Worked example:

1) A gearbox in second gear has a ratio of 2.31:1. The engine torque is 126 Nm and the output torque to the propeller shaft is 287 Nm. Calculate the mechanical efficiency of the gearbox in second gear.

η_{g2} = [(output torque) / (input torque x i_{g2})] x 100

= [287 / (126x 2.31)] x 100

= 98.6 %

2) An engine is developing 63 kW power at an engine speed of 2900 rev/min. Third gear of ratio 1.9:1 is engaged, and the final drive ratio is 4.53:1. If the rolling radius of the road wheels is 0.43 m, determine the tractive effort available if the transmission efficiency is 87%.

$T_e = (P_b \times 1000 \times 60) / (2\pi \times Ne) \cong 9550\, P_b / N_e$

$= (9550 \times 63) / 2900 = 207.47$ Nm

$TE = T_w / R_w = (T_e \times i_{g3} \times i_f \times \eta_t) / R_w = (207.47 \times 1.9 \times 4.43 \times 0.87) / 0.34$

= 4568 N = 4.568 kN

3) A vehicle in second gear, which has the ratio 2.68:1, is producing a torque of 1260 Nm at the half-shafts. The two litre four-stroke engine is developing bemp of 790 kN/m^2. Assuming a transmission efficiency of 79%, determine the final drive reduction ratio.

$T_e = bemp \times LAn / 4\pi = bemp \times V_e / 4\pi = 790 \times 10^3 \times 0.002 / 4\pi = 125.7$ Nm

$T_w = T_e\, i_g\, i_f\, \eta_t$

$i_f = T_w / (T_e\, i_g\, \eta_t) = 1260 / (125.7 \times 2.68 \times 0.79) = 4.73{:}1$

4) A vehicle in first gear is set in motion by a tractive effort of 3.6 kN applied by the driving road wheels which have a rolling diameter of 0.72 m. The final drive and gearbox ratios are 4.56:1 and 3.41:1 respectively. The engine was developing 47 kW power and the overall transmission efficiency was 89%. Calculate the running speed of the engine in rev/min.

$TE = T_w / (1000 \times R_w) = (T_e\, i_g\, i_f\, \eta_t) / (1000 \times R_w)$

and $T_e = (TE \times 1000 \times R_w) / (i_g\, i_f\, \eta_t) = (3.6 \times 10^3 \times 0.36) / (3.41 \times 4.56 \times 0.89)$

$= 93.64$ Nm

$Pb = Te\ Ne\ /9550$

and $N_e = 9550\ P_b / T_e = (9550 \times 47) / 93.64 = \underline{4793.36 \text{ rev/min}}$

5) The torque developed by an engine is 82 Nm at 2000 rev/min. The final drive ratio is 4.73:1. In top gear the inside road wheel is making 60 rev/min. Calculate the torque and power at the inner and outer driving wheels.

$P_b = T\ N\ \eta_t / 9550 = 82 \times 2000 \times 1 / 9550 = 17.17$ kW

$T_w = T_e\, i_g\, i_f \eta_t = 82 \times 1 \times 4.73 \times 1.00 = 387.86$ Nm

$T_{wo} = T_{wi} = T_w / 2 = 387.86 / 2 = \underline{193.93 \text{ Nm}}$

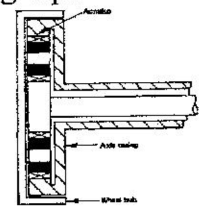
$N_c = N_e\ / (i_g\ i_f) = 2000 / (1 \times 4.73) = 422.8$ rev/min

$N_o = N_c \times 2 - N_i = 4228.8 \times 2 - 60 = 785.6$ rev/min

$P_{wi} = T_{wi} N_{wi}\ / 9550 = 193.93 \times 60 / 9550 = \underline{1.22 \text{ kW}}$

$P_{wo} = T_{wo} N_{wo}\ / 9550 = 193.93 \times 785.61 / 9550 = \underline{15.95 \text{ kW}}$

6) A hub reduction unit consists of epicyclic gearing. The sun pinion has 23 teeth and the plants 11 teeth each. The planet carrier drives the hub and road wheel. If the sun is making 162 rev/min, at what speed are the road wheels being driven if the vehicle is moving in a straight path?



