ = 0.12. Calculate its slip torque.
5. The springs in question 4 have fatigued so that each now exerts 230 N. What is the new capacity, and by what percentage has it fallen?
6. Explain how an assist-and-slipper clutch allows lighter lever effort and prevents rear-wheel hop.
7. Why must JASO MA or MA2 oil be used in a motorcycle with a wet clutch?
8. A customer reports that the bike creeps forward at traffic lights with the lever pulled and that neutral is hard to find. List three likely causes in the order you would check them.
9. During inspection, one of four clutch springs measures 34.0 mm and the others 35.6 mm (K-Light 125 limit 34.2 mm). What do you replace and why?
0. Describe what disengages a kickstart ratchet from the kick gear at the end of the stroke.
1. Where is the clutch on a twist-and-go scooter, and what makes it engage?

ANSWERS

1. Primary drive, gearbox and final drive. Placing a reduction ahead of the clutch lowers clutch and mainshaft speed, reducing centrifugal stress, oil churning losses and the inertia to be synchronised in a gear change.
2. i_p = 72/17 = 4.24. n_clutch = 8,000/4.24 ≈ 1,889 rpm.
3. (a) Friction plates (by their outer tabs). (b) Steel plates (by their inner teeth); the hub itself is splined to the mainshaft.
4. r_m = (0.038 + 0.055)/2 = 0.0465 m; F = 5 × 280 = 1,400 N; n = 12. T = 0.12 × 1,400 × 0.0465 × 12 ≈ 93.7 N·m.
5. F = 5 × 230 = 1,150 N; T = 0.12 × 1,150 × 0.0465 × 12 ≈ 77.0 N·m. The fall is (93.7 – 77.0)/93.7 ≈ 18 %, the same proportion as the fall in spring force.
6. Ramps between hub and pressure plate pull the pressure plate into the stack under drive torque, adding clamping force so weaker springs can be used; under back-torque the ramps push the pressure plate outwards, reducing clamping force so the clutch slips and limits the torque that can lock or hop the rear tyre.
7. Friction modifiers in energy-conserving car oils reduce the coefficient of friction between the plates, lowering torque capacity and causing slip; JASO MA and MA2 oils are tested for wet-clutch friction performance.
8. Excess free play or a stretched or binding cable; warped steel plates; notched basket slots or hub splines preventing the plates separating (with cold or wrong-viscosity oil as a contributing factor).

9. Replace all four springs as a set. One short spring gives uneven clamping around the pressure plate, which tilts it, causing judder and local slip, and the others will soon reach the limit too.
10. The return spring rotates the shaft back; a tab on the ratchet rides onto the fixed guide (stopper) plate, which pulls the ratchet along its helical spline and away from the kick gear.
11. On the driven (rear) pulley of the CVT; centrifugal force on three shoes overcomes their return springs as engine and pulley speed rise, pressing the shoes against the clutch bell.

CHAPTER 4.2

Gearbox

LEARNING OBJECTIVES

- → Describe the layout of a constant-mesh sequential gearbox and trace the power flow through mainshaft, countershaft and dogs in each gear.
- → Explain how the shift drum, forks, ratchet mechanism and stopper arm turn a pedal movement into a single, positive gear change.
- → Calculate gear, overall and road-speed figures from tooth counts, sprocket sizes and tyre dimensions.
- → Explain the operation of neutral finders and quickshifters.
- → Diagnose jumping out of gear, hard shifting and false neutrals from wear measurements on dogs, forks and drum.

Why a gearbox is needed

An engine produces useful torque over a limited speed band; the K-Light 125 makes 8.9 N·m at 7,500 rpm and 7.8 kW at 9,000 rpm and runs out of breath not far beyond. The gearbox selects a ratio that keeps the engine inside that band from walking pace to top speed and multiplies torque at low road speed so the machine can start on a hill with a passenger. Five or six ratios are normal on road motorcycles; competition motocross bikes use five closely spaced ratios, trials bikes six with a very low first gear, and scooters replace the gearbox with a continuously variable transmission (Chapter 4.3).

Constant-mesh layout

Almost every motorcycle gearbox is a **constant-mesh, two-shaft, sequential** type built into the crankcase (unit construction) and lubricated by engine oil. The **mainshaft (input shaft, primary shaft)** carries the clutch and receives power from it. The **countershaft (output shaft, layshaft, auxiliary shaft)** lies parallel and behind it and carries the gearbox (front) sprocket on its outer end. Each gear pair is always in mesh; what changes is which pair is locked to its shaft.

On each shaft some gears are **fixed** (machined integral with the shaft or pressed on), some are **free** (turning on a bush or needle bearing and located axially by circlips and thrust washers), and some are **sliding** gears that are splined to the shaft so they always turn with it but can move axially. A sliding gear has **dogs** (projecting lugs) on one or both faces that engage **dog slots** or matching dogs on the face of the neighbouring free gear. When a fork

slides the gear across, the dogs lock the free gear to the shaft and that ratio carries the torque; all the other pairs merely idle. The sliding gears double as gears in their own right, which keeps the box short, so on a five-speed box there are typically three sliding members serving five ratios.

Because the gears are always meshed, they can use strong, quiet helical or spur teeth, and shifting only requires the dogs to line up, not the teeth. The price is that a dog engagement is abrupt and that the gearbox has no synchromesh, so the rider must unload the dogs momentarily with the clutch or a throttle lift.

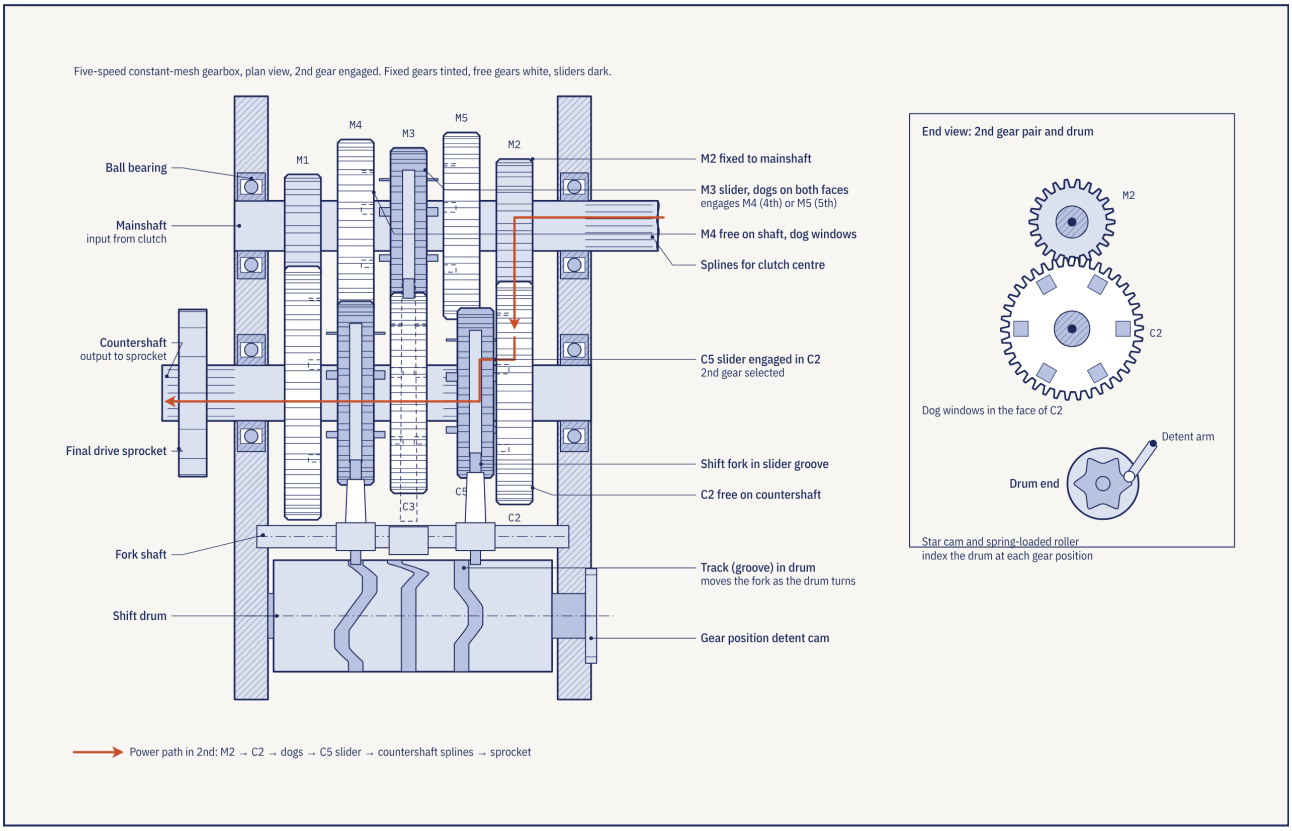


FIGURE 4.4 Constant-mesh five-speed gearbox: mainshaft and countershaft with fixed, free and sliding gears, dogs and slots, three shift forks riding in the grooves of the shift drum, and the drum detent plate.

Dogs and dog wear

Dogs transmit the full torque of the gear across a few square millimetres of contact, so the shapes matter. Road gearboxes commonly use three to six dogs per face with their driving faces **back-cut (undercut)** by 2–4°, so that the drive torque tends to pull the gears together rather than push them apart. As the driving edges wear and round off, the back-cut is lost and the axial component reverses: under load the gears are pushed out of engagement. Rounded dogs are therefore the root cause of almost every case of jumping out of gear. The K-Light 125 manual lists "joint claws are worn and the edges become round corners" as the first cause of the gear disengaging spontaneously. Race gearboxes use fewer, wider dogs with large clearances (for example three dogs into six slots) so that engagement is faster at the cost of more backlash.

The selector mechanism

Shift drum and forks

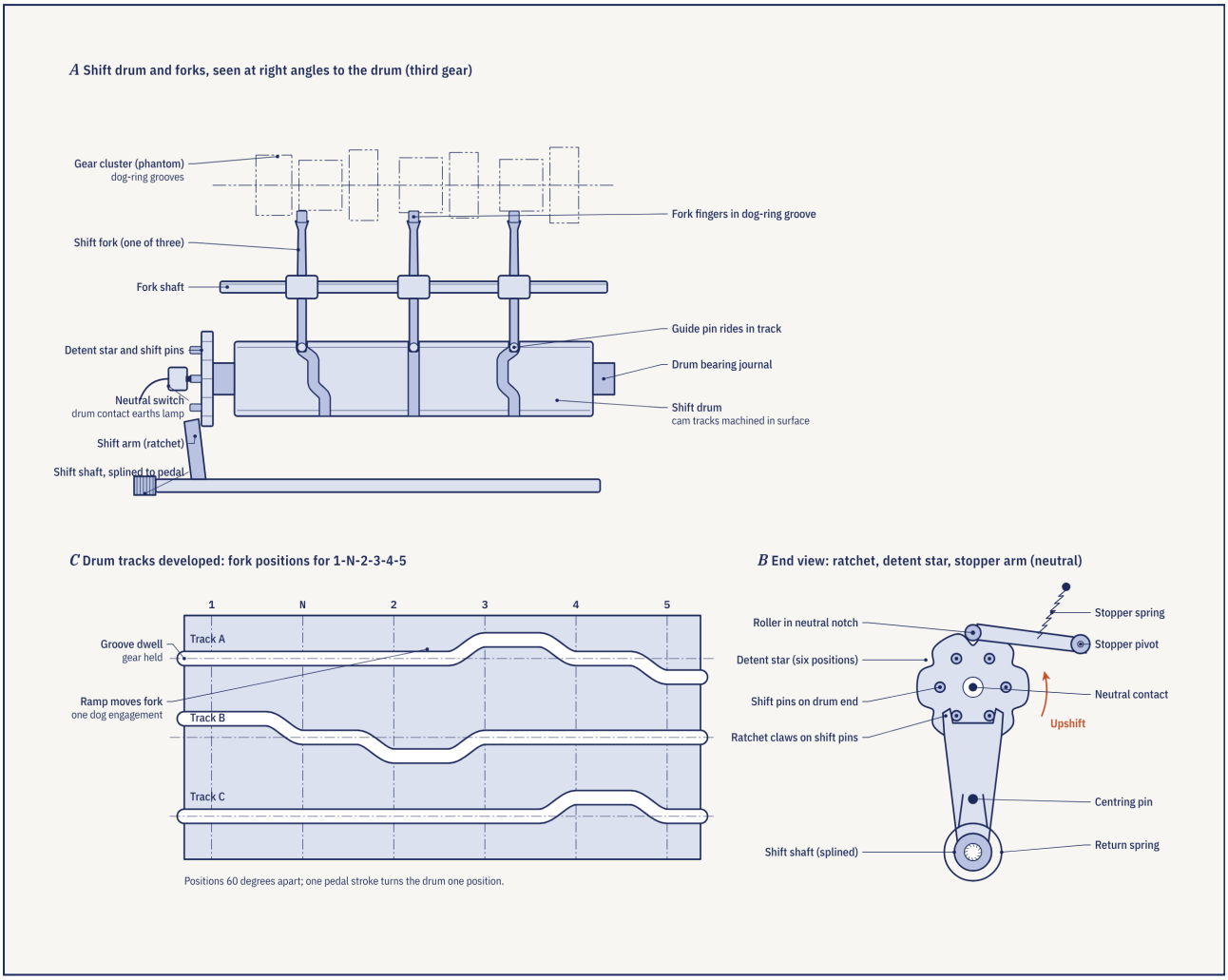


FIGURE 4.5 Gear shift mechanism: shift drum with tracks, forks, shift shaft, ratchet, detent star, stopper arm and neutral switch.

The **shift drum** is a cylinder with machined grooves (cam tracks) around its circumference. Each **shift fork** has a guide pin that rides in one groove and two prongs that sit in a groove on a sliding gear. As the drum rotates, each groove moves its fork, and so its sliding gear, sideways by a precise amount at the right moment. Drum position therefore defines the gear. On most road boxes two forks run on the mainshaft side or the countershaft side on a separate **fork shaft**, and a third on the other.

> ▤ REFERENCE DATA **K-Light 125 gearshift mechanism limits (K-Light 125 manual)**
>
> Fork shaft outside diameter 11.97–12.00 mm, limit **11.95 mm**. Fork bore 12.000–12.018 mm, limit **12.05 mm**. Fork claw (prong) thickness 4.93–5.00 mm, limit **4.7 mm**. Shift drum outside diameter 35.8–36.0 mm, limit **35.75 mm**. Drum groove width 7.05–7.15 mm, limit **7.3 mm**.

Fork prongs rub continually against the side of the gear groove when a gear is loaded slightly askew, and they wear thin or turn blue from heat. A worn prong, a worn drum groove or a bent fork reduces the distance the dog is pushed into engagement, which leads straight to jumping out of gear.

Ratchet, stopper and detent

The gear pedal is splined to a **gearshift shaft** that runs through the crankcase. On the inside, a **shift arm (shift plate)** with a pair of spring-loaded **pawls (claws)** engages pins or ramps on the end of the drum. Each stroke of the pedal rotates the drum by one step; a **return (centring) spring** then brings shaft and arm back to the centre, ready for the next stroke. This is what makes the box **sequential**: each pedal stroke can only move one gear up or down.

Drum position is held between shifts by a **stopper arm (detent lever)** with a roller, pressed by a spring into notches in a star-shaped **detent (positioning) plate** on the drum. The notch profile pulls the drum fully into position at the end of each shift, so a half-completed pedal movement either completes or falls back. The neutral position is usually a half-step between first and second, which is why the pedal moves only half as far from first to neutral, and why a hurried first-to-second shift can stop in neutral. A **neutral switch** in the crankcase is earthed by a contact on the drum in neutral, lighting the green lamp and, on bikes with starter interlocks, permitting the starter to turn with the clutch engaged (Module 3).

The K-Light 125 manual lists the parts of this mechanism as the gearshift shaft assembly, shift plate and spring, return spring, stopper lever and spring, and positioning plate, and directs that the shift plate must return freely before dismantling, that the return spring be checked for weakness, and that the shaft be checked for bending.

Neutral finders

Finding neutral at a standstill is awkward because the drum can skip past the half-step. Kawasaki's **Positive Neutral Finder** places steel balls in radial holes in a countershaft gear; when the shaft is stationary they drop into a groove and block the gear from sliding beyond neutral towards second, but when the shaft turns, centrifugal force throws them out and the shift is unaffected. Other makers achieve a similar result with detent geometry that makes the neutral notch deeper.

Quickshifters

A **quickshifter** allows full-throttle upshifts without the clutch. A load cell or strain gauge in the gear linkage (or a switch with a set pre-load) detects the rider's pedal pressure and signals the ECU, which interrupts ignition or injection for a period that shortens with engine speed, typically from about 80–100 ms at low rpm to about 50 ms near the limiter. The momentary loss of drive torque unloads the dogs, the spring-loaded drum completes the shift, and power is restored. A **bidirectional** (up-and-down) quickshifter also blips the throttle via ride-by-wire on downshifts to match revs. Quickshifters need positive dog engagement and correct linkage free play; a sloppy linkage or worn detent produces missed shifts and false neutrals.

Ratio calculations

Each gear ratio is the driven gear's tooth count divided by the driving gear's. Because power passes through three stages in series, the ratios multiply.

```
i_gear = z_countershaft gear / z_mainshaft gear
i_final = z_rear sprocket / z_front sprocket
i_overall = i_p × i_gear × i_final
n_wheel = n_engine / i_overall
v (km/h) = n_wheel × C × 60 / 1000
```

where C is the rolling circumference of the rear tyre in metres. The geometric diameter of a tyre is the rim diameter plus twice the sidewall height; the sidewall height is the section width multiplied by the aspect ratio. A tyre under load rolls on a slightly smaller effective radius, and a reduction of about 3 % from the geometric circumference is a

reasonable working allowance.

Worked example: road speed in each gear

The K-Light 125 manual gives the rear sprocket as 41 teeth, the chain as 428 pitch with 134 links and the rear tyre as 130/90-15, but does not list the primary or internal gear ratios or the front sprocket. The calculation below therefore uses a representative set typical of air-cooled 125 cc singles of this class, together with an assumed 14-tooth gearbox sprocket; the method is the same with the real figures from the parts book or from counting teeth.

Rear tyre 130/90-15: sidewall = 130 × 0.90 = 117 mm; diameter = 15 × 25.4 + 2 × 117 = 615 mm; geometric circumference = π × 0.615 = 1.932 m; rolling circumference C ≈ 1.932 × 0.97 ≈ 1.874 m.

Primary ratio 68/20 = 3.400; final drive 41/14 = 2.929.

Gear	Teeth (driven/driving)	Gear ratio	Overall ratio	km/h at 7,500 rpm	km/h at 9,000 rpm
1	33/12	2.750	27.38	30.8	37.0
2	25/14	1.786	17.78	47.4	56.9
3	26/19	1.368	13.63	61.9	74.3
4	24/22	1.091	10.86	77.6	93.2
5	18/20	0.900	8.96	94.1	112.9

Taking fifth gear as an example: i_overall = 3.400 × 0.900 × 2.929 = 8.96; at 9,000 rpm the wheel turns at 9,000/8.96 = 1,004 rpm, and v = 1,004 × 1.874 × 60/1,000 = 112.9 km/h.

The manual quotes a maximum speed of 90 km/h. With these ratios the engine would reach its power peak in fifth only at 113 km/h, which aerodynamic and rolling drag at 7.8 kW will not allow, so the machine tops out at about 7,200 rpm in fifth, below the power peak. This is deliberate on commuter machines: an "overdrive" top gear lowers cruising rpm, noise and fuel consumption at the price of top speed. Fitting one tooth fewer on the front sprocket (13T) raises i_final to 3.154 and lowers the 9,000 rpm speed in fifth to 105 km/h, bringing the power peak closer to the speed the bike can actually reach and improving acceleration in every gear.

