FACTFILE:

GCE TECHNOLOGY & DESIGN

1.20 MECHANISMS CALCULATIONS: PART 1

Rewarding Learning

Mechanisms calculations

Learning outcomes

Students should be able to:

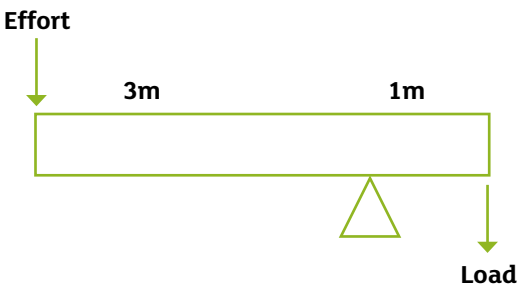
- Use given data and information to complete calculations for:
  - mechanical advantage and velocity ratio;
  - efficiency;
  - moments; and
  - simple and compound velocity ratios and transmission speeds for gears; pulleys and chains and sprockets.

Mechanical Advantage and Velocity Ratio.

Most mechanisms will provide mechanical advantage (MA), which means that you can move a large load with a small effort. The formula for working out mechanical advantage is:

MA = Load IN / Effort 3N

The MA of the lever is **3/1 = 3**



If you are looking at how far your load has moved with the effort that has been applied to it, then this can be achieved by comparing the two distances known as velocity ratio or VR. The formula for working out velocity ratio is:

VR = distance moved by effort / distance moved by load

For the lever shown the effect will always move three times further than the load so V =3/1 = 3 or 3.1.

Efficiency

There will always be energy losses in any machine so reducing its efficiency. As parts become bent, twisted, or rub against each other creating friction and wear, the mechanism may become less efficient. The efficiency of a mechanism can be worked out by using the following formula:

Efficiency = MA / VR x 100%

For example, a mechanism with a MA of 3 and a VR of 5 the efficiency would be worked out as follows:

Efficiency = 3 / 5 x 100% = 60%

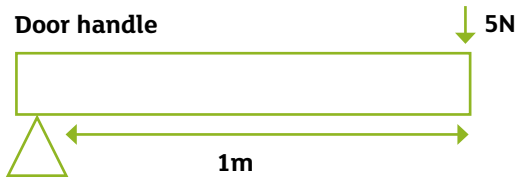
Moments

Moments make things turn or rotate as a result of forces that are applied to an object. Forces enable the turning motion which is either clockwise or anti-clockwise. The larger the force causing the moment the larger the moments will be. The greater the distance between the force and the fulcrum, the larger the moment. To work out a moment we use the following formula:

Force = Moment / Distance

The force is measured in **Newtons (N)**, the distance is measured in either **metres (m)** or **centimetres (cm)**. If the distance is measured in cm the moment will be measured in **Ncm**. Therefore if the distance is measured in m then the moment is measured in **Nm**.

An example of working out a moment can be seen below:



F = M x D
5N = ? x 1m
M = 5N / 1m
M = 5Nm

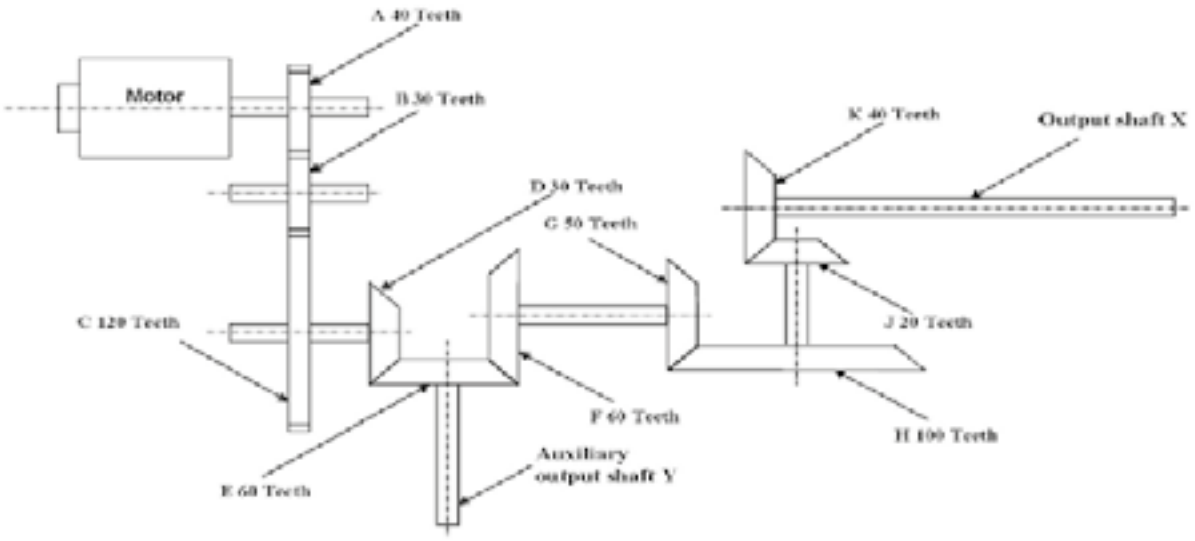
Simple & Compound Velocity Ratios & Transmission Speeds – Gears, Pulleys and chains & Sprockets

