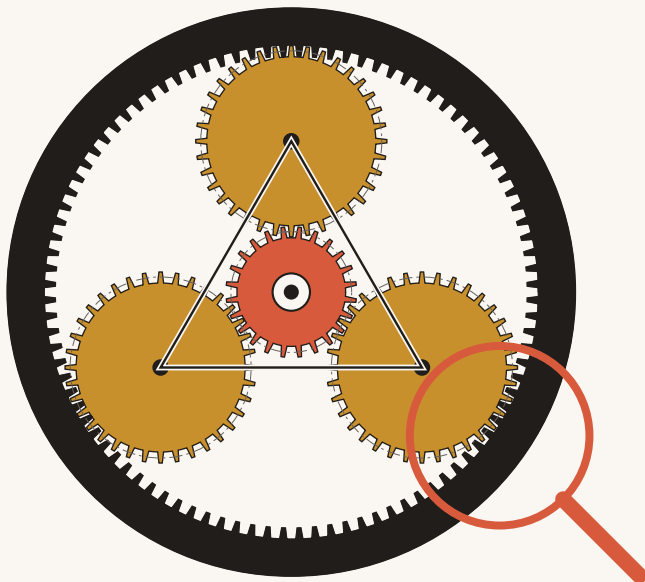


MECHANICS OF MACHINES

Exam Question Decoder

Turn a machine question into a step-by-step solution.

A 6-step method • a “which principle?” finder • 3 fully decoded questions
4-question practice test with worked answers



Start here

The problem this guide solves. A Mechanics of Machines question is a short story about a machine: a hoist lifting a cage, gears turning a drum, two wagons colliding. Many students read the story, then flip through their notes looking for a formula with the same letters. That is slow, and it often picks the wrong formula. This guide teaches a different habit: *decode* the story first, decide which law of mechanics it is about, and only then write an equation.

What you will be able to do:

- pull every given quantity out of a question and convert it to SI units;
- draw the one sketch that makes the problem clear;
- tell which “family” a question belongs to, and which principle governs it;
- tell apart problems that look alike but need different methods;
- solve hoist, epicyclic gear and collision questions fully, and check your answers.

Why these question types

We read the Mechanics of Machines section of 12 Module II papers (8 dated Oct/Nov 2019 to Mar/Apr 2025, plus 4 undated). **Gear trains** appeared in all 12; **belt drives** and **balancing** in 10; **clutches** and **vehicle, haulage or hoist** questions in 9; **momentum and impulse** in 7. The three decoded questions here come from three different families (hoists, gears, momentum), and the practice test adds belts, balancing, a pile driver and a clutch. These counts describe past papers only; they do not predict the next paper.

Scope

This is a focused starter, **not the complete Mechanics of Machines syllabus**. It teaches a way of approaching questions and gives a taste of seven topic families. It does not cover kinematics, moments of inertia in depth, compound and reverted gearboxes, cone and centrifugal clutches, V-belts in depth, multi-plane balancing, vehicle braking and cornering, or plane motion. Those are in the complete SomaReady Mechanics of Machines guide (see the last page). All questions here are **original SomaReady practice questions**, not KNEC questions.

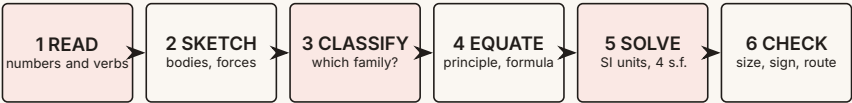
SYMBOL WATCH

T is a **torque** (N m) for drums, shafts and gears, but a **tension** (N) for ropes and belts. m is a mass (kg), except belt mass per metre (kg/m). t counts gear **teeth**. N is a speed in rev/min; ω is in rad/s, with $\omega = 2\pi N/60$. Take $g = 9.81 \text{ m/s}^2$.

PART 1

The six-step decoder

Use the same six steps on every question. They take about two minutes, and they decide most of the marks before any arithmetic starts.