The step between gears is the ratio of adjacent gear ratios: 2.750/1.786 = 1.54 from first to second, then 1.31, 1.25 and 1.21. Steps shrink towards top gear because, at higher speed, the power needed rises steeply and the engine must drop fewer revs on each upshift to stay near its power band; this approximately geometric progression is normal design practice.

> EXPLORER EXERCISE · transitionslab.org/motorcycle-anatomy **Gear ratio and engine speed**
>
> On the explorer at transitionslab.org/motorcycle-anatomy, set the RPM slider to 7,500 and then 9,000 rpm and note the piston speed for the K-Light 125 bore and stroke (56.5 × 49.5 mm). Compare these engine speeds with the road speeds in the table to see how much of the speed range each gear covers.

Gearbox faults

Symptom	Likely cause	Check	Remedy
Jumps out of a particular gear under load or on the overrun	Rounded or worn dogs and slots on that gear pair; worn or bent fork; worn drum groove; weak stopper spring	Inspect dogs for rounding; measure fork claw thickness (K-Light limit 4.7 mm) and drum groove (limit 7.3 mm); stopper spring	Replace both gears of the dog pair, the fork and if needed the drum; replace spring

Symptom	Likely cause	Check	Remedy
Hard shifting, pedal stiff	Clutch drag; bent gearshift shaft; seized fork on fork shaft; burr on drum	Check clutch release first; check shaft straightness; fork bore and shaft diameter	Correct clutch; replace shaft or forks
Pedal does not return	Broken or unhooked return spring; bent shaft rubbing the case	Remove clutch cover and observe the spring	Replace spring or shaft
False neutrals between gears	Insufficient pedal travel (boot fouling, linkage misadjusted); worn detent plate or stopper roller; weak pawl springs	Linkage free play and pedal height; detent notch edges	Adjust linkage; replace detent plate, stopper or pawl springs
Will not engage any gear	Broken fork guide pin; broken pawl; sheared drum pin	Remove clutch cover; inspect shift arm and drum end	Repair as found; inspect gears for debris
Whine in one gear only	Pitted or chipped teeth on that pair	Inspect teeth after case split	Replace gear pair

A gear that jumps out has usually been damaging its dogs for some time, and a rider who holds the lever with a boot to stop it accelerates the wear. Dogs are **always** replaced in pairs (sliding gear and its partner free gear), because a new gear against a rounded partner wears to the same shape quickly.

> NOTE **Order of diagnosis**
>
> Many shifting complaints are clutch complaints. Before splitting the crankcase, confirm that the clutch fully releases (free play, plate warp), that the oil is the correct grade and level, and that the external linkage moves freely; the K-Light 125 manual lists "clutch is not completely disengaged" as the first cause of difficult shifting.

REVIEW QUESTIONS

1. In a constant-mesh gearbox, what is the difference between a fixed gear, a free gear and a sliding gear?
2. Why are dog faces back-cut, and what happens when the back-cut is worn away?
3. Describe the function of the stopper arm and detent plate.
4. Why is neutral located between first and second rather than below first on most motorcycles?
5. A gearbox has a primary of 3.35, first gear 36/13 and a final drive of 45/15. Calculate the overall first-gear ratio.
6. Using the answer to question 5 and a rear tyre with a rolling circumference of 1.95 m, calculate the road speed at 8,000 rpm.
7. Calculate the rolling circumference of a 110/70-17 tyre using a 3 % allowance.
8. A rider changes from a 14T to a 15T front sprocket. By what percentage does road speed at a given engine speed change?
9. A K-Light 125 shift fork claw measures 4.65 mm. What does this mean and what symptom might the rider have reported?
0. How does a quickshifter permit a clutchless upshift?
1. Explain how Kawasaki's Positive Neutral Finder works.

2. A bike jumps out of third under hard acceleration. List the parts you would inspect and the measurements you would take.

ANSWERS

1. A fixed gear is permanently locked to its shaft; a free gear turns on the shaft on a bush or bearing and transmits torque only when dogged to a neighbour; a sliding gear is splined to the shaft (always turns with it) and moves axially under a fork to engage its dogs with a free gear.
2. The undercut makes drive torque pull the engaged gears together; when wear rounds the driving edges the reaction pushes them apart under load and the gear jumps out.
3. A spring-loaded arm with a roller presses into notches on a star plate fixed to the drum, holding the drum in each gear position and snapping it fully into position at the end of a shift.
4. So that the rider can always find first by pressing fully down from any gear, and so that an emergency downshift through the box ends in first rather than neutral; neutral sits at a half-step between first and second.
5. i_gear = 36/13 = 2.769; i_final = 45/15 = 3.000; i_overall = 3.35 × 2.769 × 3.000 = 27.83.
6. n_wheel = 8,000/27.83 = 287.5 rpm; v = 287.5 × 1.95 × 60/1,000 = 33.6 km/h.
7. Sidewall = 110 × 0.70 = 77 mm; diameter = 17 × 25.4 + 2 × 77 = 431.8 + 154 = 585.8 mm; circumference = π × 0.5858 = 1.840 m; rolling ≈ 1.840 × 0.97 = 1.785 m.
8. Final ratio falls by the factor 14/15, so road speed rises by 15/14 − 1 = 7.1 % at a given engine speed (and the bike accelerates less hard).
9. It is below the 4.7 mm service limit; the fork does not hold its gear fully engaged and the reported symptom is likely jumping out of gear (or noise and heat from the fork rubbing the gear groove). Replace the fork and inspect the mating gear groove and dogs.
10. A sensor in the linkage detects the rider's pre-load on the lever and the ECU cuts ignition or fuel for roughly 50–100 ms; the momentary unloading of the dogs lets the pre-loaded drum complete the shift before drive is restored.
11. Steel balls in radial holes in a countershaft gear drop into a groove when the shaft is stationary, blocking movement past neutral; when the shaft turns, centrifugal force holds the balls out and normal shifting is possible.
12. The third-gear dog pair (rounding of dog edges and slots), the fork that moves that sliding gear (claw thickness against the limit, bending, bluing), its drum groove (width), the fork shaft and fork bore (clearance), the stopper arm spring and detent plate, and the external linkage for adequate travel.

CHAPTER 4.3

Final drive and CVT

LEARNING OBJECTIVES

- Describe roller chain construction, decode chain size codes and compare plain, O-ring and X-ring chains.
- Measure chain slack and wear, and judge sprocket wear.
- Compare chain, toothed belt and shaft final drives, including the shaft-drive jacking effect.
- Explain how a scooter CVT varies its ratio and how roller weight changes engine speed.
- Carry out chain and CVT inspection to manufacturer limits.

Roller chain

A roller chain is built from alternating **inner links** (two inner plates pressed onto two **bushings**, with a free-turning **roller** on each bushing) and **outer links** (two outer plates pressed onto two **pins** that pass through the bushings). The pin-to-bushing joint is the wear surface: as it wears, every pitch lengthens slightly and the chain "stretches". In a **plain chain** the joint is lubricated only by what the rider sprays on. An **O-ring chain** traps factory grease in each joint with rubber rings between the inner and outer plates; an **X-ring** (or similar quad-lip) chain uses a ring of X-shaped section that touches the plates on four smaller lips, reducing friction and drag while sealing at least as well. Sealed chains typically last two to three times as long as plain chains on road machines, at the cost of a little extra friction and width.

The three-digit size code gives pitch and roller width. The first digit is the pitch in eighths of an inch and the last two digits the roller width in eightieths of an inch.

Size	Pitch	Roller width	Typical use	Typical tensile strength
415	12.70 mm (1/2 in)	4.76 mm (3/16 in)	Mopeds, 50 cc racers	10–15 kN
428	12.70 mm	7.94 mm (5/16 in)	100–200 cc commuters, K-Light 125	17–22 kN
520	15.875 mm (5/8 in)	6.35 mm (1/4 in)	250–700 cc, most off-road	30–40 kN
525	15.875 mm	7.94 mm	600–1,000 cc road	35–45 kN
530	15.875 mm	9.53 mm (3/8 in)	Large road bikes	40–50 kN

Tensile values vary by maker and grade; the chain's catalogue figure is the one to use. The K-Light 125 chain is a 428 type with 134 links (428HO-1×134), so its nominal length is 134 × 12.70 = 1,701.8 mm. Chains are joined either by a **spring clip** master link, whose open end must face away from the direction of travel (MAVCC Unit XI), or by a **rivet link** peened with a press tool; sealed chains on larger bikes are riveted because a clip can come off at high speed, and MAVCC notes that the master link is usually the point of failure.

Sprockets and ratio

Final-drive ratio is the rear sprocket teeth divided by the front sprocket teeth. Small front sprockets wear fastest because each tooth engages more often and the chain articulates through a larger angle, which also raises friction and polygon effect (speed pulsation as the chain rises and falls on the flats). For a given ratio, larger sprockets give longer life and smoother running but cost ground clearance and weight; a front sprocket below 13–14 teeth on a 428 or 520 chain is avoided on road bikes for this reason. A worn sprocket shows hooked or pointed teeth leaning against the direction of rotation; the K-Light 125 manual calls for replacement when about a quarter of the tooth form is worn. Because a stretched chain rides high on the teeth and wears them to its own pitch, chain and both sprockets are **replaced together**.

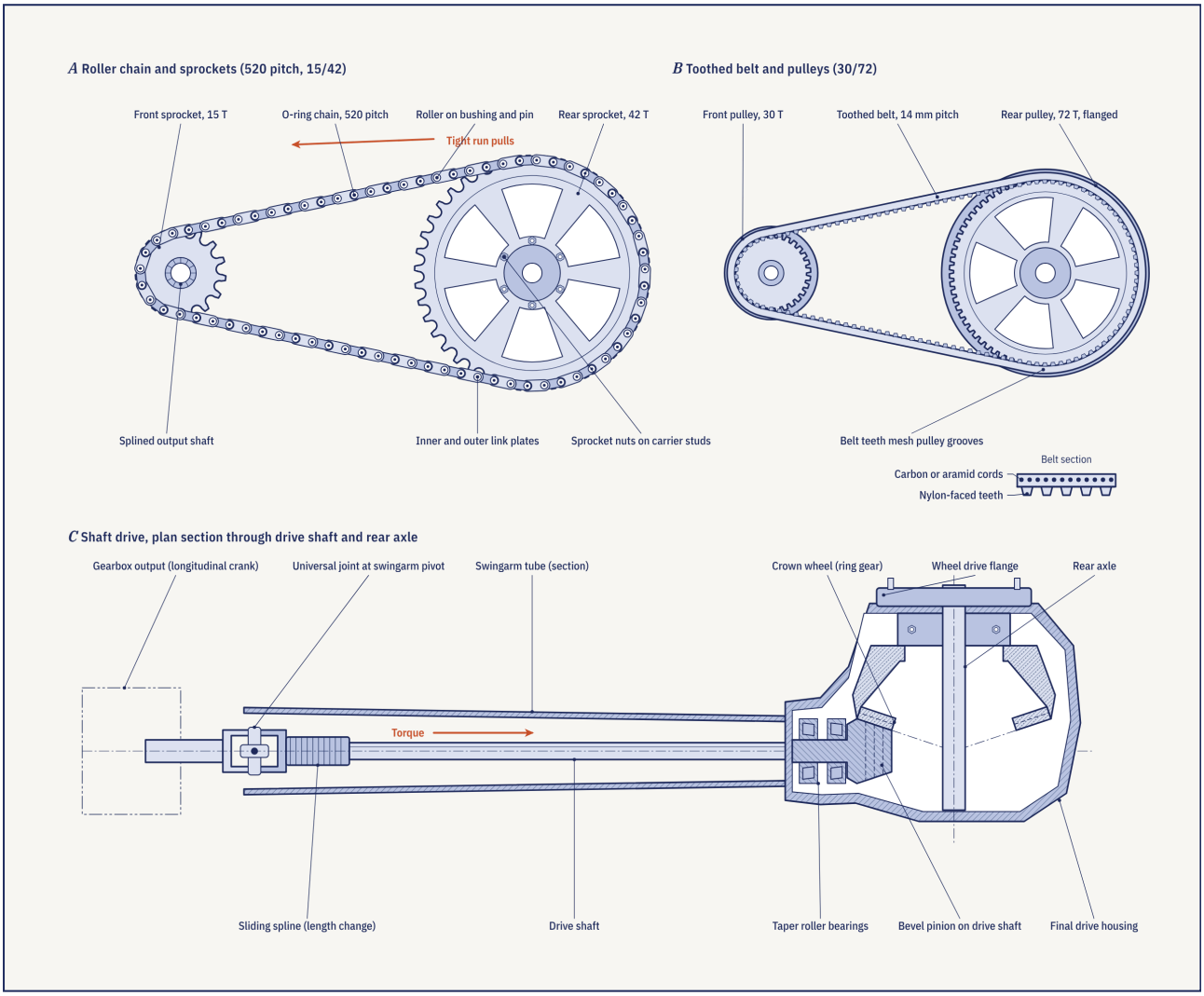


FIGURE 4.6 Final drive types compared: chain and sprockets, toothed belt and pulleys, and shaft drive with bevel gears in section.

Belt drive

Toothed (synchronous) belts with carbon or aramid tensile cords have been used on Harley-Davidson models since 1980 and are now common on electric motorcycles because they are quiet, clean and need no lubrication. A belt is wider than a chain for the same load and cannot be split, so the swingarm must be removable or open at one side. Belts are inspected for missing or cracked teeth, frayed edges and stone damage on the pulley faces; MAVCC notes that a stretched belt usually results from overtightening or misalignment. Tension is set with a gauge at a specified force and deflection, not by feel.

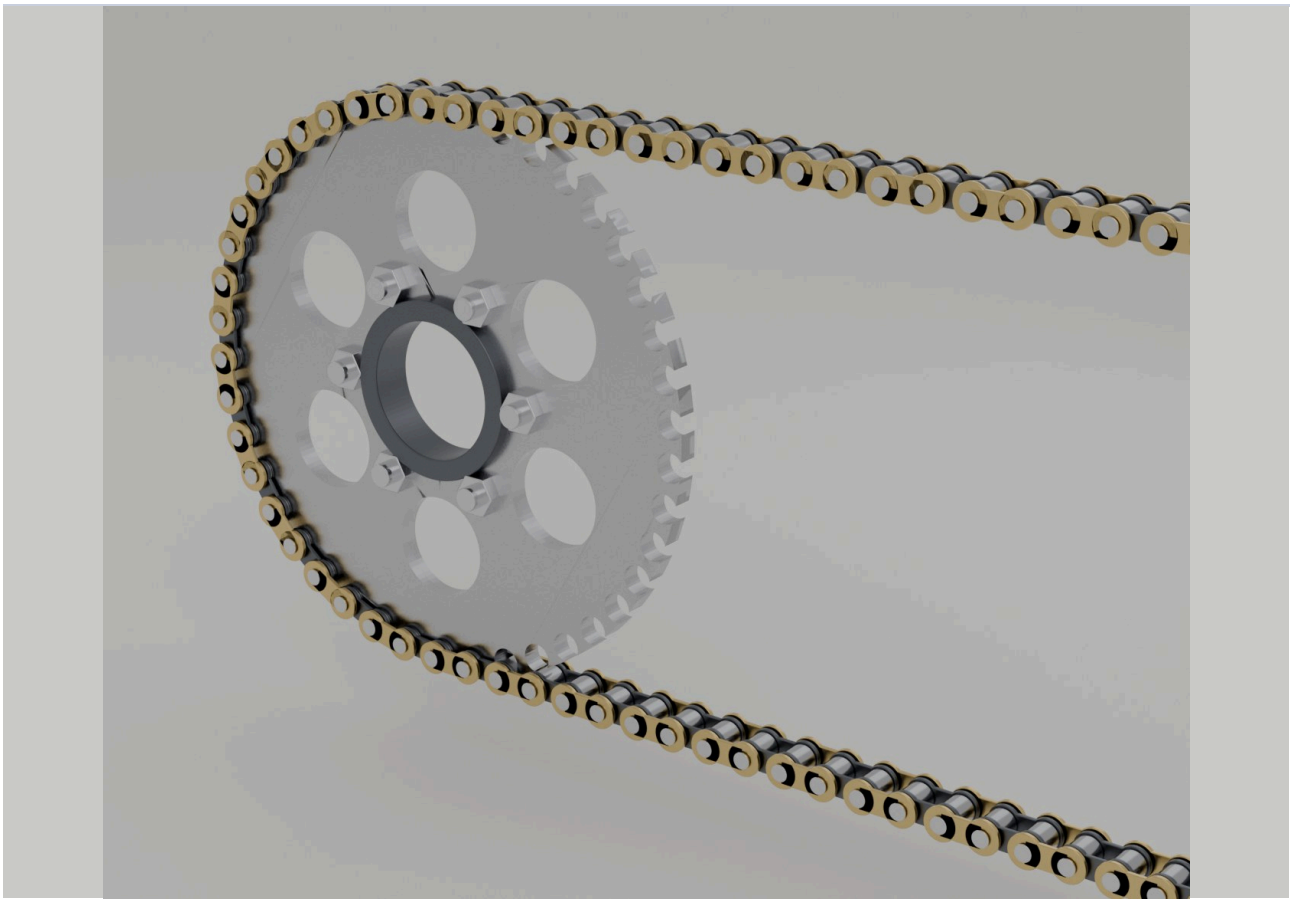


FIGURE 4.7 A 428 O-ring chain on a 42-tooth rear sprocket: the chain wraps half the sprocket, each roller sits in a tooth seat on the pitch circle, gold outer plates alternate with dark inner plates, and the sprocket is bolted to the hub carrier with six nuts.
Render: Transitions Lab, CC BY-SA 4.0

Shaft drive

A shaft drive uses a bevel gear set at the gearbox (unless the crankshaft lies along the frame, as on BMW boxers and Moto Guzzi V-twins), a drive shaft with a universal joint at the swingarm pivot and a sliding spline to accommodate length change, and a bevel (crown-wheel-and-pinion) set in a housing at the wheel, lubricated by its own gear oil, typically an 80W-90 hypoid oil changed at specified intervals. Shafts are sealed and need little service but are heavier, lose about 2–4 % more power than a clean chain, and cannot easily change ratio.