The velocity ratio for two gears is given by;
Velocity ratio = number of driven gear teeth/number of driving gear teeth.

For a compound gear system where a number of gears are connected the velocity ratio is given by;
Velocity ratio = product of number of driven teeth/ product of number of driving teeth

Worked example 1

Consider the gear based transmission system shown below.



In order to calculate the overall velocity ratio of the gear based transmission system.

$$\text{Velocity Ratio} = \frac{\text{Number of teeth on driven}}{\text{Number of teeth on driver}}$$

Therefore to calculate VR of A-C we must work out A-B then multiply it by the VR of B-C as shown below:

VR of A-B =	30/40	= 0.75
VR of B-C =	120/30	= 4
Therefore, VR of A-C =	0.75 x 4	= 3

The VR for the remaining sets of gears within the system are listed below:

VR A-C=3
VR D-F=2
VR G-H=2
VR J-K=2

Therefore, the total VR of the system = 3×2×2×2=24

Total VR=24

Worked example 2

One rotation on output shaft X produces a linear movement of 20cm on the conveyor mat. Calculate the linear distance moved by a passenger during 20 seconds of operation if the motor rotates at 360 rev/min.

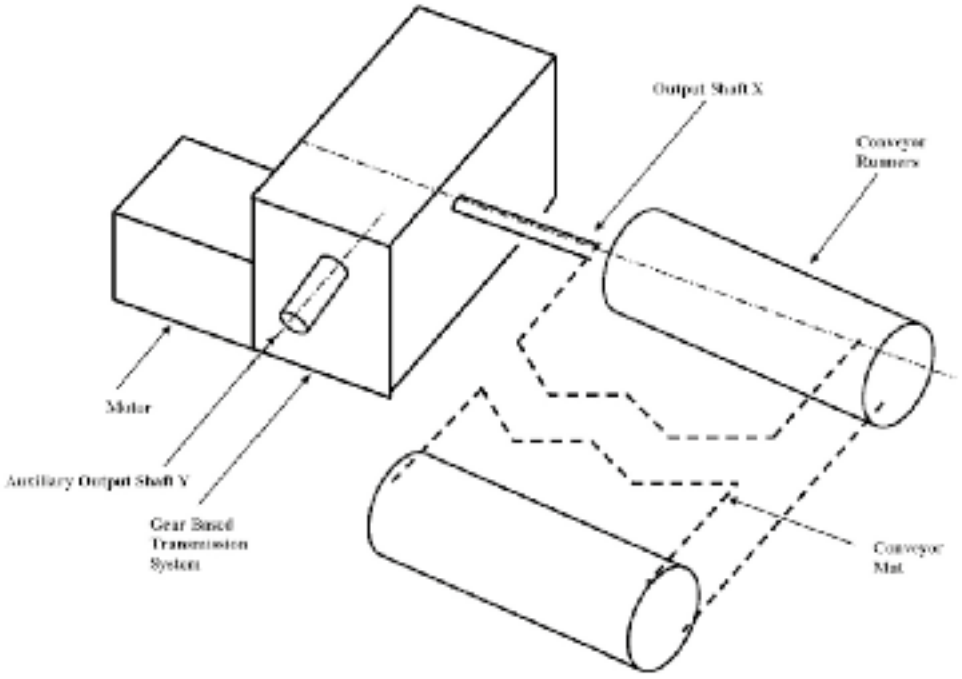
Output speed = Input speed / VR

360/24=15 rev/min

5 revs in 20s

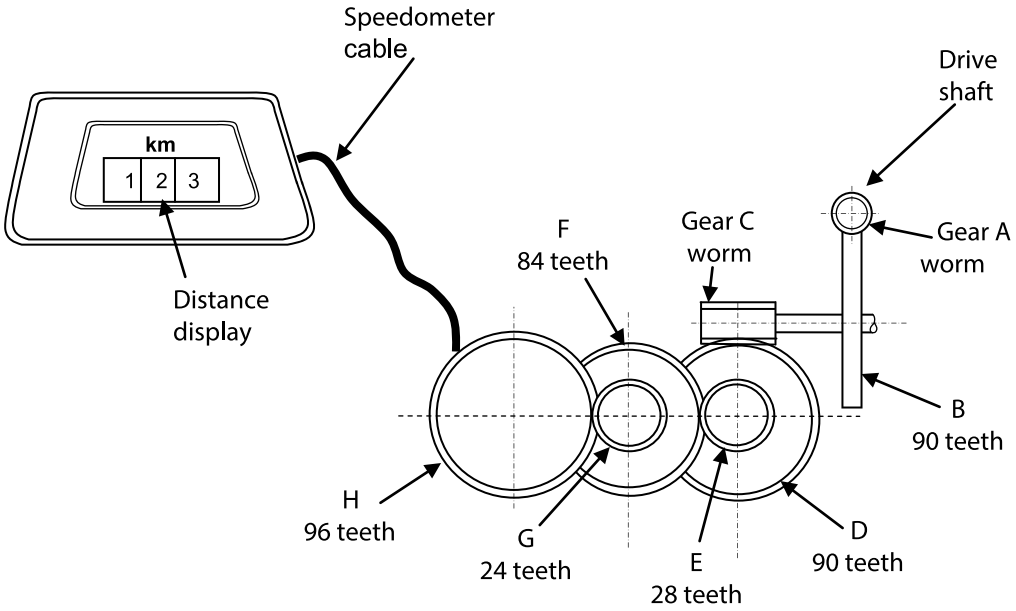
5×20=100cm

Linear distance =100cm



Worked example 3