1.1 Steps 1 and 2: read, then sketch

Read every number and every verb. Make a two-column list: *given* (symbol, value, unit, converted to SI) and *find*. Verbs carry information too:

Words in the question	What they tell you
"from rest", "starts"	initial speed $u = 0$
"uniformly", "steadily accelerates"	acceleration is constant: the equations of motion apply
"at constant speed", "steady"	acceleration is zero: no inertia term
"lock together", "couple", "do not rebound"	one common velocity after impact
"is held", "is fixed"	that member's speed is zero
"on the point of slipping"	friction has reached its limit: $T_1/T_2 = e^{\mu\theta}$ or $F = \mu N$
"neglect friction / losses"	efficiency = 1; no friction torque

Sketch. Draw each moving body on its own. Mark the direction of motion and choose it as positive. Show every force or torque that acts on that body. A good sketch often shows that the question has two parts: for a hoist, the cage (a straight-line problem) and the drum (a rotation problem).

1.2 Step 3: classify the question

Most questions belong to one of a few families. The family tells you the governing principle.

If the question has...	it is about...	start from...
a drum, cage, rope, hoist or wagon on a slope	Newton's second law for the load <i>and</i> the drum	$T_r - mg = ma;$ $T = T_r r + I\alpha + T_f$
gears, teeth, an arm or annulus	speed ratios and torque balance	tooth ratios; table; $\Sigma T = 0$
a collision, a blow, "couple", a pile	conservation of momentum (impact)	$\Sigma mu = \Sigma mv$
a belt, pulley, angle of lap	friction on a curved surface	$T_1 / T_2 = e^{\mu\theta};$ $P = (T_1 - T_2)v$
a clutch, friction plates, springs	friction torque on a disc	$T = n\mu WR$
masses on a shaft, "balance"	centripetal force $m\omega^2 r$	$\Sigma mr = 0$ (vectors)

1.3 Steps 4 to 6: equate, solve, check

Equate. Write the principle in words, then the formula, then the formula rearranged for the unknown, all in symbols. **Solve.** Substitute SI values with their units; keep 4 significant figures until the end. **Check.** Is the size sensible? Is the sign or direction stated? Does a second route give the same number? Each worked question below ends with such a check.

1.4 Look-alikes: same picture, different method

- **Hoist at constant speed or accelerating?** Constant speed: $a = 0$, so $T = mgr + T_f$ only. Accelerating: add mar for the load *and* $I\alpha$ for the drum.
- **Impact or energy?** Through an impact, momentum is conserved but kinetic energy is not. Before or after the impact (a hammer falling, a pile sinking), use energy.
- **Simple or epicyclic gears?** If every gear turns on a fixed axis, use tooth ratios. If some gears ride on a rotating arm, use the table method.
- **Belt with or without belt mass?** If the mass per metre is given, centrifugal tension $T_c = mv^2$ reduces the usable tension: $T_1 = T_{\max} - T_c$.
- **Static or dynamic balance?** Masses in one plane: $\Sigma mr = 0$. Masses in several planes: also $\Sigma mrl = 0$.

PART 2

Three questions, fully decoded

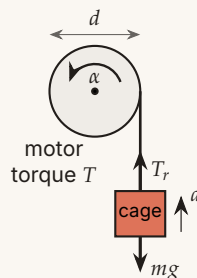
Each question below is original and written in exam style. Before the working, a decode panel shows steps 1 to 3. Cover the working and try each step yourself first.

2.1 Question 1: a hoist (rotation and translation together)

WORKED EXAMPLE Q1

EXAM STYLE: HOIST DRUM TORQUE AND POWER

A mine cage of mass 600 kg is raised by a rope wound on a drum of 0.8 m effective diameter. The drum has a mass of 250 kg and a radius of gyration of 0.3 m, and its bearing friction torque is 120 N m. The cage starts from rest and accelerates uniformly at 1.5 m/s^2 to 4 m/s. Ignore the rope's mass. Find (a) the rope tension, (b) the drum torque needed during acceleration, (c) the power at the end of acceleration, (d) the torque and power once the cage moves at a steady 4 m/s.



