Solutions to Problems Sets of Chapter 7 (sections 8 and 9)

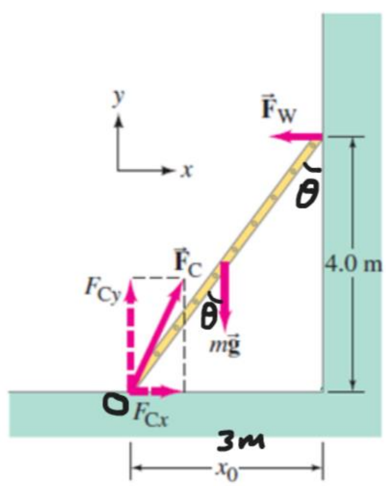
The University of Jordan/Physics Department

Prof. Mahmoud Jaghoub

أ.د. محمود الجاغوب

Example

Ladder. A 5.0-m-long ladder leans against a wall at a point 4.0 m above a cement floor as shown in the Figure. The ladder is uniform and has mass m = 12.0 kg. Assuming the wall is frictionless, but the floor is not, determine the forces exerted on the ladder by the floor and by the wall.



Static Equilibrium ⇒

$\Sigma \tau = 0$ half length of ladder

$+\circlearrowleft O \quad F_W(4) - mg\left(\frac{5}{2}\sin\theta\right) = 0$

$4F_W - 12g\left(\frac{\cancel{5}}{2} \times \frac{3}{\cancel{5}}\right) = 0$

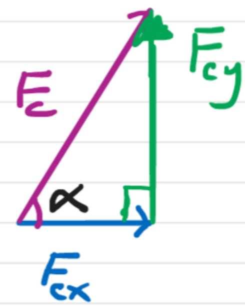
$4F_W = 18g \Rightarrow F_W = 44.1\ N.$

$\xrightarrow{+}$ $\sum F_x = 0 \Rightarrow F_{cx} - F_W = 0 \Rightarrow F_{cx} = 44.1\ N.$

$\overset{+}{\uparrow}$ $\sum F_y = 0 \Rightarrow F_{cy} - mg = 0 \Rightarrow F_{cy} = 12 \times 9.8 \simeq 117.6\ N.$

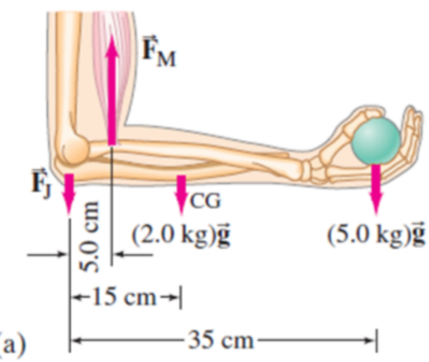
$\Rightarrow F_c = \sqrt{(F_{cx})^2 + (F_{cy})^2} \simeq \underline{125.6}\ N$

$\tan\alpha = \left|\frac{F_{cy}}{F_{cy}}\right| \Rightarrow \alpha \sim 69.4^\circ.$



9-3] Applications to muscles and joints

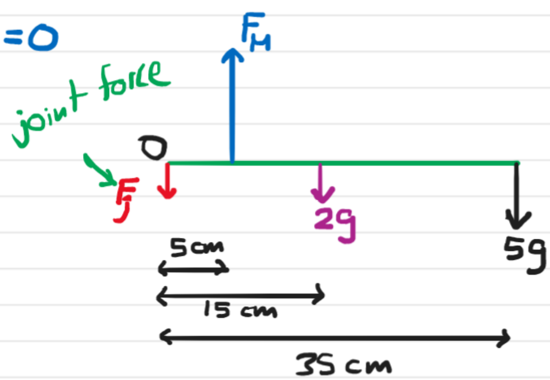
Force exerted by biceps muscle. How much force mustthe biceps muscle exert when a 5.0-kg ball is held in the hand with the arm horizontal as in the Fig. a. The biceps muscle is connected to the forearm by a tendon attached 5.0 cm from the elbow joint. Assume that the mass of forearm and hand together is 2.0 kg and their CG is as shown.



