TECHNISCHE UNIVERSITÄT WIEN
Vienna | Austria

ILSB Biomechanics

INTRODUCTION TO BIOMECHANICS 317.043, VU

Tutorial 2: Muscle & Joint loading

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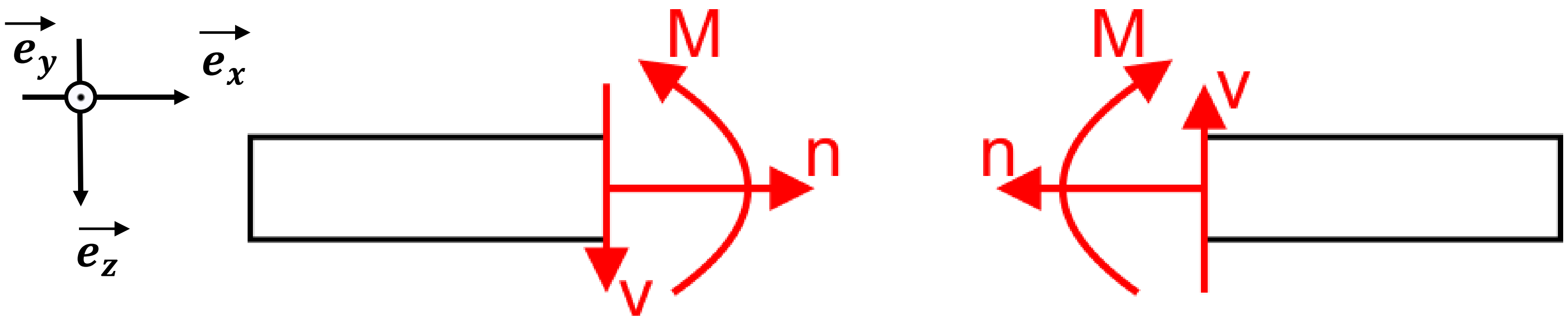
Midterm exam

- **November 16th 17h00-20h00, online**
- 20 points in total
- You'll need more than 10 points to pass
- About 50% factual knowledge
- Remaining points for worked examples
- Each exam accounts for 40% of the overall grade
- You are allowed 1 A4 page (handwritten!) of "formula collection"
- Don't forget to register
- Test-run for the exam: **Friday November 12th, 13h00**, more information follow

Reminder: Internal forces beams



Sign Convention

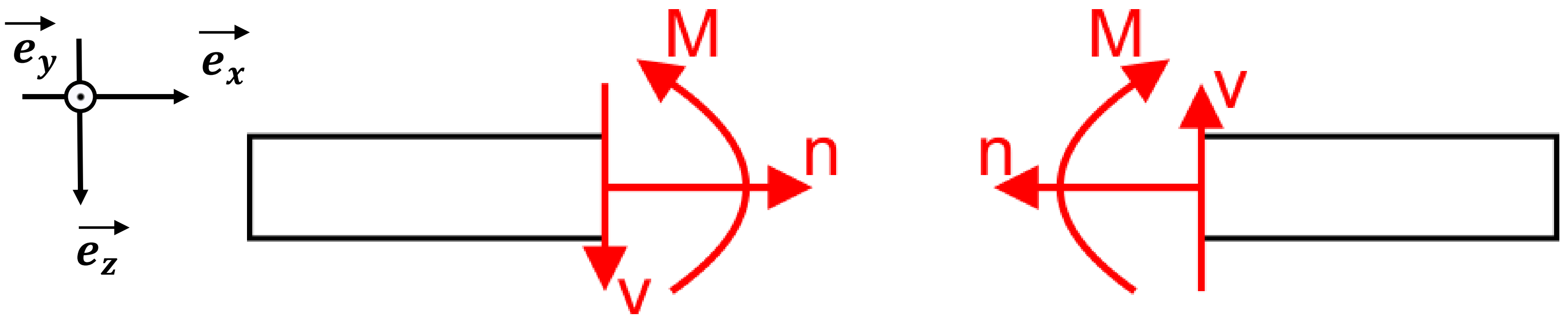
Positive normal force is said if it creates **tension**

Positive shear force will cause the beam segment on which it acts to **rotate clockwise**

Positive bending moment will tend to bend the segment on which it acts in a **concave upward manner**.

Loadings that are opposite to these are considered **negative**.

Reminder: Internal forces beams



Sign Convention

Internal forces on the **positive segment** of the cut must be **positive**

The positive axis is pointing **downwards**

The coordinate system must be **right-handed**

The arrows for the internal forces + moments should look like in the picture above

→ All of this is fulfilled with the coordinate system shown above. Use this coordinate system with the arrows for the forces as drawn above.

→ Important for all subsequent formula (e.g. bending)!

