Biomechanics

Third Stage/ Biomaterials Engineering and prosthesis Branch

Presented By

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Lecture Four
Movement Analysis
Levers

Levers- The basics

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- **The Law of the Lever**

The cross product of force and distance is **torque**. The cross product is the mathematical process between two vectors that results in a vector perpendicular to both of the initial vectors. The **law of the lever** is also known as the law of moments and equates clockwise torques and counterclockwise torques. The equation here shows the law of levers:

$$F_1 d_1 = F_2 d_2$$

Where:

F1: is force1 (load).

d1 : is the distance from the fulcrum to **force 1 is applied**.

F2 : is force 2 (effort).

d2 : is the distance from the fulcrum to **force 2 is produced**.

<u>Mechanical Advantage (M.A)</u>

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- ❖ Mechanical advantage measures the **efficiency** of a lever (how easy it is to lift the load).
- ❖ The mechanical advantage of levers may be determined using the following equations:

$$\textbf{Mechanical advantage} = \frac{\textbf{Load (resistance)}}{\textbf{Effort (force)}}$$

Or

$$\textbf{Mechanical advantage} = \frac{\textbf{Length of force (arm)}}{\textbf{Length of resistance (arm)}}$$

It has <u>no unit</u>

Mechanical Advantage (M.A)

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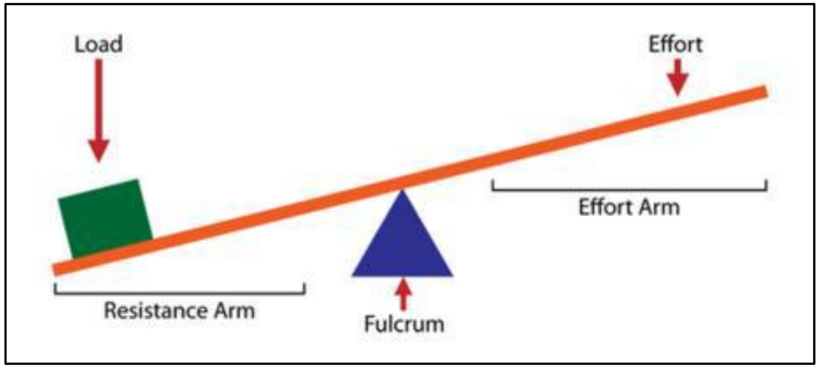
- The advantage depends on the distance between the **effort** and the **fulcrum** (**effort arm**) compared with the distance between the **load** (resistance) and the **fulcrum** (**resistance arm**).



Resistance arm = Distance between the **Load** and the **fulcrum**.

Effort arm = Distance between the **effort** and the **fulcrum**.

Mechanical Advantage (M.A)

❖ **Mechanical Advantage has three value :**

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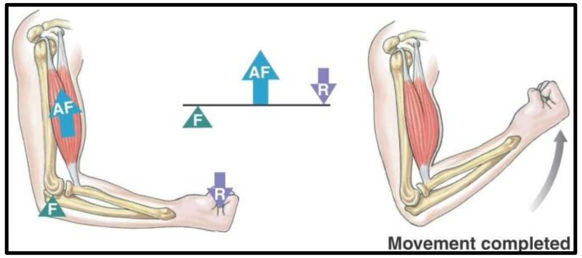
Load < Effort	Load = Effort	Load > Effort
⇩	⇩	⇩
M.A < 1	M.A = 1	M.A >1

❖ Mechanical advantage –Rule 1

- When the **effort** arm is **shorter** than it's **load** arm it has a **low** mechanical advantage.
-A **short effort** arm allows **fast movement** of the load over a **large range of movement**.
-**Third class levers always have a low mechanical advantage** E.g. Bicep curl, rowing



➢ **Examples from sport**

- Third and most 1st class lever have a **shorter effort arm** and longer resistance arm. This means a wide **range of movement** is produced and movements are done at higher **speed**.

Mechanical Advantage (M.A)

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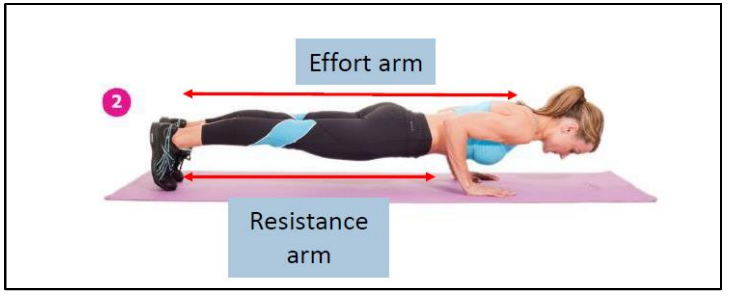
❖ **Mechanical advantage –Rule 2**

- When the **effort** arm is **longer** than it's **load** arm it has a **high** mechanical advantage.