DEFINITION • DECODE: QUESTION 1

Given: $m = 600 \text{ kg}$; $r = 0.4 \text{ m}$ (radius, not diameter); $M = 250 \text{ kg}$, $k = 0.3 \text{ m}$; $T_f = 120 \text{ N m}$; $u = 0$; $a = 1.5 \text{ m/s}^2$; $v = 4 \text{ m/s}$.

Find: rope tension T_r (N); drum torque T (N m); power P (W); steady T and P .

Clues: “from rest”, “uniformly” (constant a); “steady” in part (d) (so $a = 0$ there).

Family: hoist. Two bodies, two laws: the cage moves in a straight line ($\Sigma F = ma$); the drum rotates ($\Sigma M = I\alpha$). The rope links them: $a = \alpha r$, $v = \omega r$.

WORKED EXAMPLE Q1

WORKING

(A) CAGE: NEWTON'S SECOND LAW, UPWARDS POSITIVE

The rope pulls up with T_r ; the weight mg pulls down; the resultant must give the cage its acceleration: $T_r - mg = ma \Rightarrow T_r = m(g + a) = 600(9.81 + 1.5) = 6786 \text{ N}$.

(B) DRUM: THE MOTOR TORQUE MUST SUPPLY THREE THINGS

(1) turn the rope against its tension, $T_r r$; (2) speed up the drum itself, $I\alpha$; (3) overcome friction, T_f .

$$I = Mk^2 = 250(0.3)^2 = 22.5 \text{ kg m}^2; \alpha = a/r = 1.5/0.4 = 3.75 \text{ rad/s}^2.$$

$$T = T_r r + I\alpha + T_f = 6786(0.4) + 22.5(3.75) + 120 = 2714.4 + 84.4 + 120 = 2918.8 \text{ N m}.$$

(C) POWER AT THE MOMENT THE CAGE REACHES 4 M/S

$$\omega = v/r = 4/0.4 = 10 \text{ rad/s}; P = T\omega = 2918.8 \times 10 = 29188 \text{ W}.$$

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WORKED EXAMPLE Q1 – CONTINUED

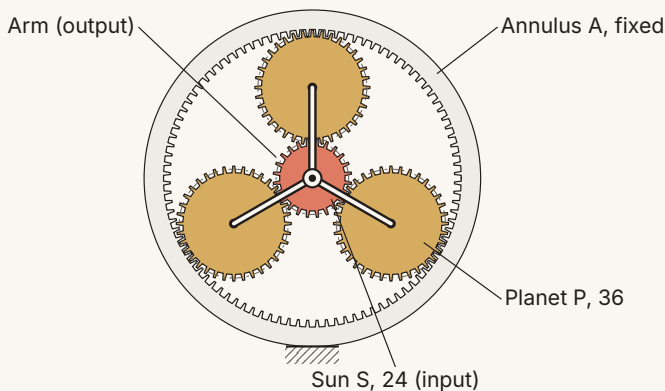
WORKING

(D) STEADY SPEED: $a = 0$, SO NO INERTIA TERMS

$$T_r = mg = 5886 \text{ N}; T = 5886(0.4) + 120 = 2474.4 \text{ N m}; P = 2474.4 \times 10 = 24744 \text{ W}.$$

(a) 6.79 kN; (b) 2.92 kN m; (c) 29.2 kW; (d) 2.47 kN m and 24.7 kW**CHECK**

Units: $\text{N} \times \text{m} = \text{N m}$; $\text{N m} \times \text{rad/s} = \text{W}$. Sense: accelerating needs more torque than steady running, as it should. The drum's own inertia adds only 84 N m: small here, but leaving it out still loses marks. Time to reach 4 m/s = $v/a = 2.67 \text{ s}$, over $v^2/2a = 5.33 \text{ m}$.