$a = s + 2\,p = 23 + 2 \times 11 = 45$ teeth

reduction ratio $(i_w) = (a+s) / s = a / s + 1 = 45/23 + 1 = 2.956:1$

$N_C = N_S / i_w = 162 / 2.956 = \underline{54.8 \text{ rev/min}}$

7) A single-plate clutch of 0.15 m effective diameter is lined with material of coefficient 0.35. If the total spring force is 2.5 kN, calculate:
(a) the torque transmitted
(b) the power transmitted at 3000 rev/min.

(a) $T = \mu\, F_n\, r_m\, n = 0.35 \times 2500 \times 0.075 \times 2 = \underline{131.25 \text{ N m}}$

(b) $P_b = T\ N / 9550 = 131.23 \times 3000 / 9550 = \underline{41.23 \text{ kW}}$

8) A six-cylinder engine running under full load conditions develops maximum torque at 1500 rev/min when the power is 22 kW. Calculate:
(a) The torque transmitted by the clutch.
(b) The force exerted by each of the eight springs if the clutch is a single-plate type. The friction surfaces are 0.25 m outside diameter and 0.18 m inside diameter, and the coefficient of friction is 0.32.

(a) $T = 9550\ P_b / N = 9550 \times 22 / 1500 = \underline{140 \text{ N m}}$

Note: To allow for wear of the friction lining material and the lowering of the coefficient of friction between the contact surfaces due to the presence of oil or a high temperature, motor vehicle clutches are usually designed to have a torque capacity about 1.5 times the maximum torque of the engine. Thus, in practice, the maximum capacity of the clutch would be equal to:

$T_{max} = T \times 1.5 = 140 \times 1.5 = \underline{210\ N\,m}$

b) The mean radius $R = (r_1+r_2) / 2 = (0.125 + 0.09) / 2$

$= 0.1075$ m

$T_{max} = \mu\ 8W\ n\ R$

$8W = T_{max} / \mu\ n\ R = 210 / (0.32 \times 2 \times 0.1075)$

$= 3052.33$ N

$W = 3052.33 / 8 = \underline{381.54\ N}$

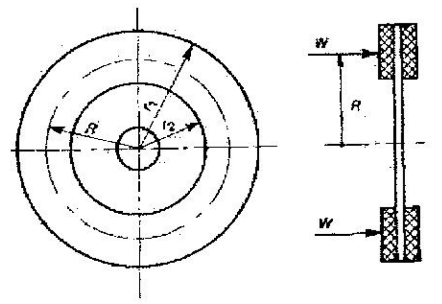
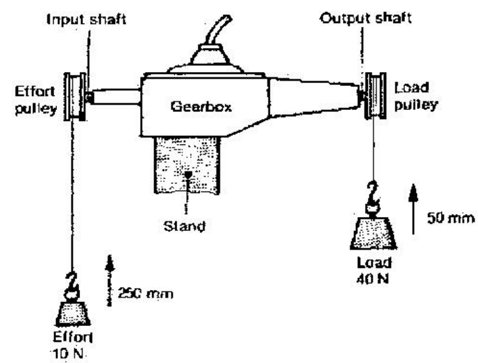


Figure Forces acting on a single-plate clutch

9) A test gearbox was arranged with a pulley on the input shaft and another pulley of the same diameter on the output shaft. With second gear selected, it was found that a load of 40 N was raised 50 mm by applying an effort of 10 N moving through 250 mm. Calculate the efficiency of the gearbox in second gear.



Input work = Output work + Friction work

Gearbox efficiency (η_{g2}) = Output work / Input work

$= (50 \times 40) / (10 \times 250)$

$= 200 / 250 = \underline{80\ \%}$

10) A gearbox is driven in second gear. The constant-mesh pinions A and B have 15 and 32 teeth respectively. The second gear pinion D on the mainshaft has 30 teeth and meshes with tht layshaft gear C having 16 teeth. Calculate:

(a) the second gear ratio

(b) the propeller shaft speed for an engine speed of 4000 rev/min.

(a) $i_{g2} = (N_B / N_A) \times (N_D / N_C) = (32/15) \times (30/16) = \underline{4:1}$

(b) $N_p = N_e / i_{g2} = 4000 / 4 = \underline{1000\ rev/min}$.