-This means **heavy loads** can be lifted with **little effort.**

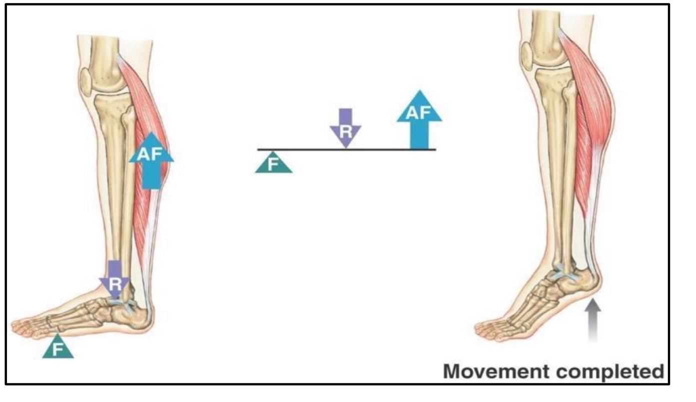
- **Second class levers always have a high mechanical advantage**



➢ **Examples from sport**

E.g. Standing on tip toes, or performing a press up.

- The gastrocnemius can easily create enough force to move the whole weight of the body upwards.



Exercises

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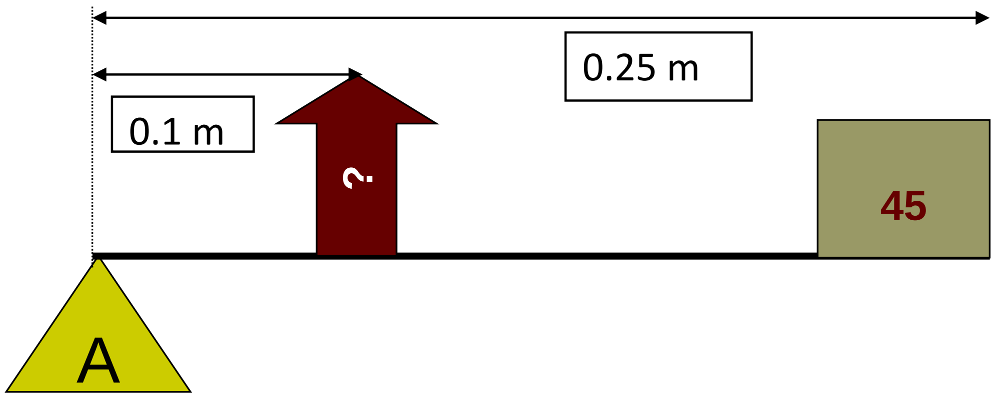
Ex.1: For the following figure how much force needs to be produced to move 45 kg when the length of resistance arm is 0.25 m and the length of effort arm is 0.1 m? With explain the class of this lever?

Solution: Third class lever



$$F_1 d_1 = F_2 d_2$$

$45*0.25=F_2*0.1$

$F_2 = 112.5$ Kg

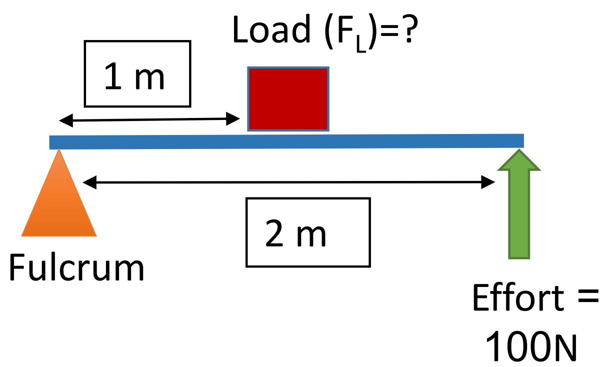
Ex.2: **for the following figure find the following:**

1. **Fulcrum, Effort, Load.**
2. **The class of lever.**
3. **if the force produced was 100 N calculated the force applied with take the distance as following =1m and =2m ?**
4. **calculated the mechanical advantage?**

Solution:

1. Fulcrum= Ankle joint
   Effort= Gastrocnemius
   Load= Body
2. Second class lever
3. $F_L * d_L = F_e * d_e$

$F_L * 1 = 100 * 2 \rightarrow F_L = 200$ N



$$4.\ M.A = \frac{\text{Length of Force}}{\text{Length of Resistance}}$$

$$M.A = \frac{2\ m}{1\ m} = 2$$

<u>Ex.3</u>: for the following figure find F_e and explain the class of lever?