2.2 Question 2: an epicyclic gear train

WORKED EXAMPLE Q2

EXAM STYLE: SPEEDS AND HOLDING TORQUE

In the simple epicyclic train shown, the sun S has 24 teeth and each of the three planets P has 36 teeth; all gears have the same module. The annulus A is fixed. The sun is the input, receiving 8 kW at 1200 rev/min, and the arm is the output. The efficiency is 92%. Find (a) the number of teeth on the annulus, (b) the speed of the arm and of each planet, (c) the torque needed to hold the annulus.

DEFINITION • DECODE: QUESTION 2

Given: $t_S = 24$, $t_P = 36$; annulus fixed ($N_A = 0$); $N_S = +1200 \text{ rev/min}$ (take the sun's direction as +); $P_{\text{in}} = 8000 \text{ W}$; $\eta = 0.92$.

Find: t_A ; N_{arm} and N_P (rev/min); holding torque T_{fix} (N m) and its direction.

Family: epicyclic gears, because the planets ride on a moving arm. Simple tooth ratios do not work here. Use the **table method** for speeds and the **torque balance** $T_{\text{in}} + T_{\text{out}} + T_{\text{fix}} = 0$ for the holding torque.

WORKED EXAMPLE Q2

WORKING

(A) ANNULUS TEETH (SAME MODULE, SO DIAMETERS $\propto$ TEETH)

The annulus pitch diameter equals the sun's plus two planets': $t_A = t_S + 2t_P = 24 + 72 = 96$.

(B) TABLE: FIRST LOCK THE ARM AND TURN THE SUN +1 TURN

Sun to planet (external mesh) reverses: planet $-24/36$. Planet to annulus (internal mesh) keeps direction: annulus $-24/96 = -0.25$. Multiply by x , then add y to every column:

Condition	Arm	Sun	Planet	Annulus
Arm fixed, sun +1	0	+1	-0.6667	-0.25
Total ($\times x$, then $+y$)	y	$x + y$	$y - 0.6667x$	$y - 0.25x$

Annulus fixed: $y - 0.25x = 0$. Sun: $x + y = 1200$. So $1.25x = 1200$, $x = 960$, $y = 240$.
Arm = $y = 240$ rev/min (same direction as the sun). Planet = $240 - 0.6667(960) = -400$ rev/min.

(C) TORQUES

$T_{\text{in}} = \frac{60P}{2\pi N} = \frac{60 \times 8000}{2\pi \times 1200} = 63.66 \text{ N m}$ (positive: it drives in the sun's direction).

$P_{\text{out}} = 0.92 \times 8000 = 7360 \text{ W}$ at 240 rev/min: $T_{\text{out}} = \frac{60 \times 7360}{2\pi \times 240} = 292.8 \text{ N m}$. The load resists the arm's rotation, so $T_{\text{out}} = -292.8 \text{ N m}$.

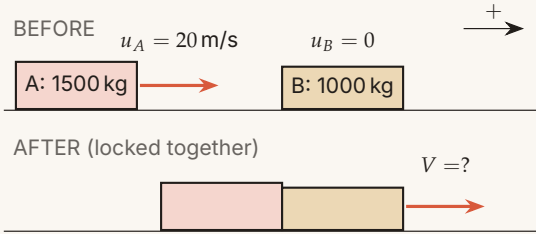
$T_{\text{fix}} = -(T_{\text{in}} + T_{\text{out}}) = -(63.66 - 292.85) = +229.2 \text{ N m}$.

(a) 96; (b) arm 240, planets -400 rev/min; (c) 229 N m, sun's sense

CHECK

Shortcut for this layout: $N_S/N_{\text{arm}} = 1 + t_A/t_S = 1 + 4 = 5$, and $1200/5 = 240$. The gearbox multiplies torque by $292.8/63.66 = 4.6 = 0.92 \times 5$ ($\text{MA} = \eta \times \text{VR}$). Assembly: $(t_S + t_A)/3 = 40$, a whole number, so three planets fit evenly.