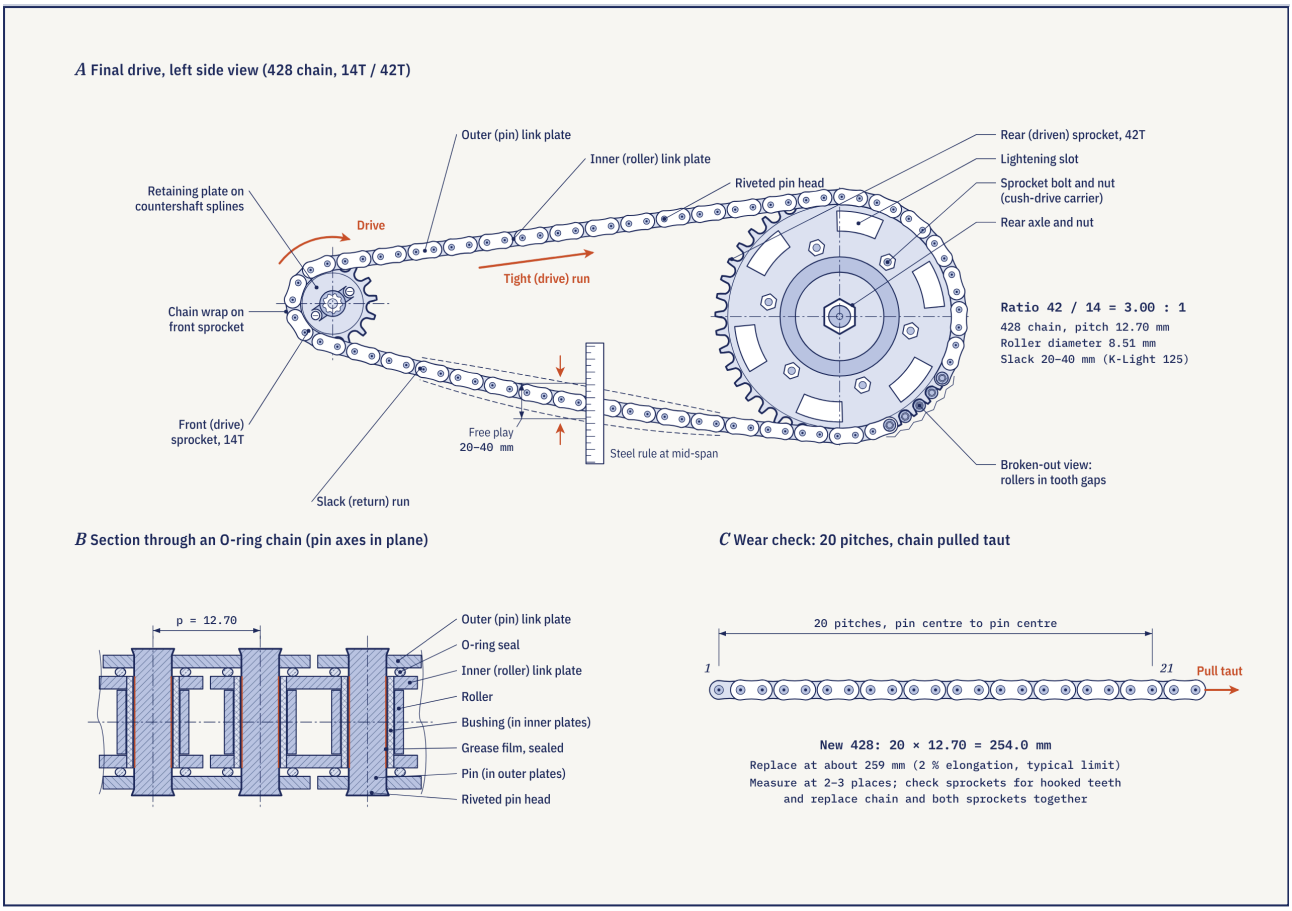


FIGURE 4.8 Chain final drive: gearbox and rear sprockets with the chain run, a section through an O-ring chain showing pin, bushing, roller, inner and outer plates and O-rings, slack measured at the midpoint of the lower run, and a 20-link length measurement for wear.

The reaction torque at the rear bevel housing tries to rotate the housing around the wheel axle. On a simple swingarm that reaction lifts the rear of the machine on acceleration and lets it squat on closing the throttle: the **shaft-drive jacking effect**. Designs such as BMW's Paralever (introduced on the R80GS and R100GS in 1987) and Moto Guzzi's CARC add a torque arm that forms a parallelogram with the swingarm, so the bevel housing cannot rotate relative to the frame and the reaction is fed into the chassis.

Scooter CVT

A twist-and-go scooter uses a **continuously variable transmission** consisting of two variable-diameter V-belt pulleys inside the left-hand side of the swinging engine unit, with a dry centrifugal clutch and a fixed reduction gearbox (typically about 9:1 to 11:1 in two stages, in an oil bath) to the rear wheel.

- **Drive pulley (variator)**: on the crankshaft. The fixed outer half faces a movable half whose back carries ramps. Six **rollers** (weights) sit between those ramps and a fixed **ramp plate**. As engine speed rises, centrifugal force drives the rollers outwards, they wedge between ramp plate and ramps, and push the movable half towards the fixed half, so the belt climbs to a larger radius.
- **Belt**: a cogged, aramid-corded rubber V-belt of fixed length. As it climbs the drive pulley it must sink deeper into the driven pulley.
- **Driven pulley**: the movable half is pushed closed by a strong **contra (torque) spring** and is guided on its hub by a helical **torque cam** (slots with guide pins). Belt tension tries to open it; drive torque through the cam tries to close it. When the rider opens the throttle hard at speed, the higher torque makes the cam squeeze the belt outwards on the driven pulley, which forces a lower ratio: an automatic kickdown.

- **Centrifugal clutch**: on the driven pulley, its shoes engage the clutch bell attached to the gearbox input shaft.

At rest the drive pulley is open (small belt radius) and the driven pulley closed (large radius), so the belt ratio is low, typically about 2.4–2.8:1. At full speed the positions reverse to about 0.8–0.9:1, a total spread of about 3:1. Because the variator decides the ratio from engine speed, the engine runs at a nearly constant rpm while the scooter accelerates, set by the balance between roller centrifugal force and belt and contra-spring forces.

Tuning roller weights

Lighter rollers need more rpm to generate the force to close the variator, so the engine revs higher during acceleration (closer to peak power) and the scooter accelerates harder but cruises noisier and uses more fuel. Heavier rollers shift up at lower rpm for a calmer, more economical ride but less acceleration, especially uphill. Typical 125 cc scooters use six rollers of about 13–20 g in sizes such as 16 × 13 mm or 20 × 15 mm; a change of 1–2 g per roller moves the acceleration rpm by very roughly a few hundred rpm. A stiffer contra spring raises the rpm at which the belt can move on the driven pulley and so has a similar effect at the upper end. Rollers wear flat spots that make them slide rather than roll, which shows as a ratio that changes in steps and a loss of top speed.

Job sheet 4.3.1: Chain and sprocket inspection, adjustment and lubrication

Tools and materials	Reference values
Centre or paddock stand, steel rule, vernier caliper or 300 mm rule, axle and adjuster spanners, torque wrench, chain cleaner (neutral, non-solvent), chain lubricant, soft brush, gloves, safety glasses	K-Light 125: slack 20–40 mm; chain 428, 134 links; rear sprocket 41T; rear axle nut 100–113 N·m; sprocket nuts 45–50 N·m (K-Light 125 manual)

1. Switch off the ignition, select neutral and support the machine upright on level ground (the K-Light 125 manual specifies upright, not on the side stand). **Never** turn the wheel by pulling the chain with the engine running; fingers are drawn into the sprocket.
2. Rotate the rear wheel slowly and find the tightest point of the chain (chains and sprockets wear unevenly). At that point, push the lower run up and down at its midpoint and measure the total vertical movement with the rule. K-Light 125: **20–40 mm**. Less than 20 mm overloads the gearbox output bearing and the chain once the suspension compresses; more than 40 mm lets the chain whip and jump teeth.
3. Look for **tight spots**: if slack varies by more than about **10 mm** around the run, the chain or sprocket is unevenly worn and adjustment will not correct it.
4. Check for kinked (stiff) links by running the chain over a finger on the lower run, and inspect rollers, side plates and O-rings for cracks, missing rollers, rust and dry joints. The K-Light 125 manual directs replacement of a chain with damaged rollers or plates or hard (seized) joints that cleaning and lubrication do not free.
5. Measure wear: pull the chain taut and measure across 10 pitches from the far side of roller 1 to the near side of roller 11 (the K-Light 125 method), or across 20 pitches. For 12.70 mm pitch the new 10-pitch length is 127.0 mm and the 20-pitch length 254.0 mm; the K-Light 125 manual quotes 127 mm, which is the **new** length, so apply the chain maker's elongation limit, typically about **1.5–2 %** (about **129 mm** over 10 pitches, **258–259 mm** over 20). Measure in two or three places.
6. Inspect the sprockets for hooked, pointed or broken teeth and for loose rear sprocket nuts. Check the cush drive rubbers in the hub for cracks and free play (more than a few millimetres of rotational movement of the sprocket carrier against the wheel).

7. To adjust, loosen the rear axle nut and the adjuster locknuts, then turn both adjusters by equal amounts until slack is within the specified range at the tight spot. Check that the alignment marks on both swingarm adjusters show the same position, and sight along the chain from behind the rear sprocket to confirm it runs straight.
8. Tighten the axle nut to **100–113 N·m** (K-Light 125), then the adjuster locknuts. Recheck slack, which often changes slightly as the axle nut tightens.
9. Check the rear brake: on drum-braked machines moving the axle changes the brake rod geometry and pedal free play (Job sheet 4.7.3); on discs check that the caliper bracket is located and the wheel spins freely.
10. Clean the chain with a neutral cleaner and a soft brush. The K-Light 125 manual warns against steam, petrol or solvents, which swell or dissolve O-rings. Dry it, then apply chain lubricant to the inside of the lower run where the plates overlap, so centrifugal force carries it into the joints, and wipe off excess. Lubricate warm, after a ride, and every 500–800 km or after riding in rain.

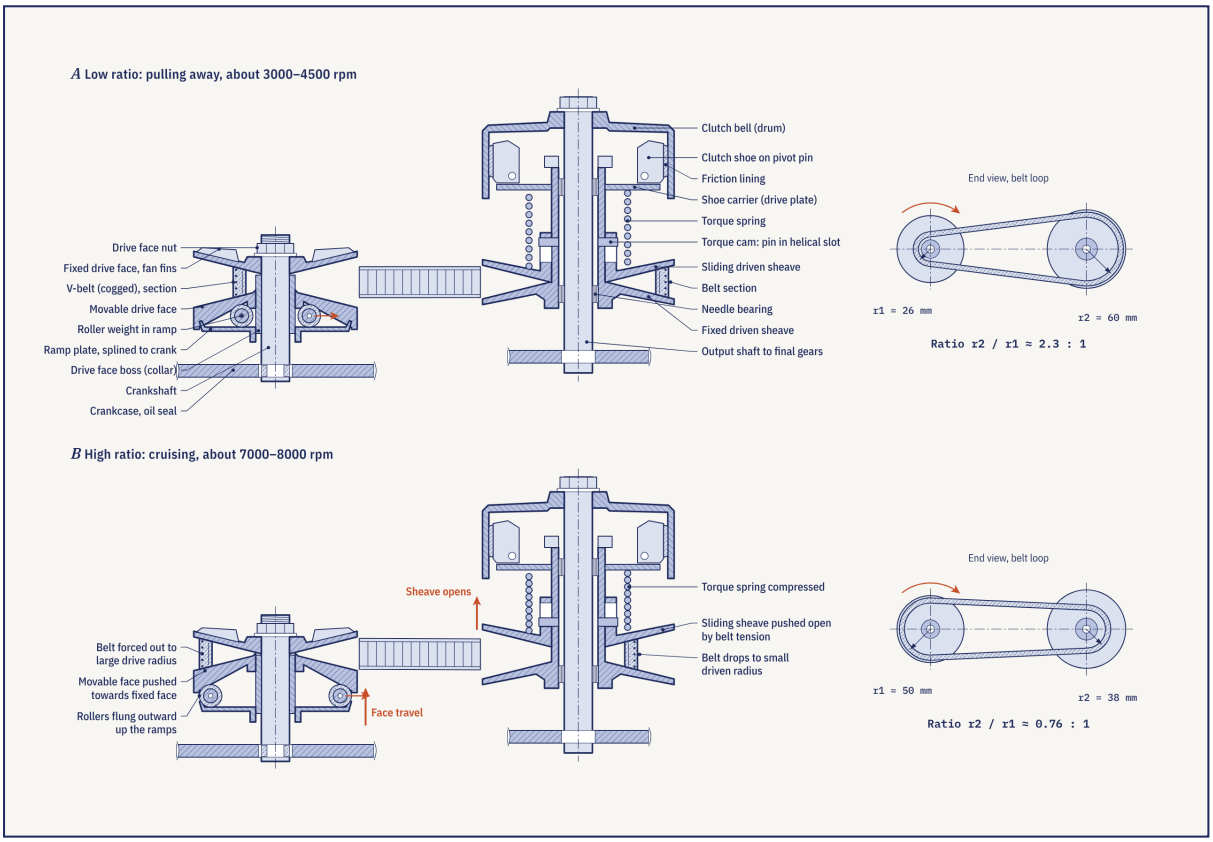


FIGURE 4.9 Scooter CVT: drive pulley with variator rollers and ramp plate, V-belt, driven pulley with torque cam, contra spring and centrifugal clutch, shown in low ratio and high ratio positions.

Pass criteria: slack 20–40 mm at the tightest point with no more than about 10 mm variation; 10-pitch length within the chain maker's limit; no hooked teeth or damaged rollers; adjusters equal and wheel aligned; axle nut at specified torque; chain clean and lubricated; brake free play correct.

Job sheet 4.3.2: CVT belt and roller inspection

Tools and materials	Reference values
Scooter service manual, variator holding tool, impact or socket set, clutch spring compressor (for the driven pulley), vernier caliper, clean rags, brake cleaner, high-temperature grease for the variator boss only	Belt width and roller outside diameter limits from the manual; typical belt width service limit about 1 mm below new; rollers replaced as a set when flat spots appear

1. With the engine cold, remove the CVT cover bolts and cover, noting the position of any air intake duct. Clean belt dust from the case with a vacuum, not compressed air; the dust from older belts and clutch linings is a respiratory hazard.
2. Hold the variator with the holding tool and remove the drive pulley nut and fixed half. Slide the belt off, then withdraw the movable half with its boss and rollers, keeping the ramp plate assembly together so the rollers do not fall out.
3. Measure the belt width across the top face at several points. Compare with the service limit; a belt below the limit runs lower in the drive pulley and higher in the driven pulley, so the scooter loses top speed. Replace the belt if it is cracked across the cogs, glazed, frayed or shows oil contamination.
4. Measure each roller's outside diameter and inspect for flat spots or worn cover. Replace all rollers as a set. Check the ramp faces and ramp plate guides for grooving.
5. Check the boss and the movable half bore for wear (the half should slide without rocking). Lightly grease the boss bore with the specified grease, keeping grease off belt faces.
6. Inspect the driven pulley: guide pins and torque cam slots for wear, contra spring free length, clutch shoe lining thickness and the bell for scoring or out-of-round. Replace shoes with less than about 1.5–2 mm of lining or the manual limit.
7. Clean both pulley faces with brake cleaner. Reassemble, fitting the belt with any direction arrow facing forward, pressing the driven pulley open by hand so the belt sits deep in it before tightening the variator nut to specification.
8. Rotate the engine with the kickstarter or starter several times to seat the belt, refit the cover, and road test: note engine rpm during full-throttle acceleration and top speed.



FIGURE 4.10 A scooter unit-swing engine on the centre stand with the CVT cover removed: the finned fan of the drive pulley, the cogged V-belt and the driven pulley with its clutch bell sit directly in front of the rear wheel, and the swingarm pivot is visible at the front of the crankcase.
Photograph: Transitions Lab collection

Pass criteria: belt width above the limit with no cracks or glazing; rollers round and of equal size; variator slides freely; clutch lining and bell within limits; correct acceleration rpm and no slip or judder on take-off.

REVIEW QUESTIONS

1. What does the code 520 mean for a chain?
2. Why do O-ring and X-ring chains last longer than plain chains, and why must solvents not be used on them?
3. Which way does the open end of a spring clip master link face?
4. A 428 chain measures 258.4 mm over 20 pitches. Calculate its elongation as a percentage.
5. A machine has 15/45 sprockets. The owner fits a 14T front and a 47T rear. Calculate the new ratio and the percentage change.
6. Why should chain and both sprockets be replaced together?
7. Explain the shaft-drive jacking effect and one design that eliminates it.
8. Describe what happens in each pulley of a CVT as the engine speed rises from idle.
9. A scooter owner fits rollers 2 g lighter each. How will acceleration rpm and cruising fuel consumption change?
0. Why does a scooter kick down to a lower ratio when the throttle is opened hard at speed?
1. A chain slack check shows 18 mm at one point and 34 mm at another. What does this indicate?

ANSWERS

1. 5/8 in (15.875 mm) pitch and 20/80 in (1/4 in, 6.35 mm) roller width.
2. Seals keep factory grease in the pin-bushing joints and exclude grit and water, so the wear surfaces stay lubricated; solvents, petrol and steam attack or swell the rubber rings and wash out the grease.
3. Away from the direction of chain travel, so the closed end leads and the clip cannot be pushed off by obstructions.
4. New length 20 × 12.70 = 254.0 mm; elongation = (258.4 − 254.0)/254.0 × 100 = 1.73 %, close to the usual 1.5–2 % limit, so replacement is due.
5. Old 45/15 = 3.000; new 47/14 = 3.357; change = (3.357 − 3.000)/3.000 = 11.9 % lower gearing (more acceleration, about 11 % less road speed at given rpm).
6. A stretched chain wears sprocket teeth to its own longer pitch; a new chain on worn sprockets (or vice versa) then rides on the wrong tooth form and wears rapidly.
7. The reaction torque at the rear bevel housing turns the housing around the axle, lifting the rear on acceleration and squatting it on the overrun; BMW's Paralever (or Moto Guzzi's CARC) adds a torque arm forming a parallelogram so the housing cannot rotate relative to the frame.
8. Rollers in the drive pulley move outwards on the ramps and push the movable half closer, so the belt rises to a larger radius; the belt length being fixed, it pulls deeper into the driven pulley, opening it against the contra spring and torque cam. Ratio falls from about 2.5:1 towards 0.8:1.
9. Lighter rollers need higher rpm to close the variator, so the engine runs higher during acceleration (stronger acceleration) and also at a given cruising speed when on part throttle, so fuel consumption and noise rise.
10. The torque cam converts higher drive torque into extra axial force on the driven pulley's movable half, closing it and forcing the belt outward there and inward on the variator, which lowers the ratio.
11. Uneven wear of the chain or a sprocket (tight spots). Adjust to specification at the tightest point (18 mm is below the 20 mm minimum) and plan to replace chain and sprockets, since the variation exceeds about 10 mm.

CHAPTER 4.4

Frame and steering geometry

LEARNING OBJECTIVES

- → Compare cradle, backbone, beam and trellis frames in steel and aluminium in terms of stiffness, weight and cost.
- → Define rake, trail, fork offset and wheelbase and calculate trail from rake, offset and wheel radius.
- → Explain how geometry trades stability against agility and why steering dampers are fitted.
- → Inspect and adjust ball and taper-roller steering head bearings.

Frame types and materials

The frame locates the steering axis, the swingarm pivot and the engine relative to each other and must hold that relationship under braking, cornering and bump loads. The quantities that matter are **torsional stiffness** between steering head and swingarm pivot (resistance to twisting, typically several kN·m per degree on a road machine), **lateral stiffness** (which designers deliberately limit on sports bikes so the chassis can flex to absorb bumps when leaned over and the suspension is working at an angle), and mass.

- **Steel tube cradle**: one or two tubes run down from the steering head under the engine (single or double cradle) and back to the swingarm pivot. Mild or chromoly steel tube is cheap, easy to weld and repair, and tolerant of fatigue; most commuter machines such as the Honda CG125 and the K-Light 125 use a welded steel tube frame with the engine as a hung load.
- **Backbone (spine)**: a single large tube or pressed-steel spine from the head over the engine, with the engine hung below. Used on step-throughs (pressed-steel spine of the Super Cub) and many small trail bikes.
- **Aluminium twin-spar (beam, perimeter)**: two large extruded or cast aluminium beams run in straight lines from the head around the engine to the pivot, the shortest load path, which gives high torsional stiffness at low mass. Aluminium has a third of the density and a third of the stiffness of steel, so sections are larger and walls thicker; it has no fatigue endurance limit and is harder to repair. Used on sports bikes and modern motocross machines.
- **Trellis**: a lattice of short straight steel (sometimes aluminium) tubes forming triangulated panels, giving high stiffness with thin tube; associated with Ducati and KTM.
- **Stressed engine and monocoque designs**: the engine crankcase carries load directly, with small subframes at front and rear; cast aluminium or carbon "frameless" designs follow the same idea. Electric motorcycles often use the battery enclosure as a structural member.



FIGURE 4.11 A classic double-cradle steel frame, the layout of most air-cooled roadsters.

Render: Transitions Lab, CC BY-SA 4.0

A frame that has been crashed is checked on a jig or by measuring between the steering head and swingarm pivot and from the head to the rear axle on both sides; small differences of a few millimetres side to side indicate a twist that will make the machine pull or weave.