Knee Joint

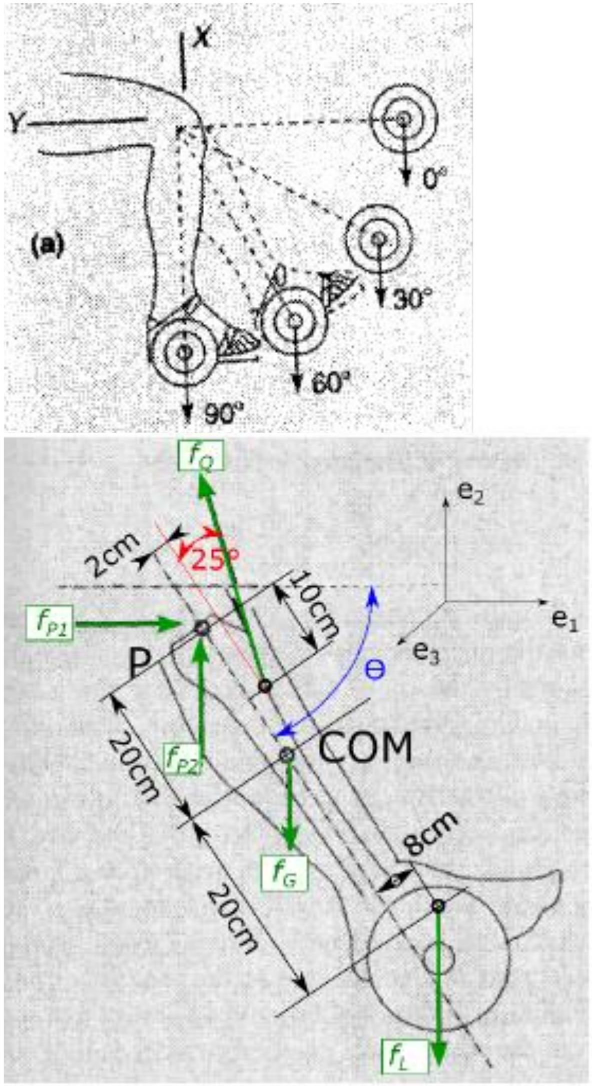
Consider a simple strengthening exercise for the quadriceps, as illustrated in the left figure below. The weight is lifted by the lower leg at different angles. Use the free body diagram in the right figure to answer the following points:

i) Derive an expression for the muscle tension f_Q of the quadriceps required for static equilibrium as a function of the flexion angle Θ

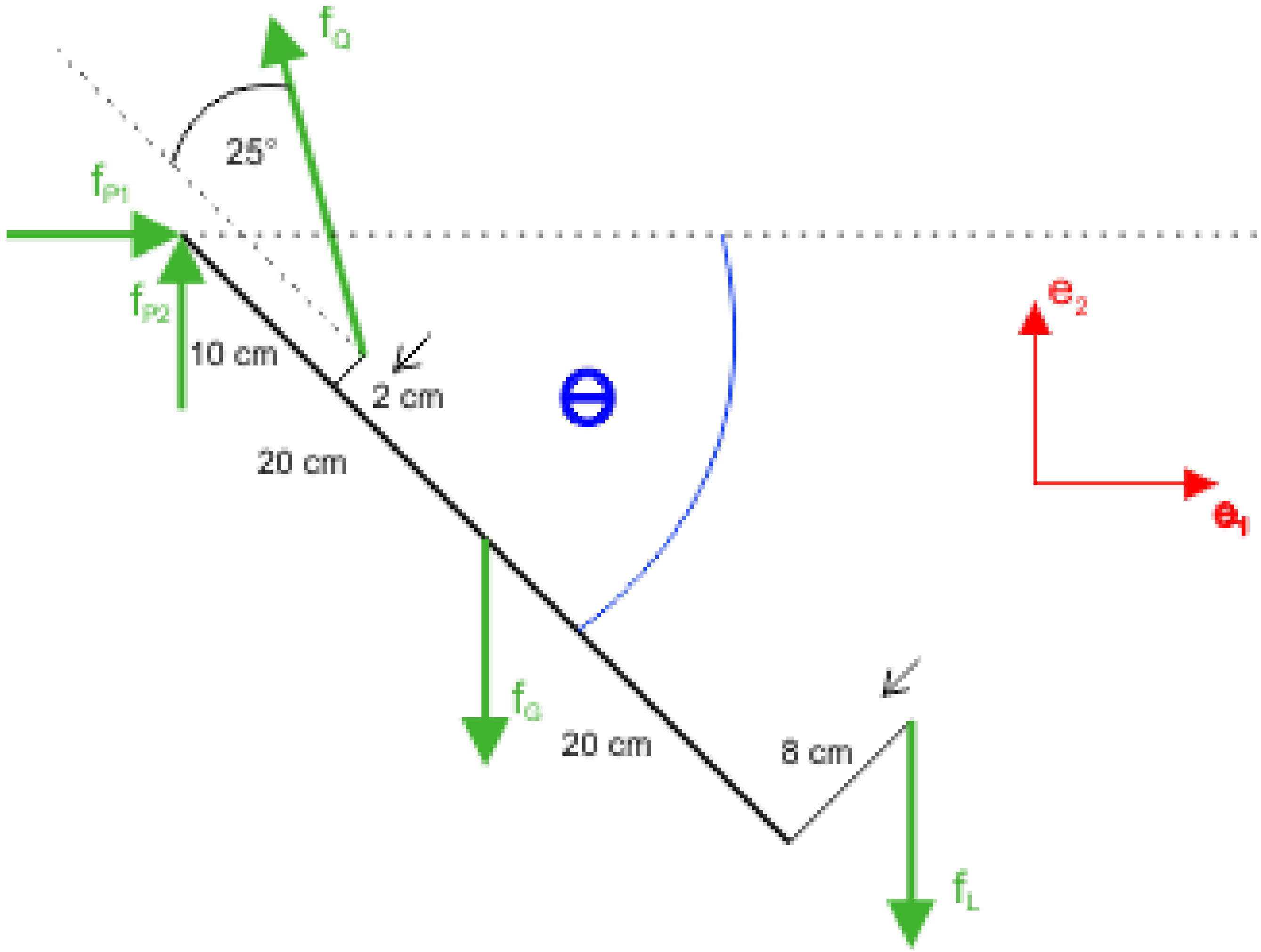
ii) Determine the reaction forces in joint *P*

iii) For f_L = 120 N, f_G = 30 N and Θ = 0°, 30°, 60°, 90° calculate the required muscle tension.