2.3 Question 3: a collision (momentum, then energy)



WORKED EXAMPLE Q3

EXAM STYLE: IMPACT, ENERGY LOSS AND FORCE

A 1500 kg car A travelling at 72 km/h runs into the back of a 1000 kg car B standing at rest. The cars lock together, and the impact lasts 0.12 s. Find (a) their common speed just after impact, (b) the kinetic energy lost, (c) the average force between the cars during impact. (d) Repeat (a) if B had been moving towards A at 36 km/h.

DEFINITION • DECODE: QUESTION 3

Given: $m_A = 1500 \text{ kg}$, $u_A = 72/3.6 = 20 \text{ m/s}$; $m_B = 1000 \text{ kg}$, $u_B = 0$; contact time $t = 0.12 \text{ s}$; in (d), $u_B = -36/3.6 = -10 \text{ m/s}$ (opposite direction).

Find: common speed V (m/s); energy lost (J); average force F (N).

Clues: “lock together” means one common velocity after impact.

Family: impact. During the collision the cars push on each other with equal and opposite forces (Newton’s third law), so **total momentum is conserved**. Kinetic energy is **not** conserved: some becomes heat, sound and crushed metal. The force comes from **impulse = change of momentum**.

WORKED EXAMPLE Q3

WORKING

(A) CONSERVATION OF MOMENTUM (DIRECTION OF A POSITIVE)

$$m_A u_A + m_B u_B = (m_A + m_B) V \Rightarrow V = \frac{1500(20) + 1000(0)}{2500} = 12 \text{ m/s.}$$

(B) KINETIC ENERGY BEFORE AND AFTER

Before: $\frac{1}{2}(1500)(20)^2 = 300\,000 \text{ J}$. After: $\frac{1}{2}(2500)(12)^2 = 180\,000 \text{ J}$.

Lost: $300\,000 - 180\,000 = 120\,000 \text{ J} = 120 \text{ kJ}$ (40% of the original).

(C) IMPULSE ON CAR B

Impulse = change of B’s momentum = $m_B(V - u_B) = 1000(12 - 0) = 12\,000 \text{ N s}$.

$$F = \frac{\text{impulse}}{t} = \frac{12\,000}{0.12} = 100\,000 \text{ N.}$$

(D) B MOVING TOWARDS A: ITS VELOCITY IS NEGATIVE

$$V = \frac{1500(20) + 1000(-10)}{2500} = \frac{20\,000}{2500} = 8 \text{ m/s, in A's direction.}$$

(a) 12 m/s; (b) 120 kJ lost; (c) 100 kN; (d) 8 m/s

CHECK

Car A’s impulse is $1500(12 - 20) = -12\,000 \text{ N s}$: equal and opposite to B’s, as Newton’s third law requires. A head-on approach (d) gives a lower common speed, because the momenta partly cancel.

PART 3

Why plausible methods fail

Each mistake below looks reasonable and is common in exam scripts. Knowing why it fails is what stops you making it.

The tempting move	Why it fails
Using energy conservation <i>through</i> a collision	Energy is lost as heat, sound and deformation during impact. Only momentum is conserved there. Use energy only before or after the impact.
Treating the rope tension as mg while the load accelerates	mg is the tension only at constant speed. Accelerating upwards needs $m(g + a)$; slowing down needs $m(g - a)$.
Leaving out the drum's $I\alpha$	The drum is speeding up too. Its inertia needs torque, even though it does not move the load.
Using tooth ratios on an epicyclic train	The planets' axes move with the arm. Ratios only hold relative to the arm, so you need the table method.
Reversing direction at the planet–annulus mesh	An internal (annulus) mesh does <i>not</i> reverse direction. Only external meshes do.
Giving a holding torque without its direction	The mounting must resist it in a particular sense. Without the direction, the answer is incomplete.
Putting the angle of lap in degrees into $e^{\mu\theta}$	The formula was derived with θ in radians. Degrees give a huge, wrong ratio.
Using $T_{\max}$ as T_1 when belt mass is given	Part of the safe tension is used up by centrifugal tension. Use $T_1 = T_{\max} - mv^2$.
Adding mr values as plain numbers when balancing	Each mr points in the direction of its mass. They are vectors: add their components.
Leaving N in rev/min inside $T\omega$ or $\omega^2 r$	These need rad/s. Use $\omega = 2\pi N/60$.