Steering geometry

- **Rake (caster angle)**: the angle of the steering axis from vertical. Typical values are about 23–25° for sports bikes, 25–27° for commuters and standards, 26–28° for off-road and 30–34° for cruisers.
- **Fork offset**: the perpendicular distance from the steering axis to the front wheel spindle, created by the triple clamps and sometimes by an offset spindle position at the fork foot.
- **Trail**: the distance along the ground from the point where the steering axis meets the ground to the centre of the front tyre contact patch, which lies behind it. Typical values are 85–100 mm for sports bikes, 90–110 mm for commuters and 120–150 mm for cruisers.
- **Wheelbase**: distance between wheel spindles (1,440 mm on the K-Light 125).

```
trail = (R × sin θ − d) / cos θ
```

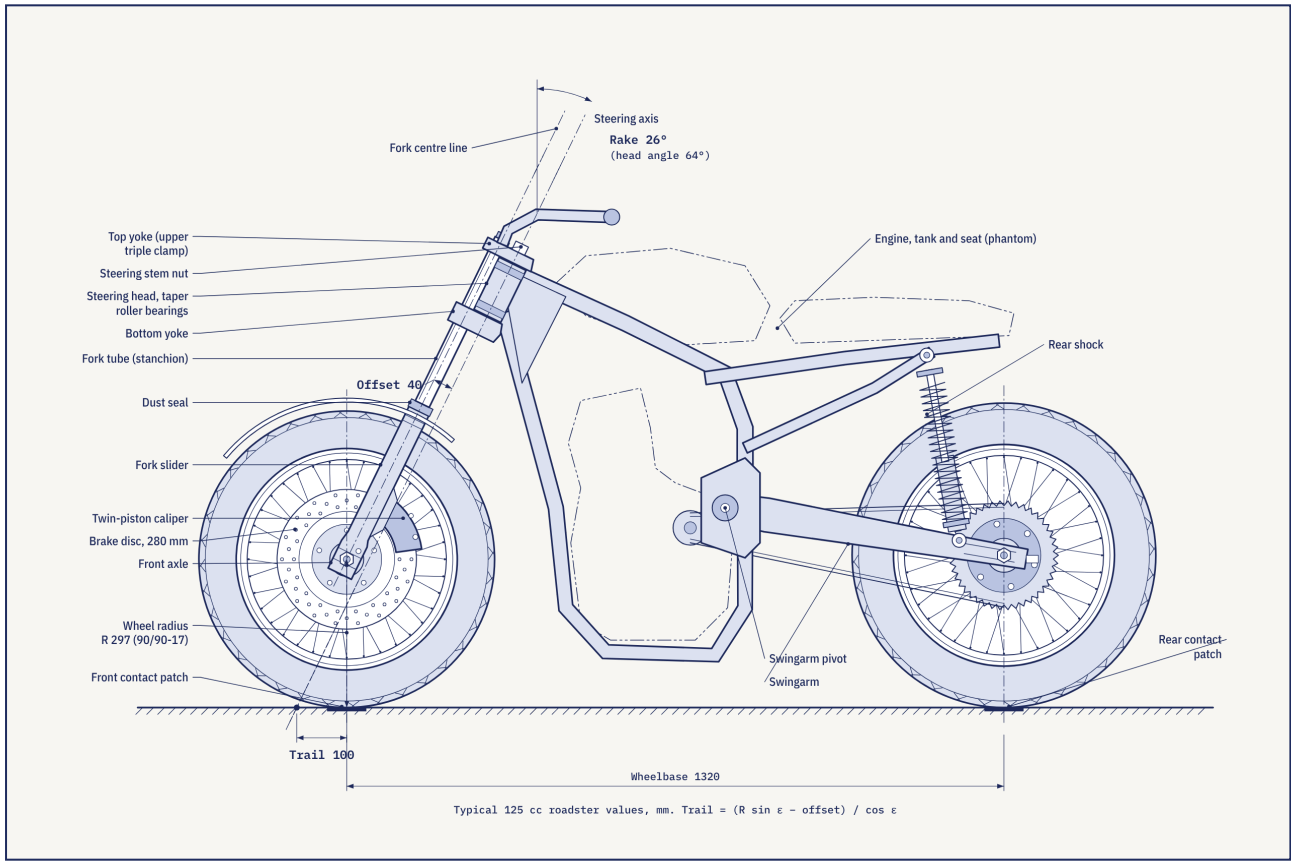


FIGURE 4.12 Steering geometry: steering axis at rake angle to the vertical, fork offset between steering axis and wheel spindle, trail from the axis intersection to the contact patch, wheelbase between contact patches, with dimension lines.

where R is the loaded front tyre radius, θ the rake angle and d the fork offset.

Worked example: a K-Light 125-type front wheel has a 90/90-17 tyre; diameter = 431.8 + 2 × 81 = 593.8 mm, so R ≈ 297 mm unloaded (a few millimetres less loaded). The manual does not state rake or offset, so assume θ = 26° and d = 30 mm as typical for a 125 cc road bike.

```
trail = (297 × 0.4384 − 30) / 0.8988 = (130.2 − 30) / 0.8988 ≈ 111 mm
```

Trail is what makes the front wheel self-centring: because the contact patch trails behind the steering axis, the tyre's side force acts on a lever arm that turns the wheel back into line, like a shopping-trolley caster. More trail and more rake give more straight-line stability and a heavier, slower steering response; less trail and a steeper head give quicker steering but less resistance to disturbances, increasing the risk of **wobble** (a 4–10 Hz front-end oscillation, mostly at medium speeds) or **kickback** (tank-slapper) when the front wheel lands askew after a bump under acceleration. A longer wheelbase adds stability and reduces weight transfer (less wheelie and stoppie tendency) but needs more steering input to turn. Geometry changes dynamically: under braking the fork compresses, the rake steepens and trail falls by 10–20 mm, which is why bikes steer more quickly on the brakes. Fitting a taller rear shock or sliding the fork tubes up in the clamps produces the same effect statically.

A **steering damper** is a small hydraulic damper (linear or rotary) between frame and lower clamp that resists rapid steering movements while having little effect at the slow rates of normal steering. It suppresses kickback on sports bikes and on off-road machines hitting rocks. Electronic dampers vary their damping with speed and acceleration. A damper treats the symptom: wobble on a road bike that did not previously wobble is first investigated by checking tyres, pressures, wheel alignment, steering head bearings, fork alignment in the clamps and luggage loading.

Steering head bearings

The steering stem, welded or pressed into the lower clamp, turns in two bearings in the frame's head tube.

- **Loose ball bearings (cup and cone)** use steel balls running between pressed races in the head tube and on the stem. They are cheap and common on commuter machines. The K-Light 125 uses 1/4 in balls, with 21 in one race and 17 to 19 in the other according to the manual's tables. Because each ball makes point contact, the races are prone to **brinelling** (indentations where the balls sit while riding straight ahead), which makes the steering notchy at the centre.
- **Taper roller bearings** carry the load on line contact and handle the combined radial and axial loads of braking far better; MAVCC Unit XI notes that their pre-load is set by the torque applied to the adjusting nut. They are standard on larger machines and a common upgrade for ball-type heads.
- **Angular contact ball bearings** in cartridge form are used on some modern machines.

Bearings that are too loose let the front end clunk under braking and allow wobble; bearings that are too tight make the bike steer heavily and weave at low speed, because the front wheel cannot make its small self-correcting movements. Balls, races and dust seals are **always** replaced as a set (K-Light 125 manual), and a new lower race on the stem must be driven on square; the manual warns that a race fitted obliquely wears the stem.

> ▤ REFERENCE DATA **K-Light 125 steering head (K-Light 125 manual)**
>
> Steering stem adjusting nut **2–2.5 N·m** (seat the bearings first by turning the bars lock to lock). Steering stem locknut **70 N·m**. Upper clamp bolt (top yoke pinch bolt) 37–44 N·m. Fork upper clamp bolts 22–29 N·m. Steel balls 1/4 in. Use a steering nut wrench with the torque wrench at right angles to it.

Job sheet 4.4.1: Checking and adjusting steering head bearings

Tools and materials	Reference values
Paddock or centre stand plus a jack under the engine to lift the front wheel, C-spanner or steering nut wrench, torque wrench, socket set, spring balance (optional), grease, new balls and races if required	K-Light 125: adjusting nut 2–2.5 N·m; locknut 70 N·m; top clamp bolt 37–44 N·m; fork clamp bolts 22–29 N·m

1. With the front wheel on the ground, apply the front brake and push the bike back and forth firmly while resting a fingertip across the gap between the lower clamp and the head tube. Any clunk or relative movement indicates loose bearings, though worn fork bushings feel similar; confirm by checking at the fork legs.
2. Lift the front wheel clear of the ground with the weight on the rear and the engine supported. Move the bars slowly from lock to lock. They should turn smoothly with no notch or tight spot at the straight-ahead position (a notch means brinelled races, which adjustment cannot cure). With cables and hoses routed correctly, a gentle tap on one bar end should let the bars fall to the lock under their own weight.
3. Grasp the bottom of the fork legs and push and pull fore and aft. Any free play at the head confirms loose bearings.
4. To adjust, loosen the fork top clamp pinch bolts and the top clamp (top yoke) centre bolt or nut, so that the stem nut can be reached and the top clamp can move. On the K-Light 125 the handlebar mounts on the top clamp and may need to be released.
5. Loosen the locknut. Using the steering nut wrench, tighten the adjusting nut to seat the bearings (many manuals specify a higher seating torque first), turn the bars lock to lock several times, then back the nut off and retighten to the specified final torque (**2–2.5 N·m** on the K-Light 125). The torque is small: the aim is zero free play with no pre-load felt as stiffness.
6. Hold the adjusting nut and tighten the locknut to 70 N·m (K-Light 125). Recheck that the adjusting nut has not moved and that the bars still fall freely.
7. Tighten the top clamp centre nut, then the fork pinch bolts to 22–29 N·m, with the fork legs aligned so the front wheel is square to the bars.
8. Repeat steps 2 and 3. If free play cannot be removed without the steering becoming notchy or tight, dismantle, clean and inspect races and balls; replace as a set, fitting the correct number of balls in grease in each race.
9. Road test at low speed (no heavy steering, no weave) and over bumps under braking (no clunk).

Pass criteria: no fore-aft free play at the fork legs, bars swing freely and without notches from lock to lock, nuts and clamp bolts at specified torque, and no clunk, weave or wobble on the road test.

REVIEW QUESTIONS

1. Why are twin-spar aluminium frames made with larger sections than equivalent steel frames?
2. Define rake, trail and fork offset.
3. Calculate the trail for a wheel of radius 310 mm, rake 24.5° and offset 32 mm.
4. What happens to trail when the fork compresses under braking, and why?

5. Name two effects of a longer wheelbase.
6. What is brinelling of a steering head bearing and how does it feel to the rider?
7. Why does an overtightened steering head make a bike weave at low speed?
8. A rider complains of a wobble at 60 km/h that appeared recently. List four checks before fitting a steering damper.
9. Why are taper roller bearings better suited to the steering head than loose balls?
0. Why must the steering nut be tightened with the torque wrench at right angles to the steering nut wrench?

ANSWERS

1. Aluminium's elastic modulus is about a third of steel's, so to reach the same stiffness the section must have a larger second moment of area; its lower density (about a third) means the larger section still weighs less.
2. Rake is the angle of the steering axis from vertical; trail is the ground distance from where the steering axis meets the ground back to the centre of the front contact patch; offset is the perpendicular distance between the steering axis and the front spindle.
3. sin 24.5° = 0.4147, cos 24.5° = 0.9100. Trail = (310 × 0.4147 − 32)/0.9100 = (128.6 − 32)/0.9100 ≈ 106 mm.
4. It falls (typically by 10–20 mm) because compressing the fork while the rear extends steepens the effective rake angle and moves the steering axis intersection closer to the contact patch; steering becomes quicker.
5. More straight-line stability and less load transfer (less tendency to wheelie or lift the rear), but slower steering and a larger turning circle.
6. Indentation of the races by balls that stay in the same position while the machine is ridden straight ahead; the steering feels notchy and tends to stick at the centre.
7. The pre-load resists the small self-correcting steering movements that trail and gyroscopic effects normally produce, so the rider must make conscious corrections, which over-correct and set up a slow weave.
8. Tyre condition and pressures; wheel alignment and wheel runout or bearings; steering head bearing adjustment; fork tube alignment and height in the clamps, plus loading (top box, luggage) and fork oil level.
9. They carry load on line contact rather than point contact, so they resist brinelling and handle the combined axial and radial loads of braking; pre-load can be set precisely by nut torque.
10. The torque wrench reading is only correct if the force acts perpendicular to the effective lever; at an angle the effective lever length and applied torque change, giving the wrong bearing pre-load.

CHAPTER 4.5

Suspension

LEARNING OBJECTIVES

- Explain sprung and unsprung mass, spring rate and preload, and calculate spring force and sag.
- Describe how compression and rebound damping are generated by orifice and shim-stack valving in damper-rod, cartridge and upside-down forks.
- Compare twin-shock and linkage monoshock rear suspension and explain rising rate.
- Measure and set static and rider sag, and change fork oil and seals to the K-Light 125 manual.

Mass, springs and preload

Sprung mass is everything carried by the springs (frame, engine, rider, fuel); **unsprung mass** is everything that moves with the wheel (wheel, tyre, brake disc and caliper, fork lower legs, about half the swingarm, shock and chain). The lower the unsprung mass relative to the sprung mass, the less force a bump transmits to the chassis and the faster the tyre can follow the road surface, which is why cast aluminium wheels, light discs and USD forks (with the heavy outer tube on top) are used on sports machines.

The spring supports the sprung mass and stores bump energy. Its **spring rate** k is the force per unit compression, in N/mm.

```
F = k × x
x_preload = initial compression when fully extended
```



FIGURE 4.13 Conventional telescopic fork with triple clamps, stanchions and sliders.

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Preload is compression applied to the spring when the suspension is fully extended, by a threaded collar, a stepped cam ring (common on twin shocks) or a spacer under the fork cap. Preload does **not** change spring rate; it changes the load at which the suspension starts to move and so the ride height and sag. A heavier rider or a passenger needs more preload to restore sag; if the correct sag cannot be reached within the adjuster's range, the spring rate is wrong. Progressive (variable-pitch) fork springs have closely wound coils that become coil-bound early, so the rate rises with travel.

Sag

Sag is how far the suspension compresses from fully extended under load. **Static sag** (free sag) is with the bike alone; **rider sag** (race sag) is with the rider in riding position. Typical targets:

Machine	Front rider sag	Rear rider sag	Rear static sag
Road and commuter	25–35 % of travel	25–33 % of travel	5–15 mm
Sports, track	25–30 mm	25–30 mm	0–10 mm
Motocross, enduro (300 mm travel)	60–70 mm	95–105 mm	30–40 mm

Static sag checks spring rate: with correct rider sag, too little static sag (bike barely settles under its own weight) means the spring is too soft and has been preloaded heavily to compensate; too much static sag means it is too stiff.

Damping

A spring alone would let the wheel bounce at the natural frequency of the system (about 1–2 Hz for the sprung mass, 10–15 Hz for the unsprung). The **damper** converts motion into heat by forcing oil through restrictions. **Compression damping** resists the wheel moving up; **rebound damping** resists the spring pushing it back down and is normally the stronger of the two, since the spring stores energy that must be released in a controlled way. Too little rebound damping gives a pogo or wallowing ride; too much makes the suspension "pack down" over successive bumps, losing travel and grip.

- **Orifice damping**: oil flows through fixed holes. Resistance rises with the square of shaft velocity, so it is soft at low speeds (poor body control) and harsh on sharp bumps. Damper-rod forks and cheap shocks use this principle.
- **Shim-stack valving**: oil flows through ports in a piston covered by a stack of thin spring-steel shims that bend open as pressure rises. The force curve can be shaped to be firm at low velocity and nearly linear at high velocity. Adjusters vary a bleed (bypass) needle that controls low-speed flow, and sometimes a preload on the shim stack for high-speed flow.

Fork types

A **damper-rod fork** has a tube (the damper rod) bolted to the bottom of the slider, with holes that meter oil and a piston ring at the top sliding inside the fork tube. It is simple and cheap and is fitted to the K-Light 125 and most commuter machines. A **cartridge fork** uses a sealed internal tube with shim-stacked compression and rebound pistons, giving far better control and adjustability; open-cartridge and closed-cartridge (pressurised, to prevent cavitation) types exist, and many modern forks separate the functions into one leg for damping and the other for the spring. An **upside-down (USD, inverted) fork** places the large tube at the top in the clamps and the slim inner tube at the bottom, which improves bending stiffness where the bending moment is highest and reduces unsprung mass, but leaves the seals exposed to stones and dirt.



FIGURE 4.14 An inverted (USD) fork: the large-diameter outer tubes are clamped in the yokes and the slim stanchions carry the axle.

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Fork oil does the damping, so **viscosity and level** set the behaviour. Viscosity controls damping force; the "W" ratings of fork oils are not standardised between brands, so compare kinematic viscosity in mm²/s (cSt) at 40 °C. The K-Light 125 manual specifies 46# shock absorber oil (an ISO VG 46 viscosity grade, about 46 mm²/s at 40 °C) at **285 ± 2 ml per leg**. The air gap above the oil acts as a progressive air spring at the end of travel: a higher level (or larger volume) increases bottoming resistance. MAVCC Unit XI notes that milky fork oil means water has entered past failed seals.

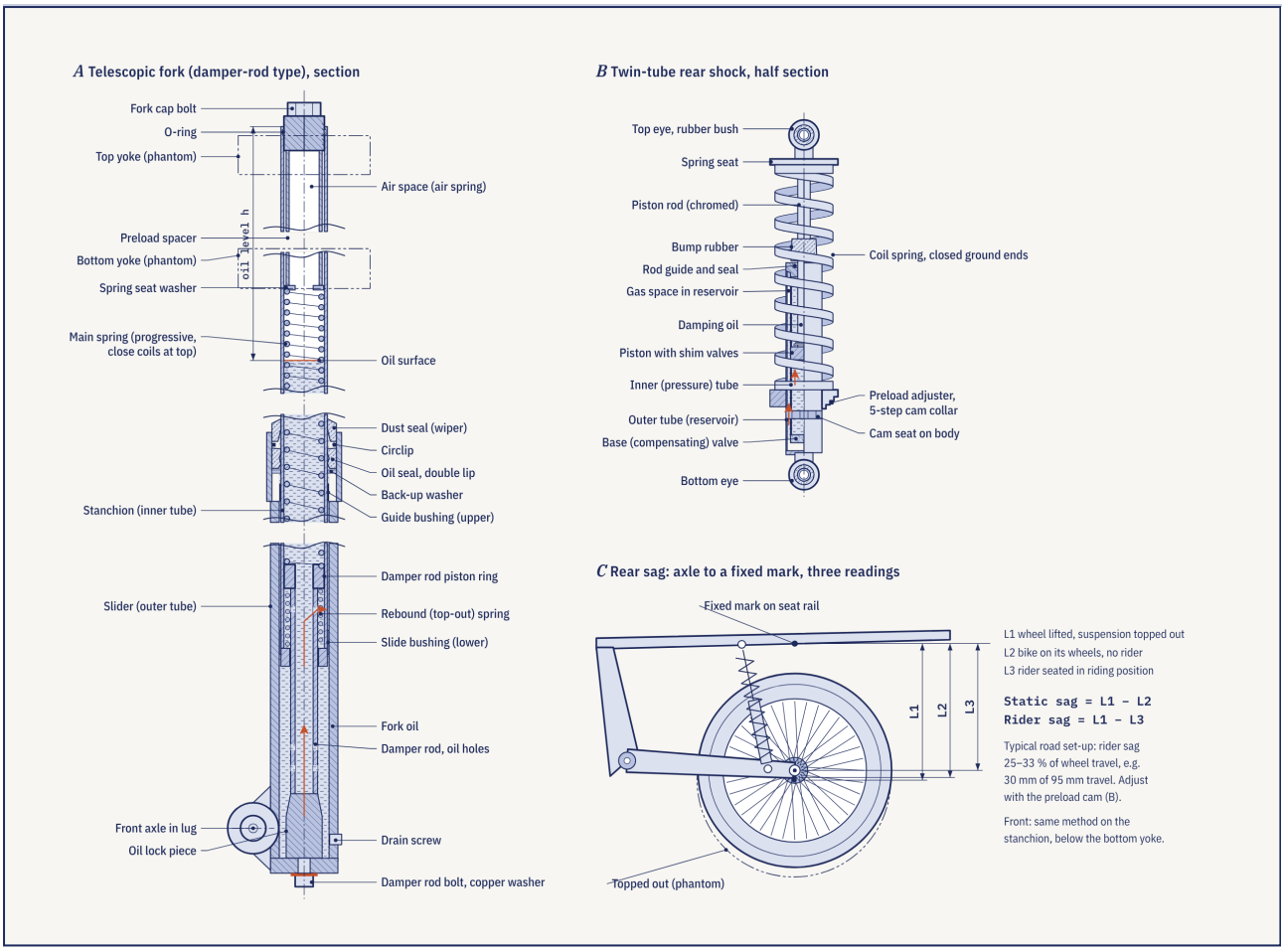


FIGURE 4.15 Suspension: cutaway telescopic damper-rod fork with spring, damper rod, oil level, bushings, oil seal and dust seal, and a rear monoshock with rising-rate linkage beside a twin shock, with sag measurement points.