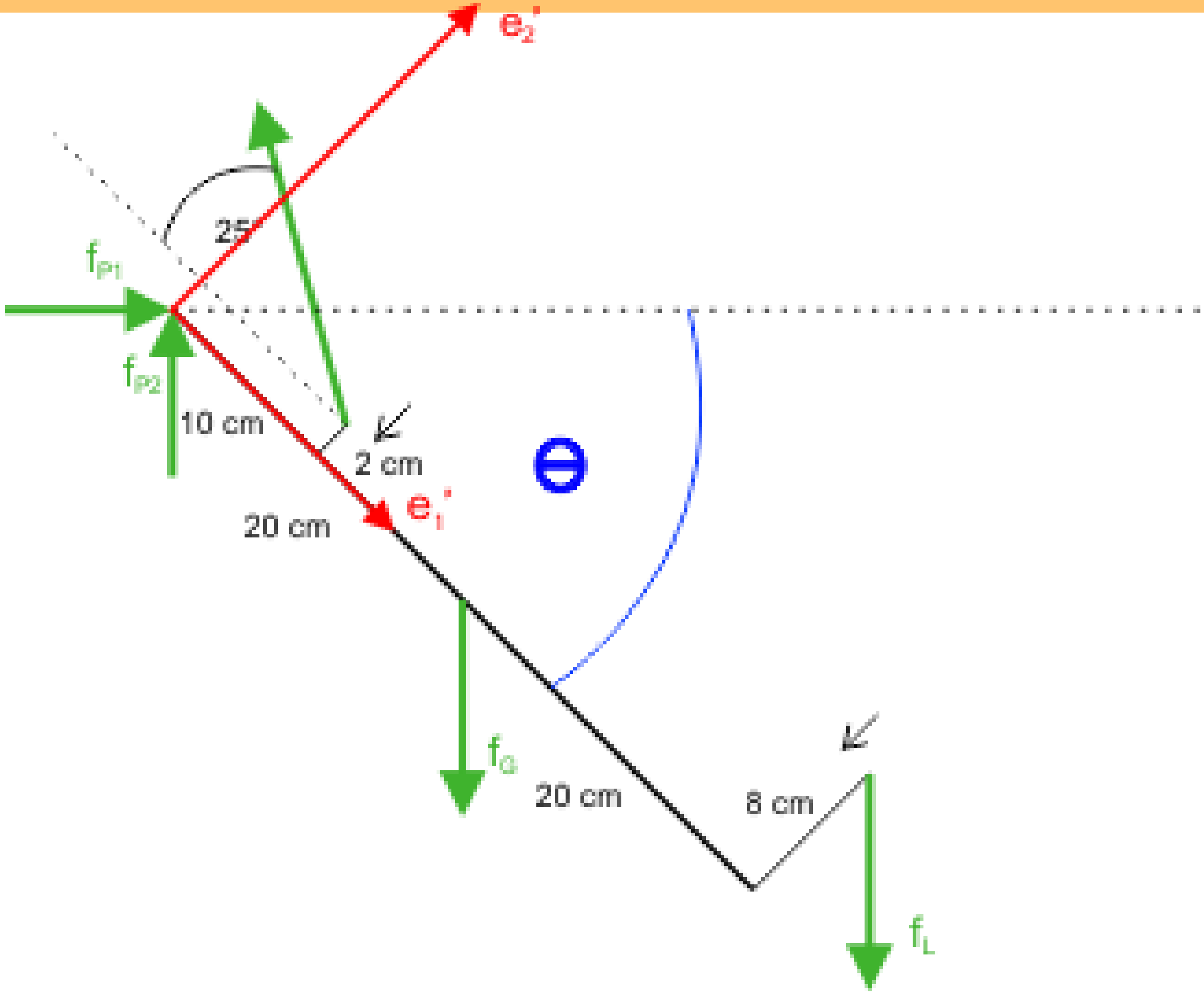
iv) Sketch $f_Q(\Theta)$ (with the inserted force values) from Θ = 0° to 90°