Calculate the velocity ratio from gear **A** to gear **H**.



$$\text{Velocity Ratio} = \frac{\text{Number of teeth on driven}}{\text{Number of teeth on driver}}$$

$$\text{VR} = \frac{90}{1} \times \frac{90}{1} \times \frac{84}{28} \times \frac{96}{24} = 97200$$

Pulleys

$$\text{Velocity ratios for pulleys} = \frac{\text{diameter of the driven pulley}}{\text{diameter of the driver pulley}}$$

$$= \frac{\text{rotary velocity of driver pulley}}{\text{rotary velocity of driven pulley}}$$

Pulley shaft rotary velocities can be calculated using the formula below:

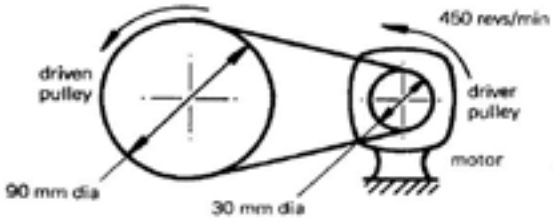
Rotary velocity of driven pulley x diameter of driven pulley
= Rotary velocity of driver pulley x diameter of driver pulley.

Therefore, rotary velocity of driven pulley =

$$\frac{\text{Rotary velocity of driver pulley x diameter of driver pulley}}{\text{diameter of driven pulley}}$$

Worked example 4

A 30mm diameter driver pulley is attached to a motor which rotates at 450 rev/min (see diagram) by means of a belt. The motor drives a driven pulley of 90mm diameter. What is the rotary velocity of the driven pulley?



Rotary velocity of driven pulley

$$= \frac{\text{rotary velocity of driver pulley x diameter of driver pulley}}{\text{diameter of driven pulley}}$$

$$= \frac{450 \text{ x } 30 \text{ rev/min}}{90}$$

Therefore, rotary velocity of driven pulley = 150 rev/min.