▤ REFERENCE DATA **K-Light 125 front fork (K-Light 125 manual)**

Damper-rod fork with oil seal 37 × 50 × 11 mm. Fork spring free length **300 mm, minimum 295 mm**. Oil 46# shock absorber oil, **285 ± 2 ml per leg**. Damper rod bolt 15–20 N·m with thread-locking compound. Fork cap bolt 12–18 N·m. Lower clamp bolts 45–50 N·m (assembly table) and upper clamp bolts 22–29 N·m. Rear shock upper nut 45–50 N·m, lower bolt 22–29 N·m; swingarm pivot nut 85–98 N·m.

Rear suspension

Twin shocks mount from the swingarm near the axle to the frame rails; they are simple, cheap and give a nearly constant (linear) ratio between wheel and shock movement. The K-Light 125 uses twin shocks with preload adjustment. A **monoshock** uses one shock on the centreline, either mounted directly to the swingarm (as on many small road bikes and the Yamaha Monocross pattern) or through a **linkage** of rocker and pull rod. The linkage gives a **rising rate**: the shock moves little for each millimetre of wheel travel near full extension and more near full compression, so the suspension is soft on small bumps and resists bottoming on large ones. The **motion ratio** (wheel travel/shock travel) is typically 2–3:1, so the shock spring rate is several times the effective wheel rate; for a linear ratio R the wheel rate is k_shock/R².



FIGURE 4.16 A tapered aluminium box-section swingarm with chain adjusters, pivot and linkage mounts.
Render: Transitions Lab, CC BY-SA 4.0

Linkage bearings (needle roller and bushing) are greased at intervals of about 10,000–20,000 km on road bikes and after every few wet rides off-road; seized linkages make the rear harsh and wear the shock. Shock absorbers are checked for oil leakage at the shaft seal, a bent shaft, worn mounting bushes and fading damping (bouncing more than once after being pushed down). Most OEM shocks on small bikes are sealed and replaced as a unit, as the K-Light 125 manual directs for a bent rod or fatigued spring.

> SAFETY **Gas-charged shocks**
>
> Many rear shocks contain nitrogen at 1–2 MPa behind a floating piston or bladder. **Never** heat, puncture or dismantle a gas shock without first releasing the gas through the Schrader valve or following the maker's procedure, and dispose of unwanted shocks as directed.



FIGURE 4.17 A monoshock with spring, preload collar, damper body and piggyback reservoir.
Render: Transitions Lab, CC BY-SA 4.0

Job sheet 4.5.1: Measuring and setting sag

Tools and materials	Reference values
Steel tape or sag tool, a helper, notepad, C-spanner or preload tool, centre or paddock stand	Rider sag road **25–33 % of travel**; static sag rear **5–15 mm** (road); manual travel figures

1. Set tyre pressures and fill fuel to the usual level. Put the bike on the stand with the rear wheel off the ground. Measure vertically from the rear axle centre to a fixed mark on the subframe directly above it: **L1** (fully extended).
2. Take the bike off the stand, bounce the suspension, and let it settle; measure **L2a** after lifting the rear slightly and letting it settle down, then **L2b** after pushing it down and letting it rise. The true value lies between (stiction makes them differ). Static sag = L1 − (L2a + L2b)/2.
3. With the rider in normal riding position (feet on pegs, a helper steadying the bike), repeat the measurement to obtain L3. Rider sag = L1 − L3.
4. Compare with the target. To reduce sag increase preload; to increase sag reduce it. On cam-ring twin shocks, set both shocks to the same step.
5. Repeat for the front, measuring from the dust seal to the fork lower clamp or slider with the forks extended and then loaded. A cable tie around a fork tube pushed against the seal records maximum travel used after a ride.
6. Check static sag: if correct rider sag leaves almost no static sag, the spring is too soft; if static sag is excessive, too stiff. Recommend the correct spring rate rather than more preload.
7. Record the settings, adjuster positions and rider mass for future reference.

Pass criteria: rider and static sag within target at both ends with preload adjusters inside their range; front and rear sag balanced so the bike sits level; both twin shocks set identically.

Job sheet 4.5.2: Fork oil change and seal replacement

Tools and materials	Reference values
Service manual, stand and engine jack, socket set, Allen key, T-handle damper rod holder (K-Light 125 special tool) or impact driver, seal driver (fork oil seal installation tool), circlip pick, graduated measuring cylinder, 46# fork oil, new oil seals and dust seals, drain tray, soft-jawed vice	K-Light 125: **285 ± 2 ml per leg**; spring free length **300 mm, limit 295 mm**; damper rod bolt **15–20 N·m** with thread lock; cap bolt **12–18 N·m**; inner tube bend limit per manual

1. Support the bike with the front wheel clear of the ground. Remove the front wheel, front brake caliper (hang it from a cable tie, **never** by the hose) and mudguard. Loosen the fork top-clamp pinch bolts and crack the fork cap before the lower pinch bolts are loosened, while the clamps still hold the tube.
2. Remove the fork leg. Hold it upright and remove the cap bolt and O-ring, keeping pressure on it; it is under spring preload. Remove the plug (spacer) and spring, noting which way up it goes.
3. Invert the leg over the tray and pump the tube to drain the oil. Inspect the oil: milky oil means water ingress through the seals; metallic grey oil means bush wear.
4. For a seal change, prise off the dust seal, remove the wire clip (circlip) without scratching the inner tube, then hold the damper rod with the T-handle tool and remove the damper rod bolt from the bottom of the slider (K-Light 125 manual). Pull the tube from the slider with sharp outward strokes so the upper bush drives the old seal out.
5. Inspect: inner tube for pitting, scoring or bending (roll it on a flat surface or measure runout in V-blocks with a dial gauge); bushings for worn-through PTFE coating showing copper; damper rod and piston ring for scratches or bending (**never** straighten a bent damper rod, the manual warns); spring free length against the **295 mm** limit. Clean oil holes with compressed air.
6. Reassemble with new seals and dust seals. Fit the damper rod and spring, clamp the slider in soft jaws, and tighten the damper rod bolt to **15–20 N·m** with thread lock and a new washer. Lubricate the seal lip with fork oil, wrap the tube end with film to protect the lip, and drive the seal square with the installation tool until the clip groove is visible. Fit the clip and dust seal.
7. With spring removed and the leg fully compressed, pour in **285 ± 2 ml** of 46# oil measured in a graduated cylinder, then pump the tube slowly through its full travel to purge air (manual step). If the manual for your machine specifies an oil level instead, measure it from the top of the tube with the spring removed and the fork fully compressed.
8. Fit the spring, plug and cap with a new O-ring, starting the thread by hand to avoid cross-threading (MAVCC Unit XI), and tighten to **12–18 N·m**.
9. Refit the legs at the same height in the clamps (the K-Light 125 manual requires the tube end to be flush with the top clamp) and tighten pinch bolts to specification. Refit the wheel, caliper and mudguard; pump the front brake before riding.

Pass criteria: equal oil volume in both legs, no leaks after compressing the fork several times, smooth travel without notches, legs at equal height, all fasteners at specified torque and brake lever firm before the road test.

REVIEW QUESTIONS

1. Give two reasons why low unsprung mass improves ride and grip.
2. Does increasing preload change the spring rate? Explain what it does change.
3. A fork spring compresses 42 mm under 840 N. What is its rate?
4. A rear suspension has 120 mm travel. L1 = 610 mm and with the rider aboard L3 = 575 mm. Calculate rider sag and express it as a percentage of travel.
5. Why is rebound damping normally stronger than compression damping?
6. Compare orifice and shim-stack damping.
7. What does milky fork oil indicate?
8. Why does a higher fork oil level increase bottoming resistance?
9. Explain rising rate in a linkage monoshock.
10. A shock has a motion ratio of 2.5:1 and a spring of 50 N/mm. What is the approximate wheel rate?
11. Why must the damper rod not be straightened if bent?

ANSWERS

1. A lighter wheel assembly can accelerate up and down faster to follow the surface, keeping tyre load more constant, and less of the bump force is transmitted into the sprung mass.
2. No. Preload changes the initial force in the spring and so the ride height, sag and the load at which the suspension starts to move; the force per millimetre is unchanged.
3. k = 840/42 = 20 N/mm.
4. Rider sag = 610 − 575 = 35 mm; 35/120 × 100 = 29 % of travel, within the 25–33 % target.
5. The spring returns stored energy on rebound; without strong rebound control the chassis and wheel would overshoot and oscillate, while compression damping must stay light enough to let the wheel rise over bumps without harshness.
6. Orifice damping force rises with roughly the square of velocity, soft at low speeds and harsh at high; shim stacks bend open progressively so the force curve can be firm at low speed and nearly linear at high speed, and can be tuned.
7. Water contamination, normally entering past worn or damaged fork seals; seals and oil must be renewed.
8. The air above the oil is compressed as the fork travels; less air volume reaches high pressure sooner, acting as a progressive spring near full travel.
9. The linkage geometry makes shock movement per millimetre of wheel travel increase as the wheel rises, so the effective wheel rate is low at the start of travel and rises towards the end, giving compliance and bottoming resistance.
10. Wheel rate ≈ 50/2.5² = 50/6.25 = 8 N/mm.
11. Straightening introduces cracks and local yielding and cannot restore straightness or surface finish accurately; the rod may fail or bind, so it is replaced.

CHAPTER 4.6

Wheels and tyres

LEARNING OBJECTIVES

- Compare spoked and cast wheels and true a spoked wheel to runout limits.
- Inspect and replace wheel bearings.
- Explain bias, bias-belted and radial tyre construction and decode size, load, speed and date markings.
- Set pressures, judge wear, repair a tubeless puncture correctly and balance a wheel.

Wheels

Spoked wheels use a steel or aluminium rim laced to the hub with 32–40 steel spokes in tension, usually crossing (tangential lacing) so that drive and brake torque is carried by spokes pulling on the hub. They absorb impacts, can be repaired by replacing spokes and are standard on off-road machines, but they need a tube unless the rim is sealed (as with cross-spoke rims that anchor the spokes outside the air chamber). **Cast wheels** (aluminium alloy, sometimes magnesium) are stiff, run tubeless tyres and need no truing; they crack or bend rather than deform gracefully and cannot be repaired. The K-Light 125 uses aluminium alloy wheels, 1.85 × 17 front and 3.00 × 15 rear (rim width in inches × diameter).

Runout is measured with a dial gauge as the wheel turns on its own bearings or in a truing stand: **radial (vertical)** runout is up-and-down movement of the rim, **axial (lateral, horizontal)** runout side-to-side. The K-Light 125 manual gives standard **within 1.0 mm** and a limit of **2.0 mm** in both directions, plus a spindle bend limit of **0.2 mm**. Many manufacturers specify tighter limits for spoked rims, typically 0.5–1.0 mm radial and 0.5–0.8 mm axial in service.

Truing a spoked wheel

Truing corrects runout by adjusting spoke nipples. Tightening a spoke pulls the rim towards the hub flange it comes from, and towards the hub radially. For lateral runout, tighten the spokes from the side opposite the high spot and loosen those from the same side by equal amounts, a quarter to half a turn at a time over three to five spokes either side of the high point. For radial runout, tighten spokes at the high spot and loosen those opposite. Work gradually round the wheel, checking the rim's offset relative to the hub (dish) with a ruler against the hub face, and finish with all spokes at similar tension (an even ring when tapped, or a tension meter). After truing, file any spoke ends that protrude through the nipples and fit a sound rim band before the tube; MAVCC Unit X job sheets cover respoking a damaged rim.

Wheel bearings

Wheel bearings are sealed deep-groove ball bearings (K-Light 125: 6202-2RS front, 6303-2RS rear) separated by a spacer tube that is clamped by the axle. Check by turning the inner race with a finger (roughness, notchiness) and rocking it radially and axially; on the bike, lift the wheel and rock it at top and bottom with the axle tight. The K-Light 125 manual states that bearings removed **must not be reused**. Remove with a bearing puller or drift on the inner race through the spacer, after removing the oil seal; fit new bearings by pressing only on the **outer race** with a driver matched to its diameter, with the sealed side outwards, ensuring the spacer is in place before the second bearing goes in.



FIGURE 4.18 A cast alloy rear wheel with cush-drive hub and sprocket carrier.
Render: Transitions Lab, CC BY-SA 4.0

Tyres

Construction

- **Bias (cross-ply)**: two or more carcass plies of nylon or polyester cord laid at about 30–40° to the circumference, each ply crossing the previous one. The sidewall and tread work together, which makes the tyre stiff and resistant to damage, suited to heavy loads, small machines, off-road and cruisers, but it runs hotter at speed and the contact patch distorts in corners.
- **Bias-belted**: bias carcass with a belt of aramid or glass under the tread to stabilise it at speed.
- **Radial**: one or two carcass plies laid at close to 90° to the circumference, with a belt (often a **zero-degree** spiral-wound steel or aramid belt) under the tread. Sidewall and tread work independently, giving a flatter, more stable contact patch, lower heat build-up and lower weight. Radials need wider rims and are standard on sports and touring bikes above about 400 cc.

Markings

A size of **110/70-17 54H** reads: section width 110 mm, aspect ratio 70 % (sidewall height 77 mm), "-" for bias construction (R for radial, B for bias-belted), 17 in rim diameter, load index 54 and speed symbol H. A **load index** of 54 means **212 kg** per tyre at the reference pressure; for comparison 49 is 185 kg, 59 is 243 kg and 73 is 365 kg. Speed symbols include **J 100, K 110, L 120, M 130, N 140, P 150, Q 160, R 170, S 180, T 190, H 210, V 240 and W 270 km/h**. Older sizes use inch markings such as 3.00-18 or 90/90-17 without a load and speed suffix on some commuter tyres.

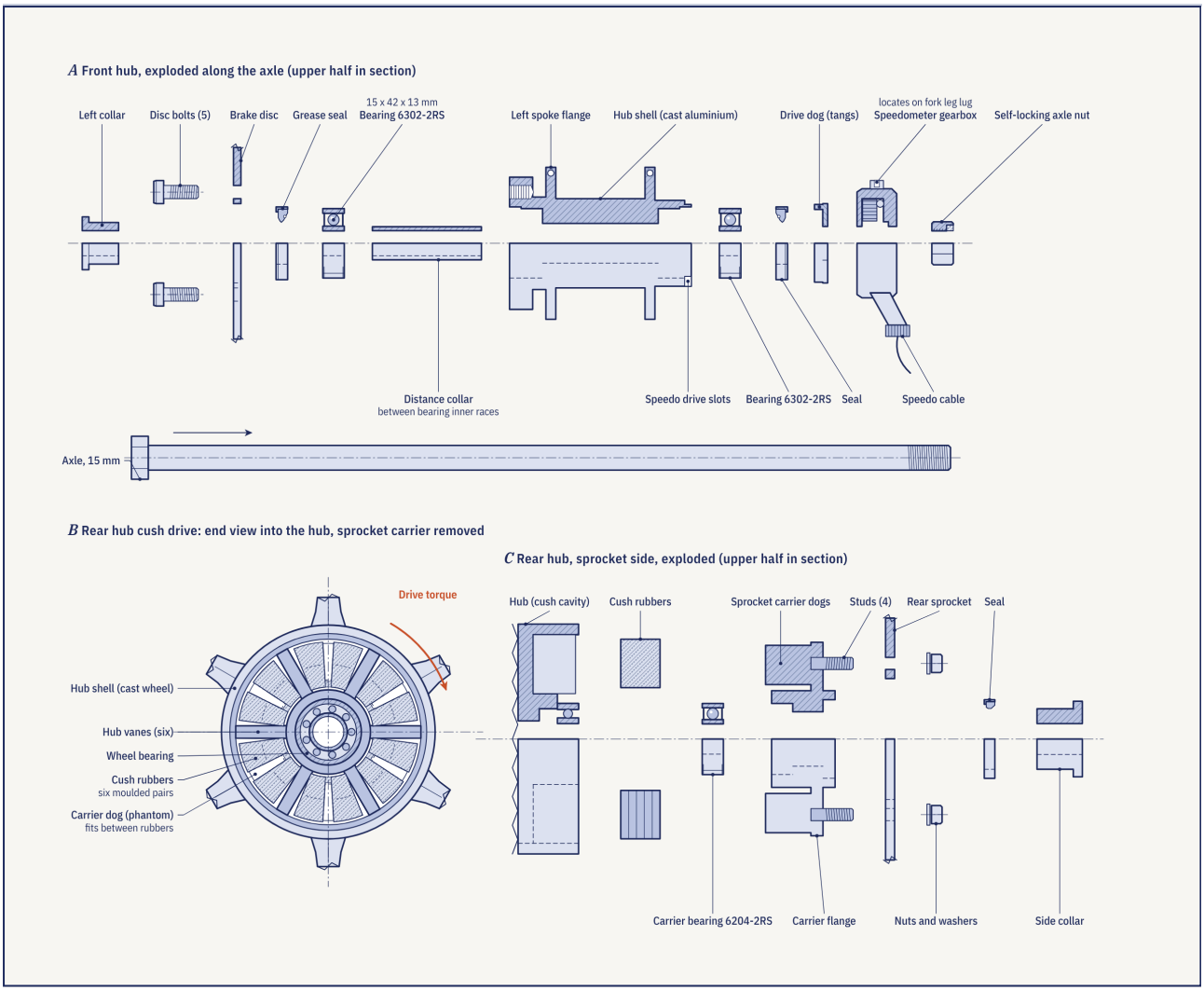


FIGURE 4.19 Hubs and bearings: exploded front hub with axle, spacers, sealed bearings and seals, and the rear hub with cush drive and sprocket carrier.