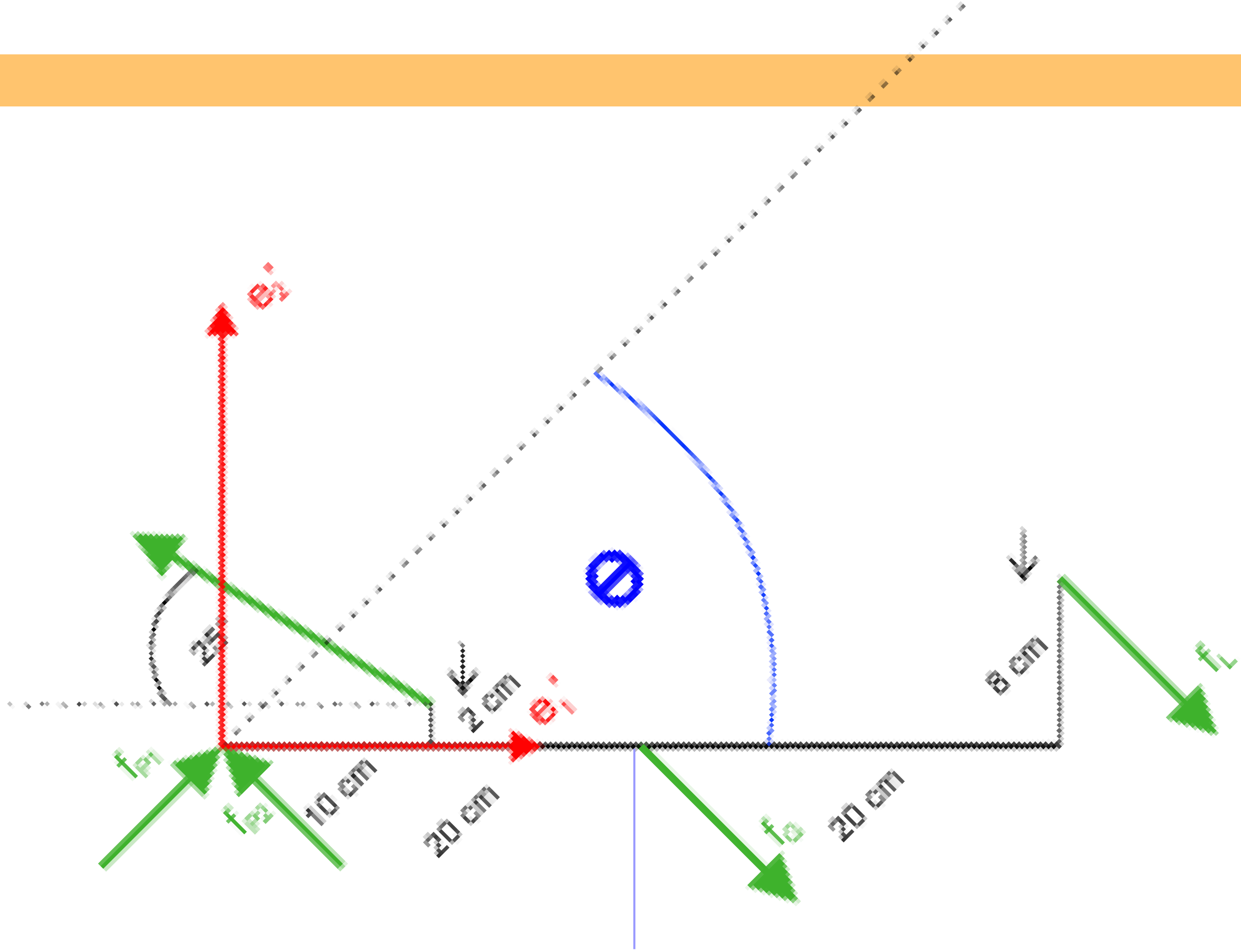
Knee Joint - FBD



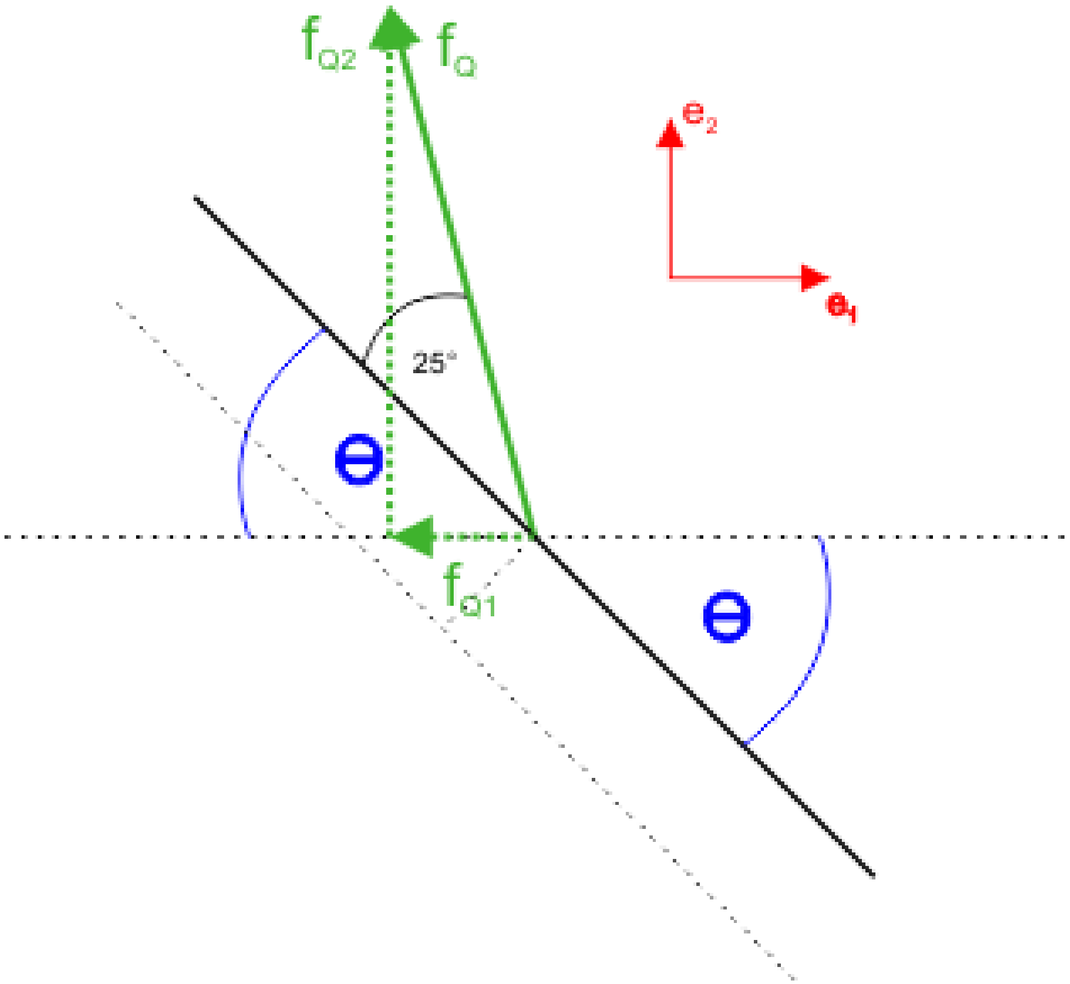
Knee Joint – rotated axes



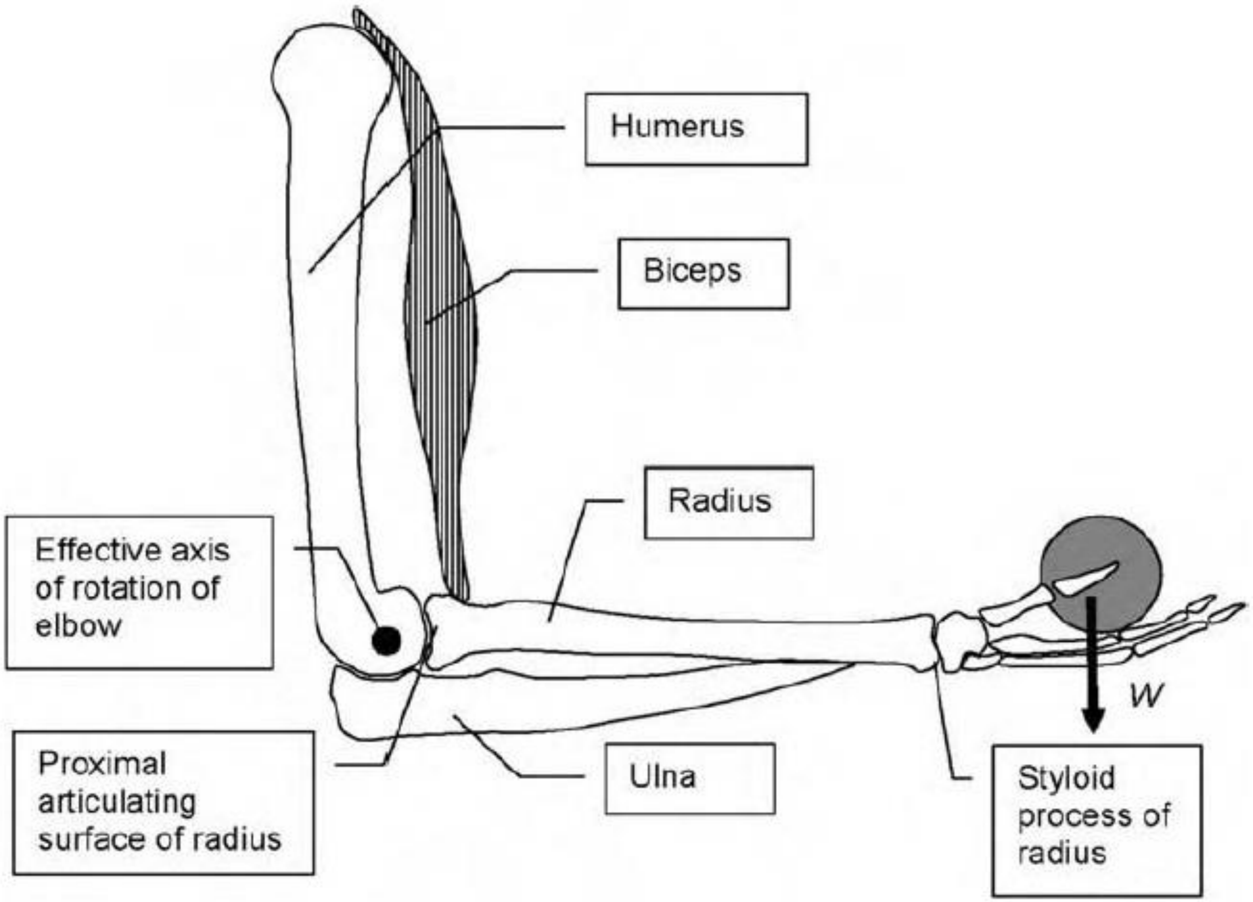
Knee Joint – rotated axes



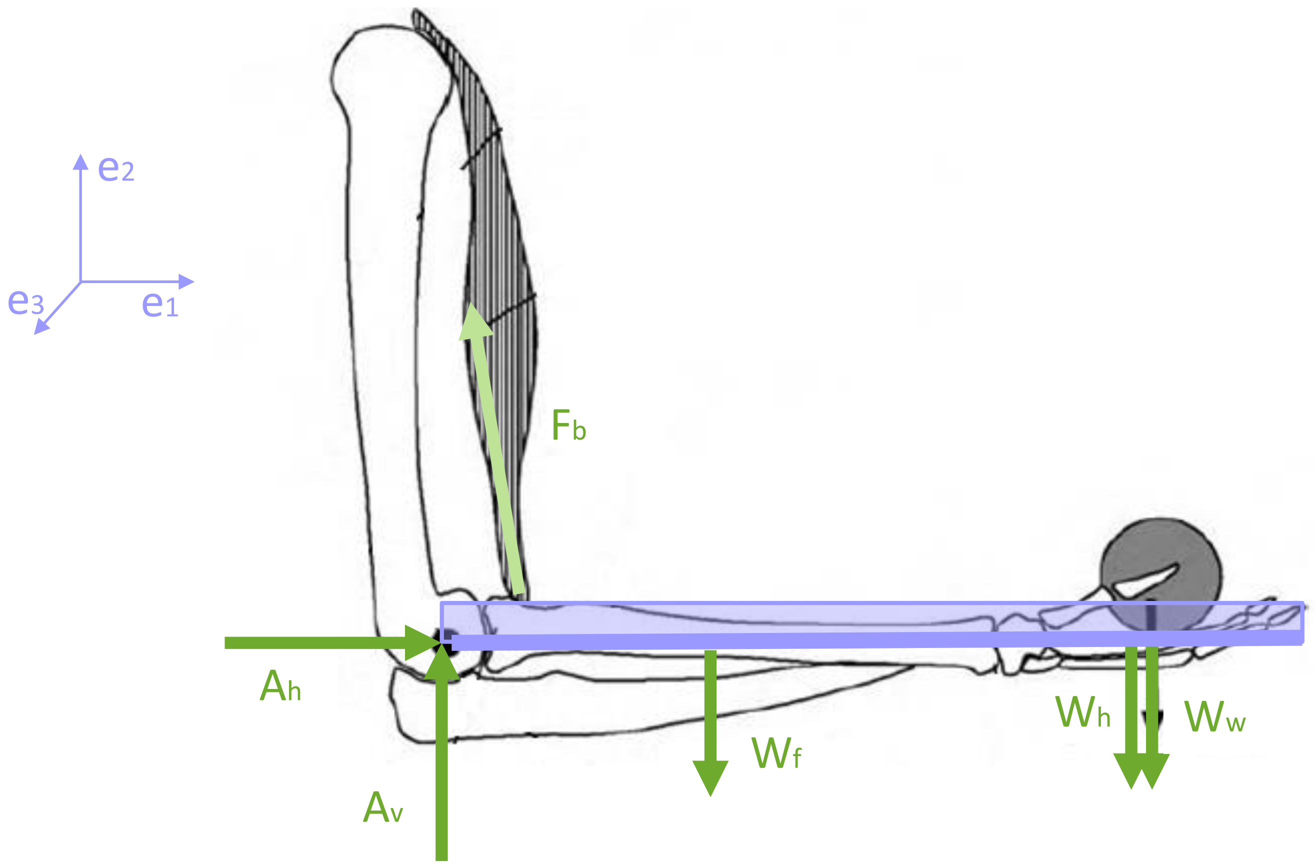
Knee Joint – Quadriceps angle



Elbow joint

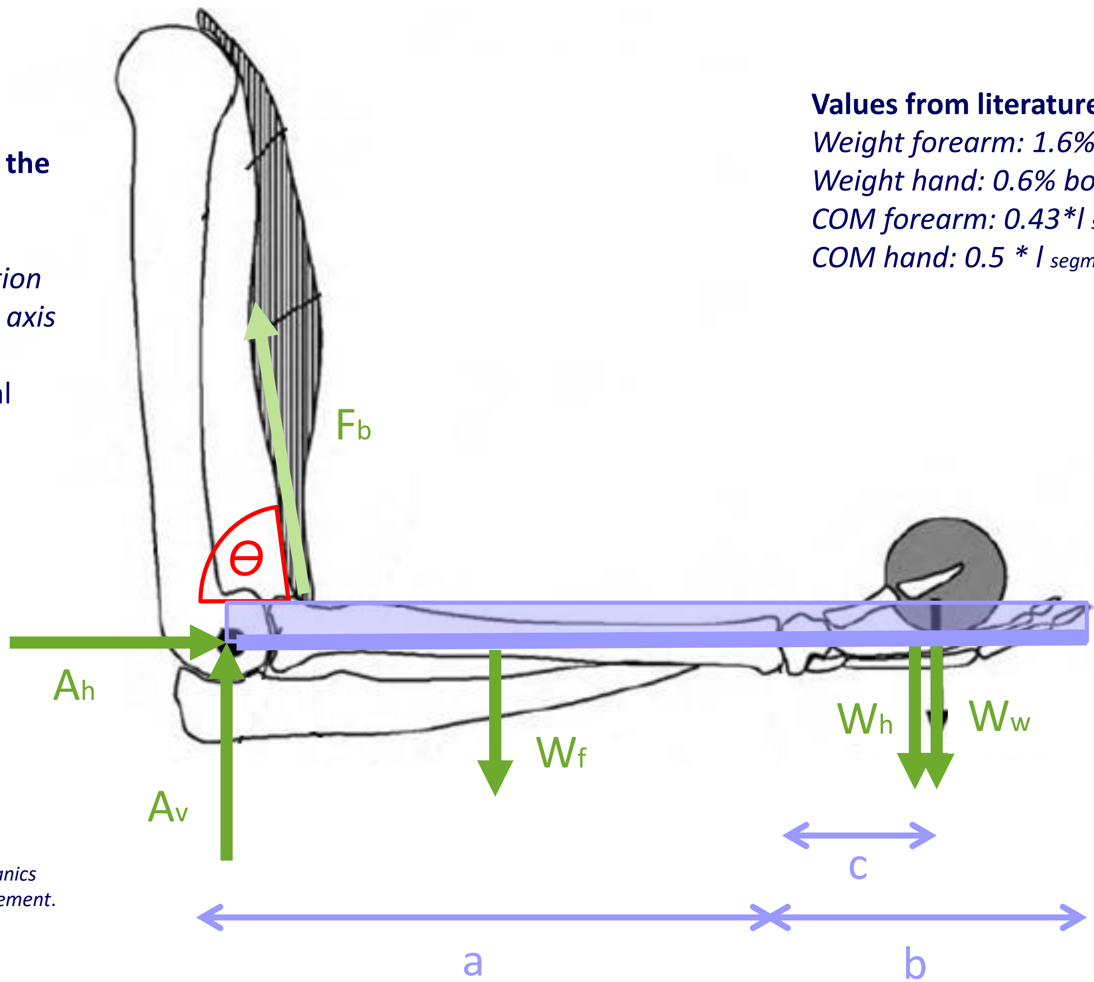

Humerus