Worked example 5

A motor pulley has a diameter of 40mm and is driving a machine pulley of diameter 20mm. If the motor driver pulley rotates at 100 revs/min, what is the rotary velocity of the driven machine pulley?

$$\text{Velocity ratio} = \frac{\text{diameter of driven pulley}}{100 / 0.5 = 200 \text{ rev/min}} = 20/40 = 1/2$$

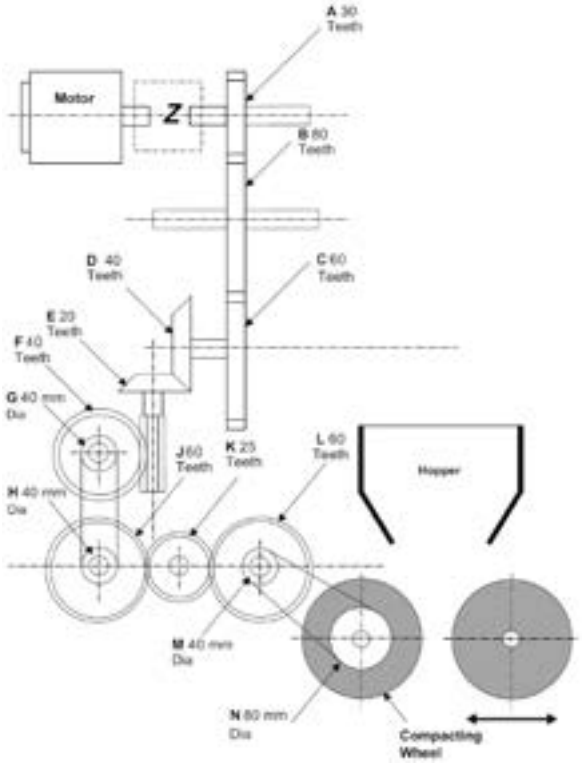
Velocity of driven pulley = Velocity of driver pulley / velocity ratio

= 100 / 0.5 = 200 rev/min

Gears and Pulleys Combined

Worked example 6

The diagram below shows part of a prototype industrial waste compactor.
The waste falls down from the hopper and is crushed between the compacting wheels.



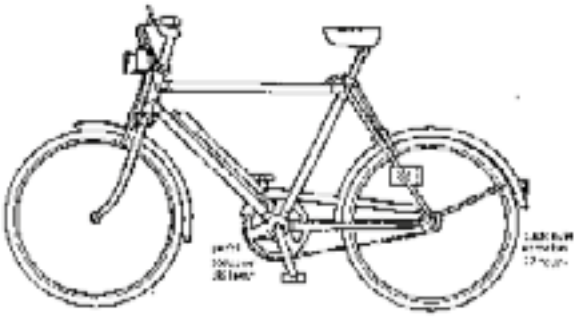
Calculate the overall velocity ratio between A and N.

VR from A-C	= 2
VR from D-E	= 0.5
Wormwheel	= 40
VR from G-H	= 1
VR from J-L	= 1
VR from M-N	= 2
Total VR	= 2 x 0.5 x 40 x 1 x 1 x 2 = 8

Chain and sprockets

Worked example 7

The bicycle shown has a driver sprocket (pedal sprocket) with 36 teeth. If the pedal sprocket is rotated through one revolution, how many times does the back wheel go round? What is the velocity ratio of the sprocket and chain mechanism?



If the driver sprocket turns one revolution, then 36 teeth mesh with the chain in one revolution. Because the driver sprocket and driven sprocket are connected with chain, 36 teeth on the driven sprocket must mesh with the chain. The driven sprocket only possesses 12 teeth, therefore it must revolve 3 times for every 1 revolution of the driver sprocket.

Worked example 8

The engine sprocket of a racing kart has 9 teeth and the sprocket positioned on the back axle has 72 teeth. If the engine rotates at 4800 rev/min, calculate the rotary velocity of the back axle.

Rotary velocity of back axle

$$= \frac{\text{rotary velocity of driver sprocket x number of teeth on driver sprocket}}{\text{number of teeth on driven sprocket}}$$

$$= \frac{4800 \times 9}{72} = \frac{4800 \text{ rev/min}}{8}$$

Therefore, rotary velocity of the back axle = 600 rev/min.