PART 4

Practice test

Four original practice questions from four more topic families. Decode each one first (given, find, clues, family), then solve. Allow about an hour, then mark your work with the answers that follow.

PRACTICE • WORKED ANSWERS FROM PAGE 11

P1 BELT DRIVE An open flat-belt drive has two equal pulleys 400 mm in diameter, so the angle of lap is 180° . The driving pulley turns at 900 rev/min, $\mu = 0.3$, and the greatest safe belt tension is 1.5 kN. (a) Ignoring the belt's mass, find the power the belt can transmit. (b) Repeat (a) if the belt has a mass of 0.5 kg per metre.

P2 STATIC BALANCING Three masses rotate in one plane on a shaft: 5 kg at 120 mm radius at 0° , 4 kg at 150 mm at 120° , and 3 kg at 100 mm at 225° (angles measured from the first mass). Find the balancing mass needed at 150 mm radius, and its angle. What rotating force would the bearings feel at 500 rev/min without it?

P3 PILE DRIVER A 500 kg hammer falls freely through 3 m onto a 300 kg pile. The hammer does not rebound, and the pile is driven 80 mm into the ground. Find the common velocity just after impact, the energy lost in the impact, and the average resistance of the ground.

P4 PLATE CLUTCH A single-plate clutch has both sides effective. The friction faces have outer and inner diameters of 280 mm and 160 mm, the axial spring force is 2.5 kN, and $\mu = 0.3$. Assuming uniform wear, find the torque and the power it can transmit at 1600 rev/min.

Worked answers

If your method is different but correct, your answer will agree to about 3 significant figures. Compare your *decode* with ours as well as the numbers.

P1 Family: belt friction; the belt is about to slip, so $T_1/T_2 = e^{\mu\theta}$ with $\theta = \pi$ rad.

$$v = \pi dN/60 = \pi(0.4)(900)/60 = 18.85 \text{ m/s}; e^{\mu\theta} = e^{0.3\pi} = 2.566.$$

$$(a) T_1 = 1500 \text{ N}, T_2 = 1500/2.566 = 584.5 \text{ N}; P = (T_1 - T_2)v = (915.5)(18.85) = 17.3 \text{ kW}.$$

$$(b) T_c = mv^2 = 0.5(18.85)^2 = 177.7 \text{ N}, \text{ so the usable tight-side tension is } T_1 = 1500 - 177.7 = 1322.3 \text{ N}.$$

$$T_2 = 1322.3/2.566 = 515.3 \text{ N}; P = (1322.3 - 515.3)(18.85) = 15.2 \text{ kW}. \text{ The belt's own mass costs about 12\% of the power at this speed.}$$

P2 Family: static balancing, one plane, so $\Sigma mr = 0$ as a *vector* sum. Work in kg m by components.

$$x: 0.600 \cos 0^\circ + 0.600 \cos 120^\circ + 0.300 \cos 225^\circ = 0.600 - 0.300 - 0.2121 = 0.0879.$$

$$y: 0 + 0.600 \sin 120^\circ + 0.300 \sin 225^\circ = 0.5196 - 0.2121 = 0.3075.$$

$$\text{Resultant} = \sqrt{0.0879^2 + 0.3075^2} = 0.3198 \text{ kg m at } \tan^{-1}(0.3075/0.0879) = 74.1^\circ.$$

$$\text{The balancer must be equal and opposite: } m_b(0.150) = 0.3198, \text{ so } m_b = 2.13 \text{ kg at } 74.1^\circ + 180^\circ = 254.1^\circ.$$

$$\text{Unbalanced force} = (\Sigma mr)\omega^2 = 0.3198(2\pi \times 500/60)^2 = 0.3198(52.36)^2 = 877 \text{ N, rotating with the shaft.}$$