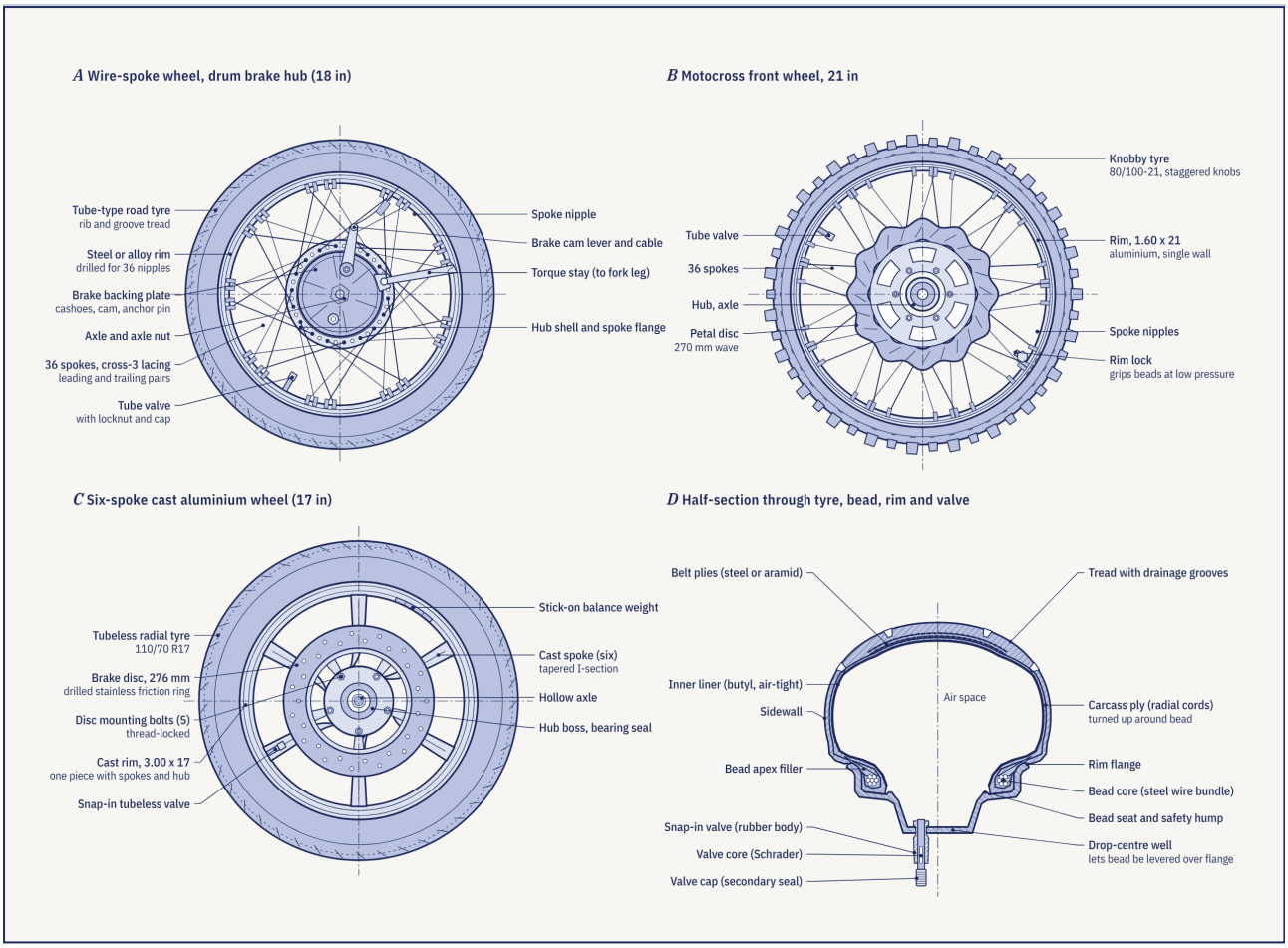


FIGURE 4.20 Wheel types: 36-spoke wire wheel with drum hub, 21-inch motocross wheel with rim lock, and a cast alloy wheel with disc, plus a half-section through rim, tyre, bead and valve.

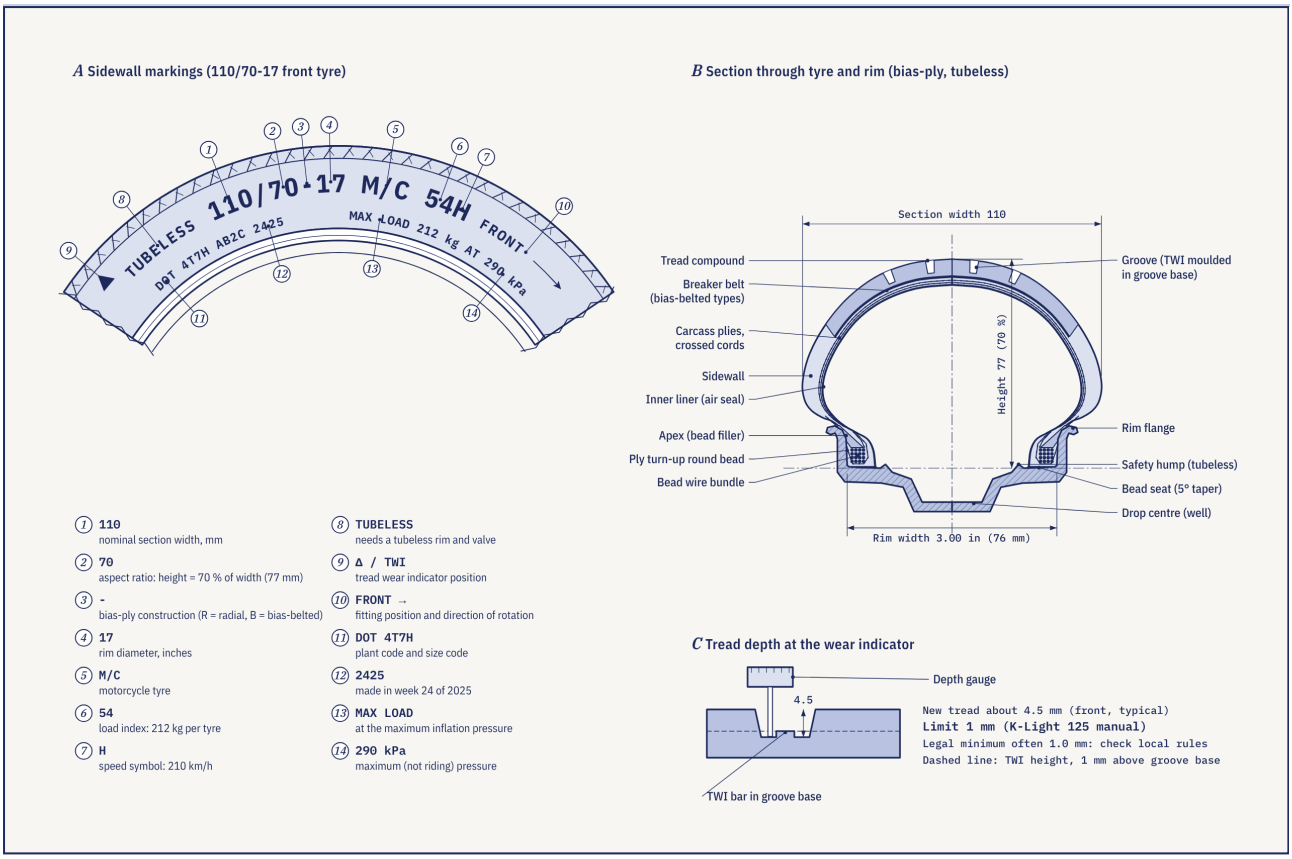


FIGURE 4.21 Tyre: sidewall markings including size 110/70-17 54H, DOT date code and tread wear indicator position, and a section through a tyre showing bead, bead wire, carcass plies, belt, sidewall and tread.

The **DOT code** ends with four digits for week and year of manufacture: **2324** means week 23 of 2024. Rubber hardens with age even unused; most makers recommend inspection from five years old and replacement at **ten years** regardless of tread. "TL" means tubeless, "TT" tube type; a directional arrow shows rotation; a coloured dot often marks the light spot for alignment with the valve.

Tread wear indicators (TWI) are small raised blocks in the main grooves, located by a triangle or "TWI" mark on the shoulder; when the tread is level with them about **0.8–1 mm** remains. The K-Light 125 manual wear limit is **1 mm**, the legal minimum in the UK for machines over 50 cc and in many other countries; check national rules. Square-worn rear tyres from straight-line commuting make the bike drop suddenly into corners and should be replaced before the legal limit.

Pressures

Set pressures cold, with an accurate gauge, to the manufacturer's figures: **190 ± 10 kPa (27.5 psi) front and 210 ± 10 kPa (30.5 psi) rear** on the K-Light 125, solo. Under-inflation makes the tyre flex and overheat, increases wear on the shoulders, and makes steering heavy and vague (the manual lists low pressure as a cause of heavy steering and instability); over-inflation shrinks the contact patch and reduces grip and comfort. Increase rear pressure with a passenger or heavy load when the handbook says so.

Tube versus tubeless and puncture repair

A **tubeless tyre** seals on the bead and rim; a puncture usually deflates slowly because the rubber grips the object. A tube-type tyre can deflate suddenly when a tube splits. A tubeless repair must be a **combined plug-patch** fitted from inside after removing the tyre: the injury is cleaned and reamed, the plug-patch stem pulled through to fill the hole and the patch bonded over the inner liner with vulcanising solution. Most tyre makers permit repairs only in the central part of the tread, for injuries no larger than about **6 mm**, with no previous repair nearby and no sidewall or shoulder damage, and some limit subsequent speed or forbid repair of motorcycle tyres entirely. External string plugs are a **temporary** get-you-home measure only. A tube is repaired with a vulcanised patch and the tyre inspected inside for the cause; a tube must **never** be fitted to cure a leak in a tubeless tyre that is damaged.

Balancing

A wheel and tyre assembly has a heavy spot; at speed the imbalance produces a vertical or lateral shake (often felt at 80–110 km/h in the bars). **Static balancing** on a stand with the wheel on its own bearings or a frictionless arbor lets the heavy spot settle at the bottom; weights are added opposite until the wheel stays where it is placed. Stick-on weights (5–10 g segments) go on the rim centre, spoke weights clip to spoke nipples. Narrow motorcycle wheels are usually balanced statically; dynamic (two-plane) balancing on a machine is used for wide rear tyres.

Job sheet 4.6.1: Removing and fitting a tubeless tyre and balancing

Tools and materials	Reference values
Manual or machine tyre changer, three tyre levers, rim protectors, valve core tool, tyre soap or lubricant, new valve, bead-breaker, balancing stand, wheel weights, pressure gauge, safety glasses	K-Light 125 tyres 90/90-17 front, 130/90-15 rear, tubeless; **190/210 kPa**; bead seating pressure per tyre maker, never above the maximum moulded on the sidewall

1. Remove the wheel (support the bike securely; the K-Light 125 manual warns not to let the front wheel float above ground unsupported). Note the rotation arrow and protect the brake disc; **never** lay a wheel on its disc.
2. Remove the valve core and deflate fully. Break both beads with the bead breaker, keeping the breaker shoe clear of the rim flange and disc.
3. Push the bead opposite the valve into the rim's central well, lubricate, and lever the upper bead over the flange near the valve with two levers and rim protectors, working in small bites. Remove the second bead the same way.
4. Inspect the rim for dents, cracks and corrosion at the bead seat; replace the rubber valve (rubber valves age with the tyre). Inspect the inside of the old tyre to find the puncture cause.
5. Lubricate both beads of the new tyre, check its rotation arrow, and align the balance dot with the valve (the K-Light 125 manual marks rotation and valve position). Fit the lower bead, then the upper, using the well and small lever bites.
6. Inflate without the valve core until both beads pop onto their seats, checking that the moulded rim line is concentric on both sides; do not exceed the maker's seating pressure. Fit the core and set pressure.
7. Balance: place the wheel on the stand, let it settle and mark the lowest point. Attach trial weights opposite (at the top) and repeat until the wheel stays in any position. Clean the rim before bonding final weights.
8. Refit the wheel, tighten axle nuts to specification (K-Light 125 front 75–88 N·m, rear 100–113 N·m) and check brake operation.

Pass criteria: beads evenly seated with the rim line concentric, no leaks at valve or bead (soap test), wheel stays in any position on the balance stand, correct rotation direction, pressures and axle torques correct.

Job sheet 4.6.2: Checking wheel runout and bearings

Tools and materials	Reference values
Dial gauge with magnetic base or truing stand, V-blocks, bearing puller, bearing driver set, grease, new bearings and seals	K-Light 125: runout **within 1.0 mm** standard, **2.0 mm** limit radial and axial; axle bend **0.2 mm**; bearings 6202-2RS front, 6303-2RS rear

1. Lift the wheel clear of the ground with the axle tight. Spin it slowly and watch the gap between rim and a fixed pointer for obvious wobble; check the tyre separately, as tyre runout is not rim runout.
2. Mount the dial gauge on the fork leg or swingarm with the stylus on the rim bead seat (radial) and then on the rim side face (axial). Zero it, rotate the wheel one turn and record the total indicator reading.
3. Compare with limits: K-Light 125 replace the rim above **2.0 mm**. For spoked wheels, true as described above.
4. Rock the wheel at top and bottom; any play with the axle tight means worn bearings. Remove the wheel, turn each inner race by finger and feel for roughness or play.
5. Remove the axle and roll it on V-blocks with the dial gauge at its centre; replace if runout exceeds **0.2 mm**. **Never** straighten an axle.
6. If bearings are faulty, remove seals and bearings with the puller, inspect the hub bores for wear, then drive in new bearings on the outer race only, sealed side out, with the spacer fitted. Fit new seals lubricated with grease.
7. Refit the wheel and recheck rotation and runout.

Pass criteria: radial and axial runout within limits, axle straight within 0.2 mm, bearings smooth with no play, seals fitted, axle nut at specified torque.

REVIEW QUESTIONS

1. Give two advantages and one disadvantage of cast wheels compared with spoked wheels.
2. Lateral runout is excessive at one point, towards the left. Which spokes do you tighten and loosen?
3. Decode 130/70R17 62H.
4. Calculate the sidewall height and overall diameter of a 90/90-17 tyre.
5. A tyre has the DOT code 0819. When was it made, and how old is it now (November 2026)?
6. Explain the difference between bias and radial construction.
7. Why must a new wheel bearing be pressed in on its outer race?
8. Why is an external string plug not a permanent tubeless repair?
9. A rider feels a shake in the bars at 90–100 km/h after a new front tyre was fitted. What is the most likely cause and the remedy?

10. What are the K-Light 125 cold pressures in psi?

ANSWERS

1. Advantages: no truing or spoke maintenance; run tubeless tyres; stiffer. Disadvantage: cannot be repaired after bending or cracking, and transmit more impact.
2. Tighten the spokes running to the right-hand hub flange and loosen those running to the left flange at that point, in small equal amounts over several spokes, pulling the rim to the right.
3. Section width 130 mm, aspect ratio 70 %, radial construction, 17 in rim, load index 62 (265 kg), speed symbol H (210 km/h).
4. Sidewall = 90 × 0.90 = 81 mm; diameter = 17 × 25.4 + 2 × 81 = 431.8 + 162 = 593.8 mm.
5. Week 8 of 2019; about seven years and nine months old, so it should be inspected carefully and replaced within about two years even if the tread is good.
6. Bias plies cross at 30–40° and the sidewall and tread work together, giving a stiff, damage-resistant but hotter-running tyre; radial plies run at about 90° with a belt under the tread, so the sidewall flexes independently and the tread stays flat and cool.
7. Force on the inner race passes through the balls to the outer race, brinelling the tracks; pressing the outer race transmits the force directly into the hub bore.
8. It is inserted from outside without inspecting the inside of the tyre for hidden damage and without sealing the inner liner, so air can migrate into the carcass and the plug can work loose.
9. An unbalanced front wheel (balance not done or a weight lost) or a tyre not seated concentrically; check bead seating line, then rebalance.
10. 190 kPa ≈ 27.5 psi front and 210 kPa ≈ 30.5 psi rear (1 psi = 6.895 kPa).

CHAPTER 4.7

Brakes

LEARNING OBJECTIVES

- Calculate the kinetic energy a brake must absorb and the resulting disc temperature rise.
- Explain drum brake shoe arrangements and hydraulic disc brake operation, and calculate force multiplication from lever and piston area ratios.
- Compare floating and fixed calipers, radial mounts, pad compounds and brake fluid grades.
- Describe combined braking (CBS) on the K-Light 125 and the operation of ABS and cornering ABS, and state the EU and Indian rules.
- Replace pads, measure discs, bleed a hydraulic system and service a drum brake.

Energy and friction

A brake converts kinetic energy into heat. The energy depends on the square of speed, so doubling speed quadruples the heat.

```
E = ½ × m × v²
ΔT = E_disc / (m_disc × c)
```

where m is the mass of machine and rider (kg), v the speed (m/s), m_disc the disc mass and c the specific heat capacity of the disc material (about 460 J/kg·K for steel).

Worked example: a K-Light 125 (145 kg curb mass) with an 80 kg rider, m = 225 kg, stops from 90 km/h (25 m/s).

```
E = 0.5 × 225 × 25² = 70,300 J ≈ 70 kJ
```

In a hard stop the front brake does about 70 % of the work. If 90 % of that heat enters a 0.9 kg steel disc before it can be shed, E_disc ≈ 0.7 × 0.9 × 70.3 kJ ≈ 44 kJ and ΔT = 44,000/(0.9 × 460) ≈ **106 K**. Repeated stops from high speed or a long descent therefore bring discs to 300–400 °C and push heat into calipers and fluid, which is why fluid boiling point and pad fade resistance matter.

Drum brakes

A **drum brake** has two curved shoes with bonded linings mounted on a backplate, pivoted at one end on an anchor pin and pushed apart at the other by a flat **cam** turned by a lever, cable or rod; **return springs** pull them back. The drum is part of the hub. In a **single leading shoe (SLS)** brake, one shoe (the leading shoe) faces the drum rotation so friction drags it harder into the drum (self-servo), while the trailing shoe is pushed away, giving roughly two-thirds of the braking from one shoe. A **twin leading shoe (TLS)** brake has two cams, each operating one shoe at its leading end, linked by an adjustable rod; both shoes self-servo forward, giving much higher forward braking (and weaker reverse braking). TLS front drums were fitted to sporting machines until discs replaced them in the 1970s. Drums are enclosed, cheap and resist water and mud, but fade with heat because the drum expands away from the shoes. The rear brake of many commuters and scooters (Honda CG125, most 110 cc step-throughs) is still a drum.

MAVCC Unit XII lists the wear signs: a lip on the drum's open edge (the original diameter, showing the friction surface has worn), hairline heat cracks (the hub is weakened and must be replaced) and glazing (blue, burnished surface that can be sanded off). Drum internal diameter and lining thickness are checked against the manual, and the **wear indicator** on the cam lever shows when the shoes are near the limit.