Biceps
Radius
Effective axis of rotation of elbow
W
Proximal articulating surface of radius
Ulna
Styloid process of radius

Elbow joint



Elbow joint

Measure from the drawing:
Θ= 80°
Distance Insertion point biceps to axis of rotation:
3 cm horizontal
1.3 cm vertical

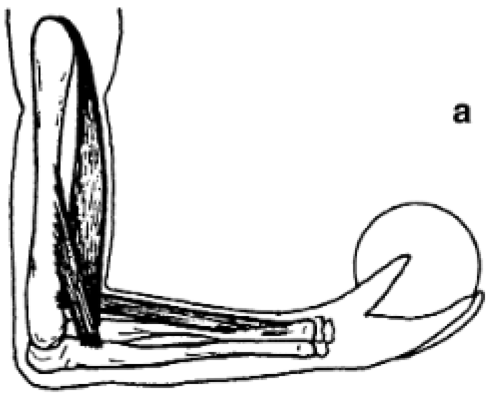


Values from literature [1)]
Weight forearm: 1.6% body weight
Weight hand: 0.6% body weight
*COM forearm: 0.43*l* $_{segment}$
*COM hand: 0.5 * l* $_{segment}$

Measure on your arm
e.g. a= 25 cm, b= 17cm, c= 6cm

1) e.g.: Winter, David A. *Biomechanics and motor control of human movement*. John Wiley & Sons, 2009

Elbow Joint



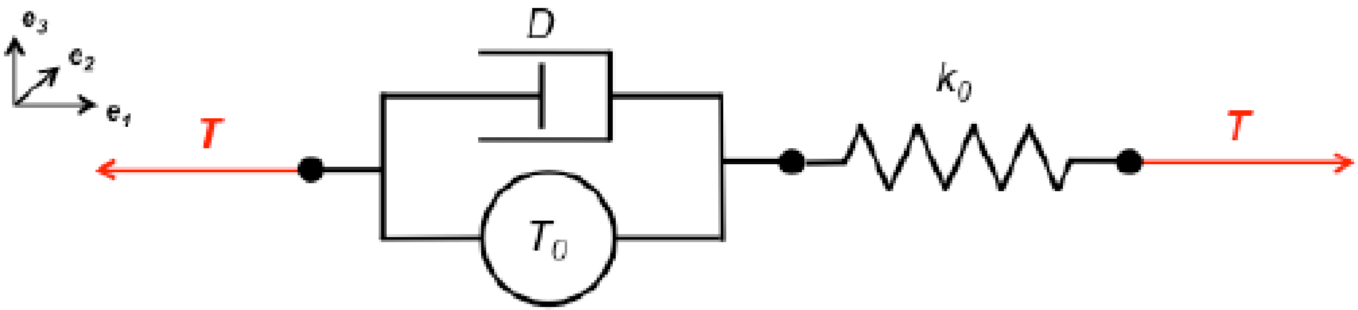
Side note:
in reality more than one muscle is active

- Biceps
- Brachialis
- Brachioradialis
- Extensor carpi radialis longus (ECRL)

Images source: Özkaya, Nihat, et al. *Fundamentals of biomechanics: equilibrium, motion, and deformation*. Springer, 2016.

Muscle lumped parameter model

Consider the three-element model of a muscle:



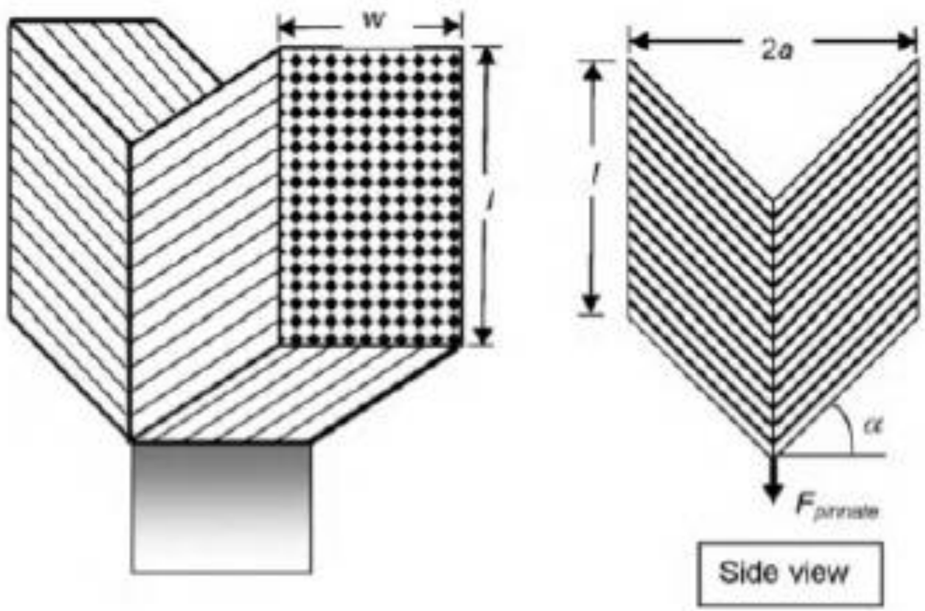
The contractile element produces a constant tension T_0 during activation – otherwise it produces no tension.

- For an isometric contraction derive an expression for $T(t)$, assuming that the contractile element is activated from $t = 0$ until $t = C$.
- Sketch $T(t)$

Pennate muscle

Prove that the force generated (per unit depth) of a pennate muscle arrangement (as per the sketch below) is:

$$F_{pennate} = 2wf_{fiber/area}l\cos(\alpha)\sin(\alpha)$$



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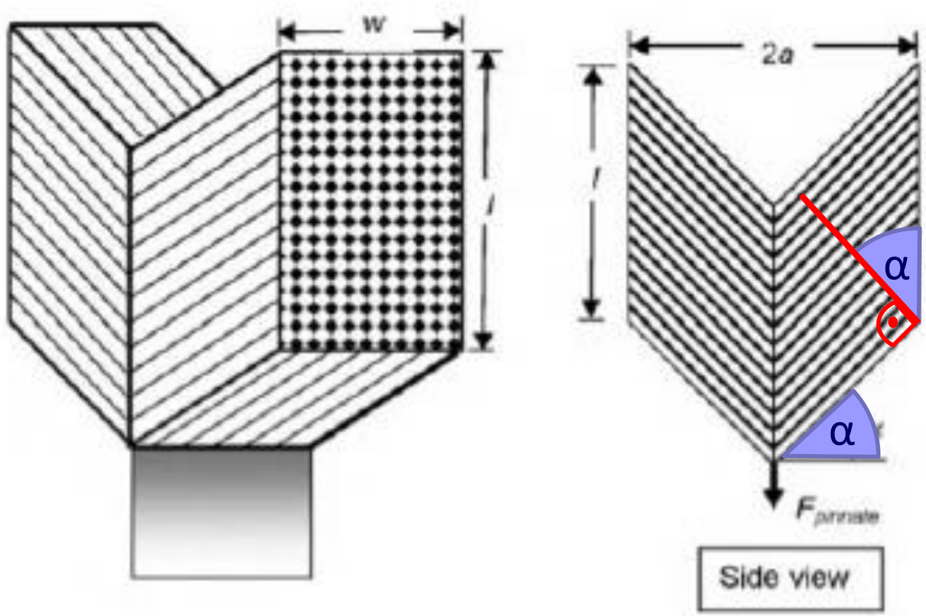


Thanks for your attention!

Elbow joint

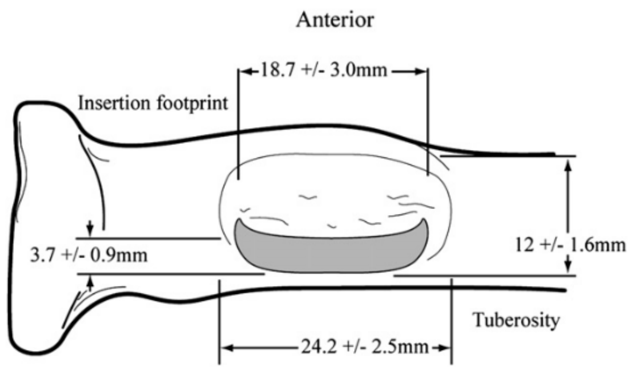
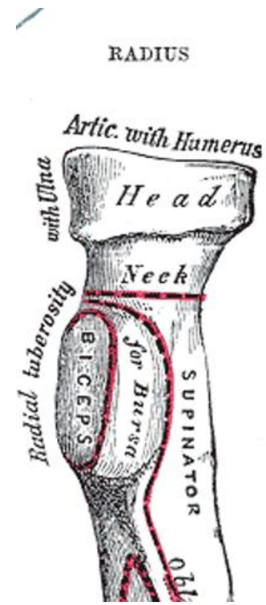


Figure 2 The transverse and axial dimensions of the radial tuberosity and distal biceps tendon footprint are shown. The shaded area represents the location of the distal biceps insertion footprint with its more common, type I, shape along the posterior ulnar aspect of the tuberosity.



Hutchinson, Hank L., David Gloystein, and Martin Gillespie. "Distal biceps tendon insertion: an anatomic study." *Journal of shoulder and elbow surgery* 17.2 (2008): 342-346.

Images source: Henry Gray (1918) Anatomy of the Human Body