P3 Family: three stages, three principles: fall (energy), impact (momentum), penetration (work-energy).

$$\text{Fall: } v = \sqrt{2gh} = \sqrt{2(9.81)(3)} = 7.672 \text{ m/s}.$$

$$\text{Impact: } 500(7.672) = 800V, \text{ so } V = 4.80 \text{ m/s}.$$

$$\text{Energy lost} = 500(9.81)(3) - \frac{1}{2}(800)(4.795)^2 = 14715 - 9197 = 5518 \text{ J} (= m/(M+m) = 3/8 \text{ of the energy before impact}).$$

$$\text{Penetration: the ground resistance } R \text{ does work against the motion while gravity still helps: } (R - 800g)(0.08) = 9197, \text{ so } R = 114961 + 7848 = 122.8 \text{ kN}.$$

P4 Family: plate clutch, uniform wear (a worn-in clutch), $n = 2$ because both sides work.

$$\text{Mean radius } R = (r_1 + r_2)/2 = (0.140 + 0.080)/2 = 0.110 \text{ m (radii, in metres).}$$

$$T = n\mu WR = 2(0.3)(2500)(0.110) = 165 \text{ N m}; P = 2\pi NT/60 = 2\pi(1600)(165)/60 = 27.6 \text{ kW}.$$

Check: the uniform-pressure assumption gives $R = 0.1127 \text{ m}$ and $T = 169 \text{ N m}$, only 2% more. Uniform wear is the safer (lower) value.

Exam-room checklist

- ☐ I listed every given quantity in SI units: $\text{km/h} \div 3.6$; $\text{rev/min} \times 2\pi/60$; $\text{mm} \div 1000$; degrees $\times \pi/180$.
- ☐ I marked the clue words: from rest, uniformly, steady, lock together, fixed, on the point of slipping.
- ☐ I drew a sketch with a chosen positive direction, and each body separately.
- ☐ I named the family and wrote the principle in words before the formula.
- ☐ I rearranged in symbols before putting numbers in.
- ☐ I gave every answer a unit, and every force or torque a direction.
- ☐ I checked the size, and used a second route where one exists.

Your next step

WHAT COMES NEXT

You can now decode a Mechanics of Machines question, pick its governing principle, and solve hoist, epicyclic, collision, belt, balancing, pile-driver and clutch problems at starter level.

Still ahead in the Module II papers: compound and reverted gearboxes, V-belts and the number of belts needed, cone and centrifugal clutches and time of slip, balancing in several planes and bearing loads, vehicle tractive effort, braking and cornering, kinematics, moments of inertia, and plane motion. Several papers also ask for derivations, such as $T_1/T_2 = e^{\mu\theta}$ and $T = \mu WR$, which this starter does not cover.

Want the full picture? The complete **SomaReady Mechanics of Machines Revision Guide** (38 pages) covers all nine outline topics in the same decode-and-solve style, with the derivations, 42 original examples and worked answers to every practice question. **Price: KSh 249** (launch price). **Get it at:** [LINK – to be confirmed].

About this guide. All explanations, questions and diagrams are original SomaReady material; no KNEC question is reproduced. Every numerical answer was checked by an independent calculation. Topic counts come from 12 Module II papers and describe that sample only. SomaReady is an independent educational publisher; this guide is not produced, approved or endorsed by the Kenya National Examinations Council and does not guarantee any examination result. You may share this free guide unchanged. © 2026 SomaReady. MOM Exam Question Decoder, Free Edition 1.