Hydraulic disc brakes

Pascal's principle and force multiplication

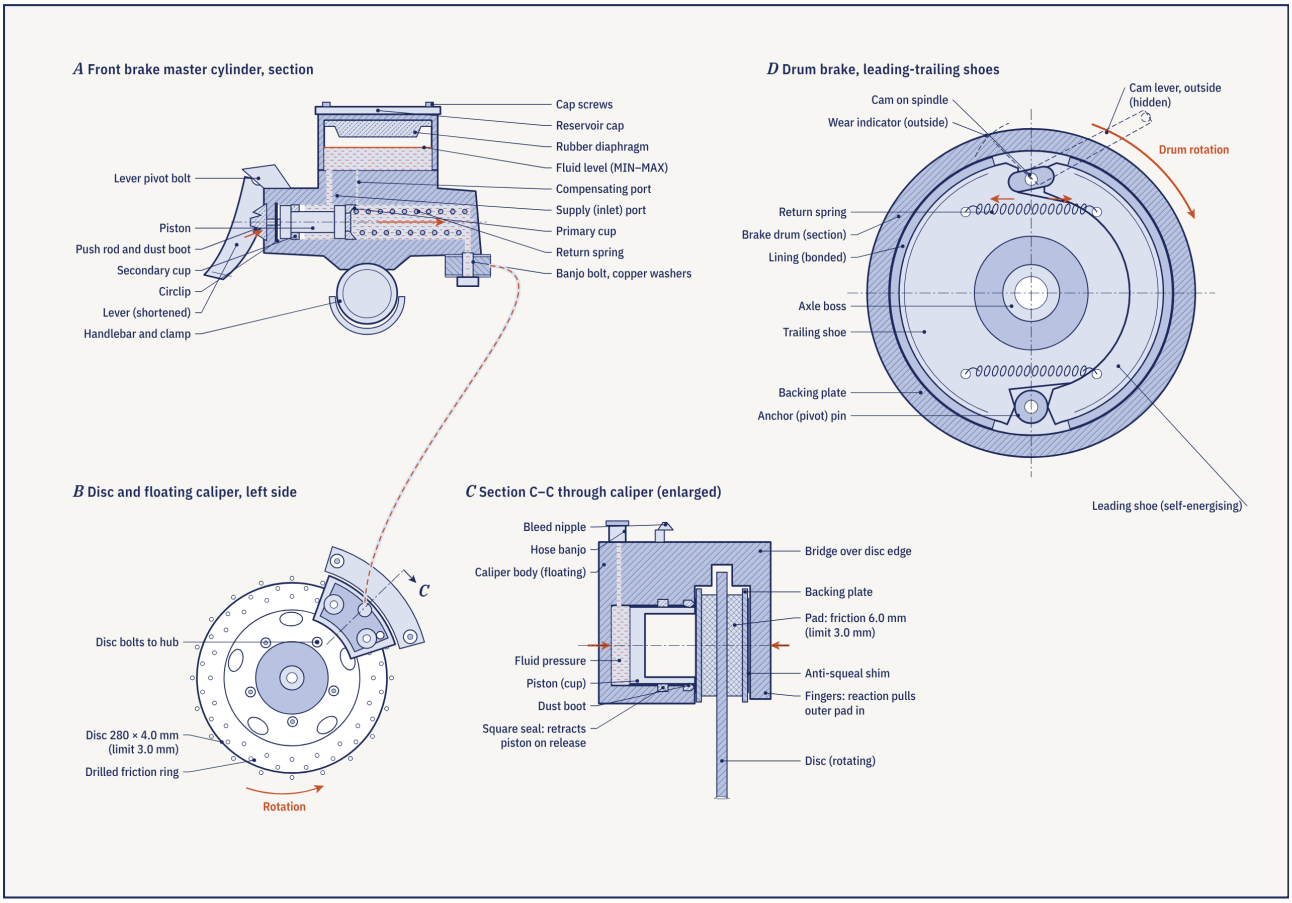


FIGURE 4.22 Brakes: hydraulic disc system with master cylinder, reservoir, brake hose, caliper section with pistons, seals and pads clamping the disc, beside a leading-trailing drum brake with shoes, cam, anchor pin and return springs.

Pressure in a confined fluid is equal throughout, so a small master cylinder piston pushing on the fluid creates the same pressure on the much larger caliper pistons, multiplying force in the ratio of their areas. Lever leverage multiplies it again.

```
p = F_mc / A_mc
F_clamp = p × A_caliper
F_friction = 2 × μ × F_clamp
T_brake = F_friction × r_eff
```



FIGURE 4.23 A floating disc gripped by a four-piston radial caliper, with pads visible in the caliper window.
Render: Transitions Lab, CC BY-SA 4.0

where A is total piston area on one side of the disc, μ the pad friction coefficient (about 0.35–0.50) and r_eff the effective radius at the pad centres.

Worked example: an 11 mm master cylinder, a lever ratio of 4:1, a hand force of 100 N, a floating caliper with two 27 mm pistons, μ = 0.40 and r_eff = 120 mm on a 280 mm disc (as on the K-Light 125).

```
F_mc = 4 × 100 = 400 N
A_mc = π × 5.5² = 95.0 mm²
p = 400 / 95.0 = 4.21 N/mm² = 4.21 MPa
A_caliper = 2 × π × 13.5² = 1,145 mm²
F_clamp = 4.21 × 1,145 ≈ 4,820 N
F_friction = 2 × 0.40 × 4,820 ≈ 3,860 N
T_brake = 3,860 × 0.120 ≈ 463 N·m
```

The hydraulic ratio is 1,145/95.0 ≈ 12, and the total ratio from hand to clamp about 48:1. At the tyre (radius 0.297 m) this torque gives 463/0.297 ≈ 1,560 N of braking force, a deceleration of 1,560/225 ≈ **6.9 m/s² (0.71 g)** from the front brake alone. The price of multiplication is movement: the master cylinder must displace twelve times the fluid volume of the pad clearance taken up, so a larger master cylinder gives a harder, less powerful lever and a smaller one a softer, more powerful lever with more travel.

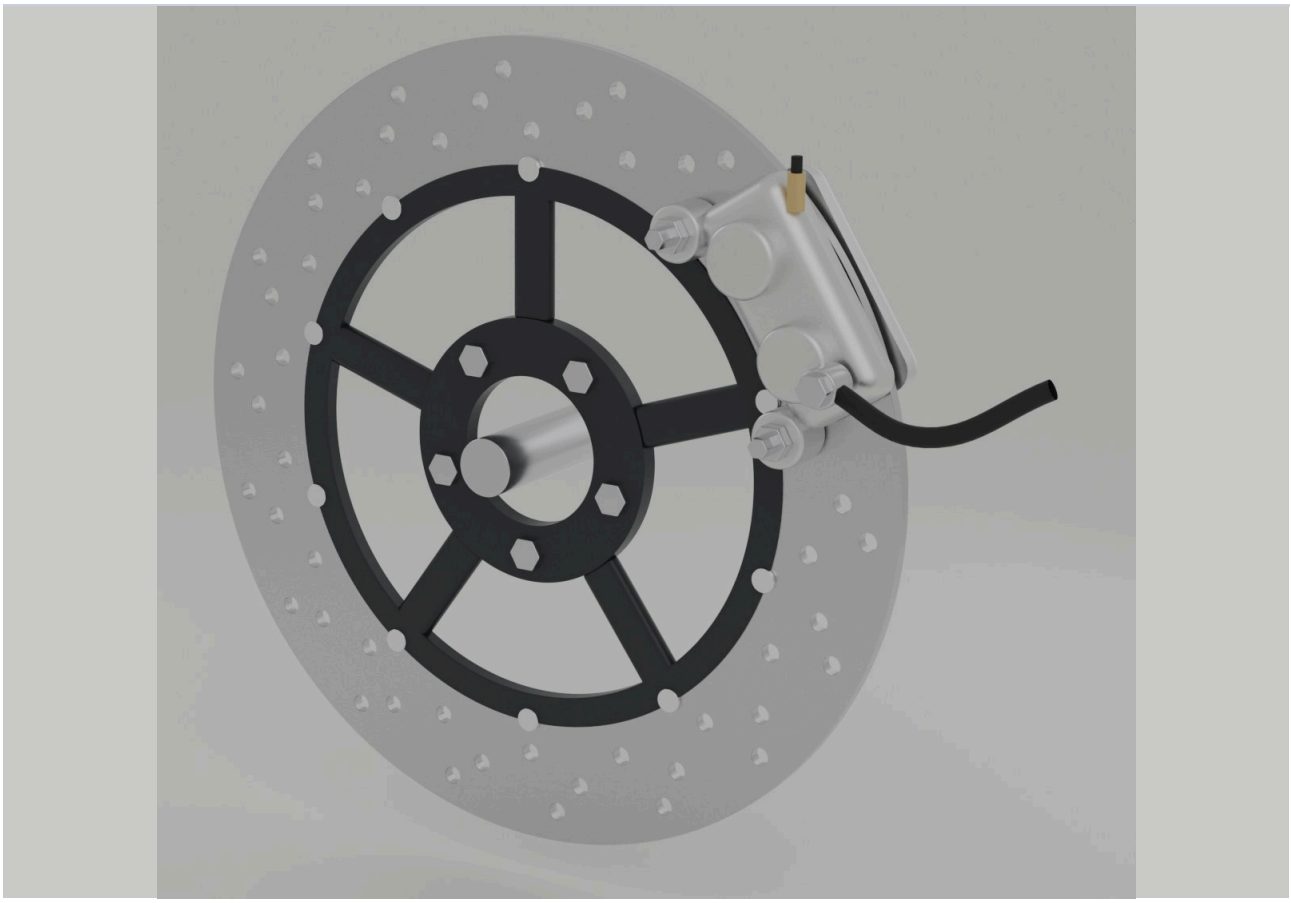


FIGURE 4.24 A floating front disc with drilled friction ring, dark carrier and riveted floating buttons, gripped by a two-piston sliding caliper with its mounting bolts, bleed nipple and banjo-fitted brake hose.

Render: Transitions Lab, CC BY-SA 4.0

Calipers and mounts

A **floating (sliding) caliper** has pistons on one side only; the caliper body slides on greased pins so that the reaction pulls the outer pad onto the disc. It is light and cheap and used on most small machines, including the K-Light 125. Seized slide pins cause uneven pad wear and drag. A **fixed (opposed-piston) caliper** has pistons on both sides of a rigid body (two, four or six pistons), giving more even pad pressure and higher stiffness. A **radial mount** bolts the caliper to the fork leg with bolts parallel to the disc's radius rather than perpendicular to it, so the caliper bracket is loaded in a stiffer direction and flex under braking is reduced. Discs are solid or drilled stainless steel, either fixed to the hub or **floating** on bobbins so they can expand radially without warping.

The piston **seal** is square-section in a groove; it distorts as the piston moves and pulls it back slightly when pressure is released (rollback), and as pads wear the piston slides further through it, so a disc brake adjusts itself.

Pads

Organic (resin) pads use fibres and fillers in a resin binder; they are quiet, gentle on discs and bite well cold, but fade at high temperature and wear quickly. **Sintered pads** are metal powders fused under heat and pressure; they work well wet and hot and last longer, but wear discs faster and must only be used on discs approved for them. Semi-metallic and ceramic compounds lie in between.

▤ REFERENCE DATA **K-Light 125 brakes (K-Light 125 manual)**

Front disc **280 mm**, thickness **4.0 mm new, 3.0 mm limit**; rear disc **240 mm**, **5.0 mm new, 4.0 mm limit**; disc runout limit **0.15 mm**. Pad friction material **6.0 mm new, 3 mm limit** front and rear. Fluid **DOT 4**. Lever free play **10–20 mm**, pedal **20–30 mm**. Caliper mounting bolts 22–29 N·m; disc bolts 10–12 N·m with thread lock; banjo (hollow) bolts **30 N·m** with new sealing washers; brake light on at about 15 mm lever travel.

Brake fluid

Glycol-ether fluids (DOT 3, DOT 4, DOT 5.1) are **hygroscopic**: they absorb water from the air through seals and the reservoir vent, typically 1–3 % in a year or two, and the boiling point falls sharply. FMVSS 116 sets minimum boiling points:

Fluid	Base	Dry boiling point	Wet boiling point (3.7 % water)	Compatibility
DOT 3	Glycol ether	205 °C	140 °C	Mixes with DOT 4, 5.1
DOT 4	Glycol ether, borate ester	230 °C	155 °C	Mixes with DOT 3, 5.1
DOT 5.1	Glycol ether, borate ester	260 °C	180 °C	Mixes with DOT 3, 4
DOT 5	Silicone	260 °C	180 °C	**Never** mix with glycol fluids

Vapour bubbles from boiling fluid compress, so a hot brake with old fluid can go to the bar suddenly. Replace glycol fluid every **two years** (typical OEM interval). Glycol fluid strips paint, so cover painted parts. The K-Light 125 manual warns **never** to reuse fluid, use fluid from an opened container that has stood for a long time, mix brands or types, or change fluid in rain or strong wind, and to clean brake parts only with brake fluid, isopropyl alcohol or ethanol, since petrol and mineral oils swell the rubber seals.

Combined braking (CBS)

A **combined braking system** applies both brakes from one control, so a rider who uses only the rear pedal (common among commuter riders) still gets front braking. The K-Light 125 uses a hydraulic CBS: the rear pedal operates a master cylinder that feeds the rear caliper and, through a **CBS pump** (a secondary master cylinder with its own reservoir, adjusting valve and plunger) and a hose, one piston circuit of the front caliper; the handlebar lever operates the front brake alone. The manual describes an internal leak test (screw in the adjusting bolt by hand while holding the pedal down: if it turns, the CBS pump leaks internally and is replaced) and an emergency setting: if the front caliper leaks, fully screwing in the CBS adjusting bolt lets the rear brake work alone. Pedal pushrod clearance is set to **0–0.2 mm** so the plunger is not pre-loaded. Mechanical CBS systems on scooters (Honda, Hero, TVS) use an equaliser link on the left lever that pulls both brake cables. Moto Guzzi fitted linked "integral" brakes from 1975 (850 T3); Honda's Dual-CBS links both levers to multiple caliper pistons on larger machines.

ABS

An **anti-lock braking system** prevents wheel lock by modulating pressure. Each wheel has a **wheel speed sensor** (inductive or Hall-effect) reading a toothed **tone ring** (pulse ring) on the hub or disc carrier. The ECU compares wheel speeds and deceleration with the estimated vehicle speed; when a wheel's slip exceeds a threshold (roughly 10–30 %) the **hydraulic modulator** closes an inlet valve to hold pressure, opens an outlet valve to release fluid into a low-pressure accumulator, and a pump returns it to the master cylinder side, cycling several times per second until the wheel regains grip. The rider feels this as pulsing at the lever. BMW offered the first production motorcycle ABS on the K100 in 1988; modern units such as Bosch's ABS 10 weigh well under 1 kg. **Cornering ABS** adds an **inertial measurement unit (IMU)** that measures lean angle and pitch, so the ECU reduces brake pressure build-up and slip thresholds at lean and limits rear-wheel lift; Bosch Motorcycle Stability Control was first fitted on the 2013 KTM 1190 Adventure. Rear-lift mitigation reduces front pressure when the rear wheel decelerates faster than the front, indicating a stoppie.

ABS faults are read with a diagnostic tool; the most common causes of a warning lamp are a damaged tone ring, a sensor air gap out of specification (typically 0.4–1.2 mm), dirty sensors, mismatched tyre sizes and low battery voltage. Bleeding an ABS system may require the diagnostic tool to cycle the modulator valves.

Regulation

In the European Union, Regulation (EU) No 168/2013 requires **ABS on L3e motorcycles above 125 cc** for new types from **1 January 2016** and for all new vehicles registered from **1 January 2017**; L3e-A1 motorcycles (up to 125 cc and 11 kW) must have **ABS or CBS**. In India, the Central Motor Vehicles Rules as amended in 2016 require **ABS on two-wheelers above 125 cc** and **CBS or ABS at or below 125 cc**, for new models from April 2018 and all new vehicles from **April 2019**. A June 2025 draft notification proposed ABS on all new L2 two-wheelers from January 2026, but manufacturers contested its scope and timing; check the current notified text before relying on it.

Job sheet 4.7.1: Replacing pads and measuring disc thickness and runout

Tools and materials	Reference values
Socket and Allen set, torque wrench, micrometer (0–25 mm), dial gauge and magnetic base, piston spreader or flat lever, brake cleaner, copper-free anti-squeal paste (backs of pads only), new pads and pins as required, gloves, safety glasses	K-Light 125: pad **6.0 mm new, 3 mm limit**; front disc **4.0/3.0 mm**, rear **5.0/4.0 mm**; runout **0.15 mm**; caliper bolts 22–29 N·m; disc bolts 10–12 N·m

1. Cover painted parts. Remove the pad pin plug and loosen the pad pin while the caliper is still bolted on. Remove the caliper mounting bolts and lift the caliper off the disc.
2. Remove the pad pin, pads and pad spring. Measure friction material at the thinnest point; if either pad is at or below **3 mm** replace **both pads in the caliper together** (K-Light 125 manual). Uneven wear indicates seized slide pins or a sticking piston.
3. Clean the caliper with brake cleaner (no compressed air on brake dust). Check piston dust seals for splits and fluid leaks. Clean and regrease slide pins with silicone grease and renew their boots if damaged.
4. Push the piston back squarely with a spreader, watching the reservoir level; it will rise as fluid returns. On CBS machines check both reservoirs.

5. Measure the disc thickness with the micrometer at several points round the swept area; replace if below the limit (front **3.0 mm**, rear **4.0 mm**) or if deeply scored. With the wheel fitted and axle tight, mount a dial gauge on the fork leg with the stylus 5–10 mm inside the disc's outer edge and rotate the wheel; replace or remount the disc if runout exceeds **0.15 mm** (check first that wheel bearings are good and the disc seats are clean).
6. If replacing a disc, clean the hub seat, apply thread lock and tighten the bolts in a diagonal pattern to **10–12 N·m**.
7. Fit new pads with their spring, insert the pad pin, refit the caliper and tighten mounting bolts to **22–29 N·m**, then the pad pin.
8. Pump the lever or pedal until it is firm **before** moving the machine. Set the fluid level. Bed in the pads with a series of moderate stops from 50 km/h, avoiding heavy stops for the first 100–200 km.

Pass criteria: both pads above limit and evenly worn, discs within thickness and runout limits, slide pins free, all bolts at torque, lever or pedal firm on the first stroke after pumping, wheel turns without drag, brake light working.

Job sheet 4.7.2: Bleeding a hydraulic brake

Tools and materials	Reference values
Ring spanner for bleed nipple, clear tube, catch bottle, sealed new DOT 4 fluid (or as marked on the reservoir cap), vacuum bleeder (manual method), rags, gloves, safety glasses	Reservoir kept **at least one-third full** (K-Light 125 manual); bleed nipple torque per manual; banjo bolts 30 N·m with new washers

1. Park upright, turn the handlebar so the reservoir is level, and cover painted parts. Remove the reservoir cap, plate and diaphragm.
2. Fit the clear tube over the bleed nipple and into the catch bottle with a little fresh fluid in it, so air cannot be drawn back.
3. Lever method: squeeze and hold the lever, open the nipple a quarter turn, close it before the lever reaches the bar, then release the lever. Repeat, topping up the reservoir so it **never** falls below one-third (MAVCC Unit XII: never allow the level to fall low enough to draw air in).
4. Vacuum method (K-Light 125 manual): apply the vacuum pump to the nipple, open it and draw fluid through while topping up the reservoir, until clear, bubble-free new fluid flows. Close the nipple, then pump the lever several times quickly.
5. Continue until the fluid in the tube is clear, the old darker fluid has been flushed, and no bubbles appear. On CBS systems bleed each circuit in the order the manual gives (front lever circuit, rear pedal circuit, CBS circuit).
6. If air persists at the high point of the system, tie the lever back overnight or tap the hose and caliper to dislodge bubbles; on ABS models use the diagnostic tool's bleed routine if specified.
7. Tighten the bleed nipple, refit the dust cap, set fluid to the upper mark, and refit the diaphragm and cap.
8. Test: the lever or pedal must be firm and not sink under steady pressure. MAVCC notes a spongy lever almost always indicates air.

Pass criteria: firm lever and pedal with free play to specification, no leaks at nipple or banjos, fluid level correct, waste fluid stored for approved disposal, brake light and (if fitted) ABS lamp self-check normal.