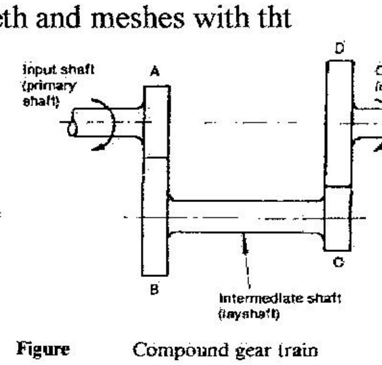


Figure Compound gear train

11) The rear axle of a motor vehicle is fitted with a crown wheel which has 72 teeth and the corresponding bevel pinion has 17 teeth. Determine the rear-axle reduction ratio.

$i_f = N_C / N_P = 72 / 17 = \underline{4.235:1}$

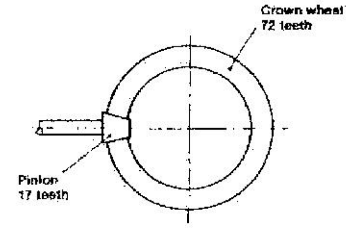


Figure Rear drive layout (bevel pinion and crown wheel)

12) A vehicle has a third gear ratio of 1.5 to 1 and a rear-axle ratio of 4.5 to 1.
Calculate:
(a) the overall gear ratio
(b) the number of revolutions made by the crown wheel per minute if the engine speed is 2700 rev/min.

(a) Over all gear ratio (i_t) = $i_g \times i_f = 1.5 \times 4.5 = \underline{6.75:1}$

(b) $N_w = N_e / i_t = 2700 / 6.75 = \underline{400 \text{ rev/min.}}$

13) A car has one of its rear wheels jacked up clear of the ground. With top gear engaged, the engine is turned by had and it is found to make 11 turns while the jacked-up rear wheel turns 4 times. With first gear engaged, 19 turns of the engine correspond to 2 turns of the road wheel. Assuming direct drive through the gearbox in top gear, calculate:
(a) the rear-axle ratio
(b) the first gear ratio of the gearbox.

(a) $i_f = (N_e \times 2) / N_w = (11 \times 2) / 4 = \underline{5.5:1}$

(b) $i_t = (N_e \times 2) / N_w = (19 \times 2) / 2 = 19:1$

$i_g = i_t / i_f = 19 / 5.5 = \underline{3.455:1}$

14) A motor vehicle gearbox has a first gear ratio of 3.75 to 1. The input shaft of the gearbox runs at 2400 rev/min with an input torque of 150 N m. The efficiency of the gearing is 80%.
Calculate:
(a) the speed of the output shaft
(b) the output torque.

(a) $N_o = N_i / i_g = 2400 / 3.75 = \underline{640 \text{ rev/min.}}$

(b) $T_o = T_i \times i_g \times \eta_{g1} = 150 \times 3.75 \times 0.80 = \underline{450 \text{ N m}}$

15) An engine develops a torque of 104 Nm at 2500 rev/min and drives through a gearbox having constant-mesh gears of 15 and 30 teeth respectively. The second gearwheel on the mainshaft has 36 teeth and the meshing pinion has 18 teeth. The rear-axle ratio is 5 to 1 and the effective radius of the tires is 0.42 m. It the overall transmission efficiency is 85 per cent, calculate:
(a) the speed of the vehicle in second gear.
(b) the torque in each half-shaft

(a) $i_{g2} = (n_i / n_I) \times (n_2 / n_o) = (30 / 15) \times (36 / 18) = 4:1$

$N_w = N_i / (i_g\, i_f) = 2500 / (4 \times 5) = 125 \text{ rev/min}$

$v = 2\pi\, r_w\, N_w \times 60 / 1000 = 0.377\, N_w\, r_w = 0.377 \times 125 \times 0.42 = \underline{19.8 \text{ km/h}}$

(b) $T_w = T_e \times i_g\ i_f \times \eta = 104 \times 4 \times 5 \times 0.85 = 1768 \text{ N m}$

$T_{one\ wheel} = T_w / 2 = 1768 / 2 = \underline{884 \text{ N m}}$