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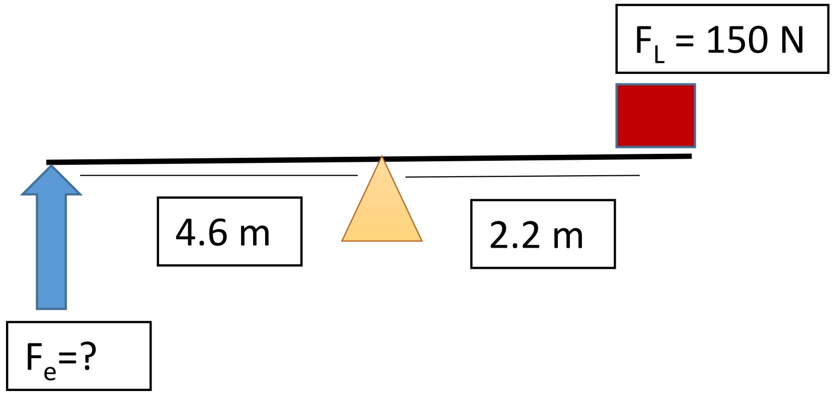
<u>Solution:</u>



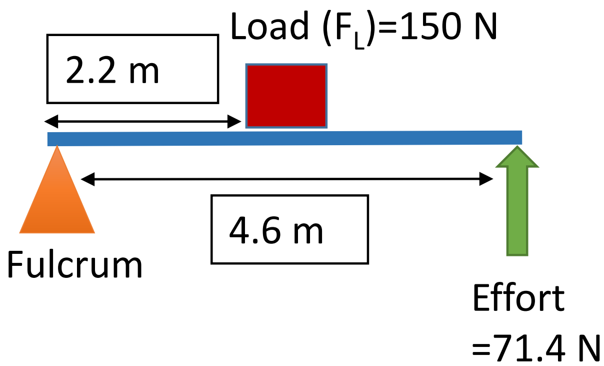
$$M.A. = \frac{\text{length of force(effort)}}{\text{length of resistance (load)}}$$

$$M.A. = \frac{4.6\ m}{2.2 m} = 2.1$$ (Second class lever)

$$[F_L * d_L = F_e * d_e\ ] \div d_L$$

$$[F_L = M.A.\ * Fe] \div M.A.$$

$$Fe = \frac{F_L}{M.A.} = 71.4\ N$$



Ex.4: for the following figure find F_L and explain the class of lever?

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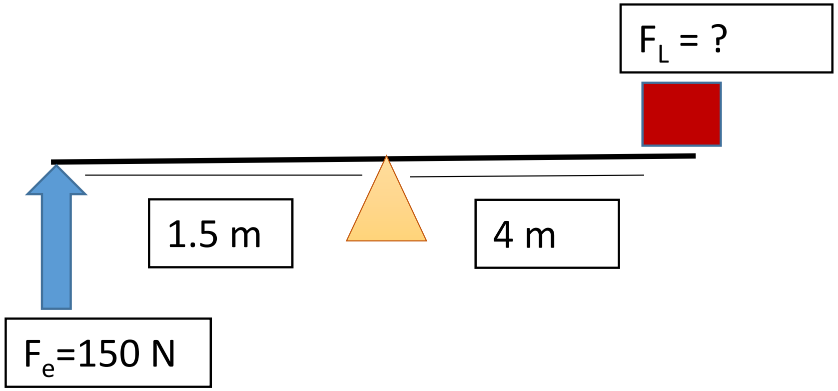
Solution:



$$M.A. = \frac{\text{length of force(effort)}}{\text{length of resistance (load)}}$$

$M.A. = \frac{1.5}{4} = 0.375$

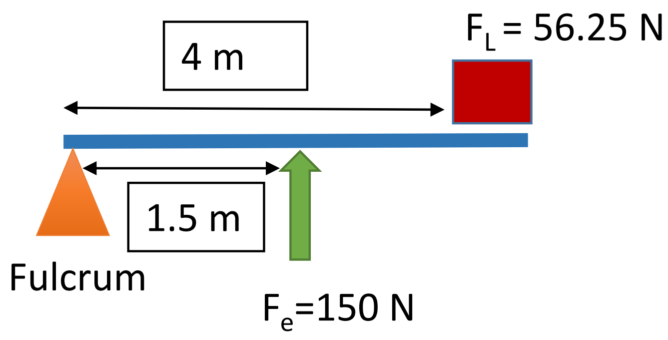
M.A. < 1 third class lever

$[F_L * d_L = F_e * d_e] \div d_L$

$F_L = M.A. * Fe$

$F_L = 0.375 * 150$

$F_L = 56.25$ N



The End of Lecture