Job sheet 4.7.3: Drum brake shoe inspection and adjustment

Tools and materials	Reference values
Socket set, vernier caliper, drum gauge or internal caliper, emery cloth, high-temperature grease, brake cleaner, dust mask	Lining thickness, drum diameter limit and pedal free play from manual (typical lining limit 1.5–2.0 mm; pedal free play 20–30 mm)

1. Check the wear indicator on the brake cam lever first: if the pointer is beyond the mark with the brake applied, the shoes or drum are worn out.
2. Remove the wheel and pull the backplate out of the drum. Wear a dust mask and wet-clean the dust; **never** blow it out with compressed air.
3. Measure lining thickness at the thinnest point and replace both shoes if at the limit, contaminated with oil or grease, or cracked. Replace the hub oil seal if grease contamination came from it.
4. Measure drum internal diameter in several directions; replace the hub if beyond the limit, out-of-round, or showing heat cracks. Remove light glazing with emery cloth (MAVCC Unit XII).
5. Remove the shoes by folding them together against spring tension. Clean the cam and anchor pin and apply a light film of high-temperature grease; check the cam for wear in its bush and the return springs for stretch.
6. Refit shoes and springs, check the cam lever's angle to the rod or cable (it should be close to 90° with the brake applied, which gives the most leverage), and refit the wheel and torque arm.
7. Adjust pedal or lever free play with the adjuster nut on the rod or cable to the specified range (rear pedal **20–30 mm** on many commuters). After any chain adjustment, recheck.
8. Spin the wheel to confirm there is no drag, and check that the brake light comes on before the brake starts to bite.

Pass criteria: linings and drum within limits, no contamination, cam lubricated and free, free play within specification, no drag, brake light operating correctly, and a confident stop on the road test.

REVIEW QUESTIONS

1. Calculate the kinetic energy of a 300 kg machine plus rider at 120 km/h.
2. Why does a twin leading shoe drum brake give more forward braking than a single leading shoe brake?
3. A master cylinder is 12.7 mm in diameter and the caliper has four 30 mm pistons (two each side, opposed). Calculate the hydraulic ratio based on one side's piston area.
4. In question 3, a force of 450 N acts on the master cylinder piston. What clamp force do the pistons on one side apply?
5. Why must DOT 5 fluid never be mixed with DOT 4?
6. Describe what happens in the ABS modulator when a front wheel begins to lock.

7. What does cornering ABS add to standard ABS?
8. What braking equipment does EU law require on a 125 cc L3e-A1 motorcycle and on a 300 cc motorcycle?
9. A K-Light 125 front disc measures 3.1 mm at its thinnest point. Is it serviceable?
10. A rider reports a spongy lever after a long mountain descent that returns to normal when cool. What is the cause and remedy?
11. On the K-Light 125, the front caliper is leaking. How can the rear brake still be used until repair?
12. Why are both pads in a caliper always replaced together?

ANSWERS

1. v = 120/3.6 = 33.3 m/s; E = 0.5 × 300 × 33.3² = 0.5 × 300 × 1,111 ≈ 166.7 kJ.
2. Both shoes are applied at their leading ends so friction drags each further into the drum (self-servo), whereas in SLS only one shoe self-servos and the trailing shoe is pushed away.
3. A_mc = π × 6.35² = 126.7 mm²; one side's pistons = 2 × π × 15² = 1,413.7 mm²; ratio = 1,413.7/126.7 ≈ 11.2.
4. p = 450/126.7 = 3.55 MPa; F_clamp = 3.55 × 1,413.7 ≈ 5,020 N.
5. DOT 5 is silicone-based and does not mix with glycol fluids; the mixture separates and seals designed for one fluid may swell or shrink, causing leaks and loss of braking.
6. The ECU sees the wheel decelerating faster than the vehicle; it closes the inlet valve to hold pressure, opens the outlet valve to release fluid into the accumulator, then the pump returns fluid and the inlet reopens to reapply, cycling until slip is controlled.
7. An IMU measures lean, pitch and yaw so the ECU adapts slip thresholds and pressure build-up rate to the lean angle and limits rear-wheel lift.
8. L3e-A1 up to 125 cc: ABS or CBS. Above 125 cc: ABS (all new registrations since 1 January 2017).
9. Yes: the limit is 3.0 mm, but it is close and will reach the limit soon; check runout and recommend replacement at the next pad change.
10. Boiling of fluid that has absorbed water (lowered wet boiling point); vapour bubbles compress. Replace the fluid with fresh DOT 4 and bleed, and check pads and caliper slide pins.
11. Fully screw in the CBS adjusting bolt, which isolates the CBS front circuit so the rear brake operates alone (K-Light 125 manual); repair the caliper before normal use.
12. Equal friction thickness keeps the caliper and pistons square to the disc and gives even clamping; a new pad against a worn one tilts the caliper and causes uneven wear and reduced efficiency.

CHAPTER 4.8

Periodic maintenance and pre-delivery inspection

LEARNING OBJECTIVES

- Read and apply a manufacturer's periodic maintenance schedule in kilometres and months.
- Carry out a T-CLOCS pre-ride check and explain each item.
- Perform a chassis tune-up covering cables, free play, fasteners, chain, wheels and lights.
- Prepare a new motorcycle for delivery using a structured pre-delivery inspection.

The maintenance schedule

Service intervals are set by distance or by time, **whichever comes first**, because oils, fluids and rubber age even when a machine is not ridden. The K-Light 125 manual bases its schedule on **1,000 km per month**, codes each task I (inspect, and clean, adjust or replace as needed), A (adjust), C (clean), R (replace) and L (lubricate), and marks emission-related items, which must be serviced to the schedule to keep the machine legal. It asks for shorter intervals for dusty roads, high-speed use and high mileage. The table combines the chassis and drivetrain entries of the K-Light 125 schedule with typical OEM practice for items the schedule does not list separately.

Item	300 km (first)	Every 3,000 km / 3 months	Every 6,000 km / 6 months	Every 12,000 km / 12 months	Notes
Engine oil	R	R	R	R	K-Light 125: replace every 3,000 km; oil filter clean at 300, 6,000, 12,000 km
Air filter	I	C	C	R	Clean more often in dust
Drive chain	I (adjust)	I, L	I, L	I, L	Slack **20–40 mm** K-Light 125; lubricate every 500–800 km
Clutch free play	I	I	I	I	**10–15 mm** K-Light 125
Brakes (pads, discs, free play, hoses)	I	I	I	I	Pads to **3 mm** limit
Brake fluid	I	I	I	I	Replace every **2 years** (typical OEM)
Tyres and pressures	I	I	I	I	Monthly and before long trips
Steering head bearings	I		I	I	Adjust or grease as needed; re-grease every 2 years typical
Suspension, fork oil	I		I	I	Fork oil change typically 12,000–24,000 km or 2 years
Wheels, runout, bearings	I		I	I	

Item	300 km (first)	Every 3,000 km / 3 months	Every 6,000 km / 6 months	Every 12,000 km / 12 months	Notes
Fasteners, side stand, footpegs	I	I	I	I	Torque wrench to spec
Lights, horn, switches, interlocks	I	I	I	I	
Chassis lubrication (pivots, cables)			L	L	K-Light 125 "lubrication of parts of body"
Valve clearance, spark plug, throttle body, emissions	per Modules 2 and 3				Engine items

An owner riding 6,000 km a year would reach the 3,000 km oil change every six months; one riding 500 km a year must still change oil and check brake fluid annually, as the time limits govern.

Pre-ride check: T-CLOCS

The Motorcycle Safety Foundation's **T-CLOCS** checklist covers what a rider should check before riding:

- **T, Tyres and wheels**: pressure (cold), tread depth and damage, spoke tension or cast-wheel cracks, bearings, brakes operating.
- **C, Controls**: levers and pedal free play and return, cables free with no kinks or fraying, throttle snapping shut in every bar position, hoses not cracked.
- **L, Lights and electrics**: headlight high and low beam, tail and brake light from both controls, indicators, horn, battery terminals secure.
- **O, Oil and other fluids**: engine oil level, brake and clutch fluid levels, coolant, fuel, and evidence of leaks underneath.
- **C, Chassis**: frame, suspension action and leaks, chain or belt tension and lubrication, fasteners.
- **S, Stands**: side and centre stands spring back fully and the side-stand switch cuts the engine when the stand is down in gear.

Chassis tune-up

MAVCC Unit XVII sets out a chassis tune-up that complements the engine tune-up of Module 2: inspect and lubricate all control cables, adjust clutch, brake and throttle free play, check every fastener, inspect, lubricate and adjust chain and sprockets, check horn, lights and safety equipment, check wheels for damage and loose spokes, set tyre pressures, check fluid levels, aim the headlight, lubricate the chassis as the manual specifies, and finish with a wipe-down.

Cables are lubricated at their pivots and inner wire by a pressure luber or drip method (Teflon-lined cables need no oil), and must be routed away from hot surfaces and tight bends. When fitting a new cable, MAVCC recommends laying it alongside the old one before removal and removing the fuel tank if the cable passes under it, so the routing is correct. With the engine idling, turn the bars from lock to lock: idle speed must not rise, which would show a cable being pulled by the steering. Headlight aim is set on level ground with the rider seated, against a wall chart or beam setter, so the dipped beam's cut-off falls the specified amount (typically about 1 %) below the lamp centre height at the stated distance.

Detailing is the final step and the one the customer sees: MAVCC's advice includes not using silicone rubber dressing on seats, grips or tyres, since it makes them slippery, and keeping wax off matt finishes.

Pre-delivery inspection

MAVCC Unit XVIII sets out uncrating, assembly and preparation of a new machine. Modern machines arrive more complete, but the pre-delivery inspection (PDI) is still the dealer's legal and safety responsibility, and the checklist below follows MAVCC's job sheet with current additions.

1. Unpack, check the frame number and engine number against the paperwork, and inspect for transit damage; record any damage before assembly.
2. Fit components shipped loose (handlebars, mirrors, front wheel, mudguard, screen) to the manual's torque values; route cables and hoses as shown in the assembly manual.
3. Fill and charge the battery if dry-charged, or test a factory-sealed battery for open-circuit voltage (above about 12.6 V for a fully charged 12 V lead-acid battery); connect **positive first, negative last**.
4. Check engine oil level, final-drive oil on shaft machines, coolant level and brake and clutch fluid levels; top up as required with the specified fluids.
5. Add fuel and check for leaks at the tank, pump, hoses and injector.
6. Set tyre pressures; check wheel nuts and axle torques and spoke tension.
7. Adjust clutch, throttle and brake free play, chain slack and alignment.
8. Check all lights, horn, indicators, instrument lamps, interlocks (side stand, clutch, neutral), kill switch and, where fitted, ABS lamp self-check.
9. Start and warm the engine; check idle speed, read the ECU for stored fault codes, and check for leaks.
10. Check fasteners across the machine, including fork clamps, steering stem nut, caliper bolts, swingarm pivot, shock mounts and footpeg brackets.
11. Road test: brakes (separately and, on CBS, the combined function), clutch, gear shifting through all gears, steering, suspension, speedometer, and absence of noises.
12. Remove transit protection and anti-corrosion wax from the exhaust (it smokes when first heated), clean the machine, fit the registration plate and record the PDI on the service record. Hand over the toolkit, manual and keys, and brief the customer on running-in and the first service at 300 km (K-Light 125).

> SAFETY **Torque and road tests**
>
> A PDI is complete only when every fastener the dealer touched has been tightened with a torque wrench to the manual's figure, and the machine has been road-tested in a safe place. Record the values; they are evidence if a fault is later disputed.

> EXPLORER EXERCISE · transitionslab.org/motorcycle-anatomy **Walk the exploded diagram as a checklist**
>
> Open the exploded diagram at transitionslab.org/motorcycle-anatomy and go through the parts in number order from "Fuel tank" to "Tail light and indicators". For each, name the inspection from this chapter that applies (for example "Drive chain": slack, wear length, lubrication; "Front fork": leaks, oil, clamp torque).

REVIEW QUESTIONS

1. Why are service intervals given as distance or time, whichever comes first?
2. What do the K-Light 125 schedule codes I, A, C, R and L mean?

3. A K-Light 125 owner rides 800 km a month. When is the second oil change after the 300 km first service due, by distance and by time?
4. List the six letters of T-CLOCS and one check under each.
5. Why must idle speed be checked with the bars turned from lock to lock?
6. Why are new cables laid alongside the old ones before the old ones are removed?
7. In which order are battery cables connected and why?
8. What must be removed from a new exhaust before delivery, and why?
9. List five items you would road-test during a PDI.
0. Why must brake fluid be changed even on a machine that covers little distance?

ANSWERS

1. Fluids, rubber, and lubricants age and absorb moisture over time regardless of use, while wear depends on distance; whichever limit is reached first governs.
2. I inspect (and clean, adjust, lubricate or replace as necessary), A adjust, C clean, R replace, L lubricate.
3. Oil is replaced every 3,000 km; at 800 km per month the next change after 300 km is due at 3,300 km, about 3.75 months later, but the 3-month interval comes first, so the change is due at about 2,700 km, three months after the first service.
4. Tyres and wheels (pressure); Controls (free play); Lights and electrics (brake light); Oil and fluids (engine oil level); Chassis (chain slack); Stands (side stand returns and switch cuts the engine).
5. A cable routed too tight or trapped by the steering pulls the throttle open as the bars turn, raising idle; this is a dangerous fault.
6. So the new cable follows exactly the same route and guides, avoiding kinks, hot surfaces and points where steering movement would pull it.
7. Positive first, negative last (and negative off first on removal), so that a spanner touching the frame while the positive terminal is being tightened cannot short-circuit the battery.
8. Anti-corrosion wax or oil applied for transit; it smokes and smells when the exhaust heats up, alarming the customer, and can stain the finish.
9. Brakes (each control and the combined function), clutch release and take-up, gear changes through all gears, steering and straight-line stability, suspension action, instruments and speedometer, and absence of abnormal noises.
10. Glycol fluid absorbs water over time, lowering its boiling point and causing internal corrosion, regardless of distance travelled.

Glossary

ABS (anti-lock braking system): a system that measures wheel speeds and modulates brake pressure to prevent wheel lock. **Aspect ratio**: tyre sidewall height as a percentage of section width. **Assist clutch**: a clutch whose ramps add clamping force under drive torque so lighter springs can be used. **Back-cut dog**: a dog whose driving face is undercut a few degrees so that torque holds the gears in engagement. **Bias tyre**: a tyre whose carcass plies cross at an angle of about 30–40° to the circumference. **Brinelling**: indentation of bearing races by balls or rollers under static load or shock. **CBS (combined braking system)**: a system in which one control applies both front and rear brakes. **Clutch basket**: the slotted outer housing of the clutch, driven by the primary gear. **Constant-mesh gearbox**: a gearbox in which all gear pairs are always meshed and ratios are selected by locking gears to their shaft with dogs. **Contra spring**: the spring that closes the driven pulley of a CVT. **Countershaft**: the gearbox output shaft carrying the front sprocket. **Cush drive**: rubber blocks between the rear sprocket carrier and hub that absorb drivetrain shock. **CVT (continuously variable transmission)**: a transmission using variable-diameter pulleys and a belt to give a stepless ratio range. **Damper-rod fork**: a telescopic fork that damps by forcing oil through fixed holes in a rod. **Detent plate**: a notched plate on the shift drum that, with the stopper arm, holds each gear position. **Dogs**: lugs on a gear face that engage slots or dogs on an adjacent gear to lock it to the shaft. **DOT code**: tyre marking whose last four digits give week and year of manufacture. **Drag (clutch)**: incomplete release of a clutch, causing creep and hard shifting. **Fixed caliper**: a caliper with opposed pistons on both sides of the disc. **Floating caliper**: a caliper with pistons on one side that slides on pins to clamp the disc. **Fork offset**: perpendicular distance from the steering axis to the front wheel spindle. **Hygroscopic**: absorbing moisture from the air, as glycol brake fluids do. **IMU (inertial measurement unit)**: a sensor of accelerations and rotation rates used to calculate lean and pitch. **Load index**: a number on a tyre corresponding to its maximum load at reference pressure. **Mainshaft**: the gearbox input shaft that carries the clutch. **Motion ratio**: ratio of wheel travel to shock travel in a rear suspension. **Preload**: initial compression of a suspension spring at full extension. **Primary drive**: the gear or chain drive from crankshaft to clutch. **Quickshifter**: a system that briefly interrupts engine torque to allow clutchless gear changes. **Radial tyre**: a tyre whose carcass cords run at about 90° to the circumference, with a belt under the tread. **Rake**: angle of the steering axis from vertical. **Rising rate**: a suspension characteristic in which wheel rate increases with travel. **Runout**: deviation of a rotating part from true rotation, radial or axial. **Sag**: suspension compression from full extension under the weight of the machine (static) or machine and rider (rider sag). **Shift drum**: a grooved cylinder whose rotation moves the shift forks. **Shim stack**: a set of thin steel discs covering damper piston ports that bend to control oil flow. **Slipper clutch**: a clutch that slips under back-torque to prevent rear-wheel hop on downshifts. **Speed symbol**: a letter on a tyre giving its maximum rated speed. **Spring rate**: force needed to compress a spring by unit distance, in N/mm. **Steering damper**: a hydraulic damper that resists rapid steering movement. **Tone ring**: toothed ring read by an ABS wheel speed sensor. **Trail**: ground distance from the steering axis intersection to the front contact patch centre. **Twin leading shoe**: a drum brake with both shoes applied at their leading ends. **Unsprung mass**: mass moving with the wheel and not supported by the springs. **USD fork**: an upside-down fork with the large tube clamped in the yokes and the slim tube at the axle. **Variator**: the drive pulley of a CVT whose rollers close it as engine speed rises. **Wheelbase**: distance between the front and rear wheel spindles. **X-ring chain**: a sealed chain using rings of X-shaped section between the plates.

Further reading

- KS Motorcycles / Qianjiang. K-Light 125 maintenance manual (manuel d'entretien K-Light 125), chassis chapters on brakes, front and rear wheels, suspension and chain drive, and engine chapters on clutch, kickstarter and gearshift.
- Mid-America Vocational Curriculum Consortium. Motorcycle Mechanic, teacher edition, 1988: Units X (Wheels and tires), XI (Steering and suspension), XII (Brakes), XIII (Clutches), XVII (Basic chassis tune-up) and XVIII (Assembly and pre-delivery).
- Hero Honda. Technician starter kit, Unit 2: The Motorcycle.
- Solomon R. Guggenheim Museum. The Art of the Motorcycle. New York: Guggenheim Museum Publications, 1998.
- Foale, Tony. Motorcycle Handling and Chassis Design: the Art and Science. Tony Foale Designs, 2nd edition, 2006.
- Cossalter, Vittore. Motorcycle Dynamics. 2nd English edition, Lulu, 2006.
- Cocco, Gaetano. Motorcycle Design and Technology. Giorgio Nada Editore / Motorbooks, 2004.
- Thede, Paul, and Lee Parks. Race Tech's Motorcycle Suspension Bible. Motorbooks, 2010.
- Robinson, John. Motorcycle Tuning: Chassis. Butterworth-Heinemann, 2nd edition, 1994.
- Robert Bosch GmbH. Bosch Automotive Handbook. 10th edition, Wiley, 2018.
- Haynes. Motorcycle Basics Techbook. Haynes Publishing.
- Regulation (EU) No 168/2013 of the European Parliament and of the Council on the approval and market surveillance of two- or three-wheel vehicles and quadricycles, Annex VIII (advanced brake systems).
- Commission Delegated Regulation (EU) No 3/2014 on vehicle functional safety requirements for L-category vehicles (braking requirements, Annex III).
- UNECE Regulation No. 78: uniform provisions concerning the approval of vehicles of categories L1, L2, L3, L4 and L5 with regard to braking.
- UNECE Regulation No. 75: uniform provisions concerning the approval of pneumatic tyres for L-category vehicles.
- US Federal Motor Vehicle Safety Standard No. 116: Motor vehicle brake fluids (49 CFR 571.116).
- ISO 10190: Motorcycle chains, characteristics and test methods.
- JASO T 903: Motorcycle four-stroke engine oil standard (MA, MA2, MB classifications).
- Motorcycle Safety Foundation. T-CLOCS inspection checklist.
- Government of India, Ministry of Road Transport and Highways. Central Motor Vehicles Rules, 1989, as amended (ABS and CBS requirements for L2 vehicles).

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Workshop procedures are general guidance. Specifications differ between machines: always confirm values and torque settings in the manufacturer's service manual, and observe the safety notes in Module 1 and Module 5.