(a)

$\overset{+}{\circlearrowleft}$ O) $F_M(0.05) - 2g(0.15) - 5g(0.35) = 0$

$\therefore F_M \sim 402\ N.$

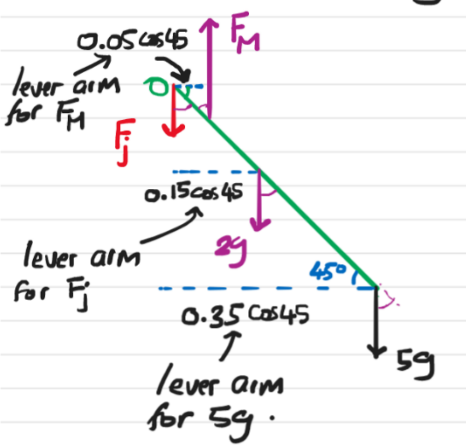


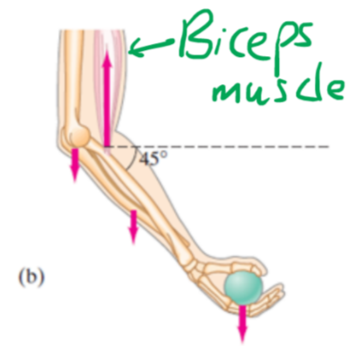
Find F_j (force at the joint)

$\overset{+}{\uparrow} \sum F_y = 0 \Rightarrow F_M - F_J - 2g - 5g = 0$

$\therefore \underline{F_J} = 333.4\ N.$

Do the same example but with formarm making an angle of 45° as shown.





$$+\circlearrowleft \quad \Sigma\tau = 0$$

lever arm

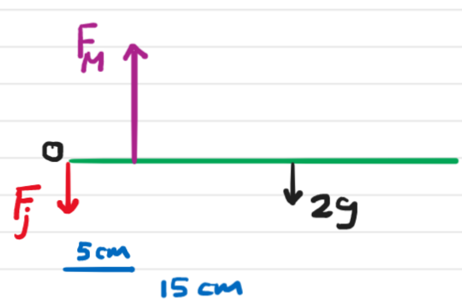
$$F_M(0.05)\cancel{\cos 45} - 2g(0.15\cancel{\cos 45}) - 5g(0.35\cancel{\cos 45}) = 0$$

$\therefore$ $F_M \sim 402$ N as before. Since all lever arms are multiplied by the same factor of $\cos 45^\circ$.

Example Same example as above but no weight is carried by the forearm.

$$+\circlearrowleft \quad \overset{F_a}{F_M}(0.05) - \overset{F_L}{2g}(0.15) = 0$$

$$\therefore \quad F_M = \frac{0.15}{0.05}(2g) = \underline{58.8\,N}$$

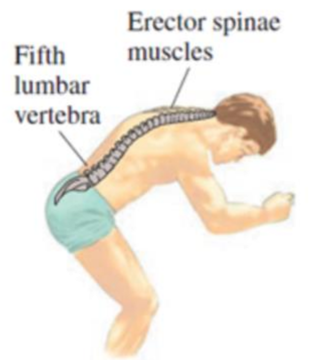


∴ Muscle exerts 58.8 N to carry the weight of the fore arm of 19.6 N !! Is the hand a good lever?

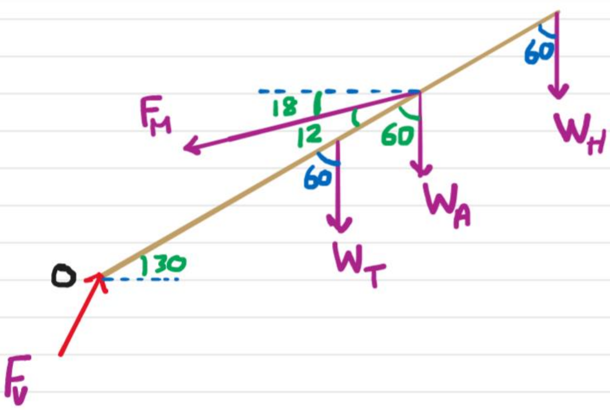
To answer, calculate the mechanical advantage (MA)

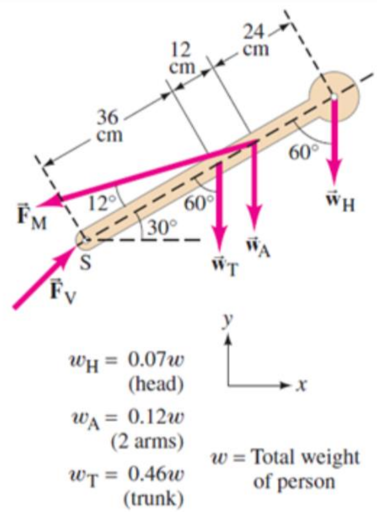
$$MA = \frac{F_L}{F_a} = \frac{X_a}{X_L} = \frac{0.05}{0.15} = \frac{1}{3} < 1 \Rightarrow \text{Not a good lever.}$$

Forces on your back. Calculate the magnitude and direction of the force acting on the fifth lumbar vertebra as represented in Fig. 9–14b.



(a)





(b)

$+\circlearrowleft$

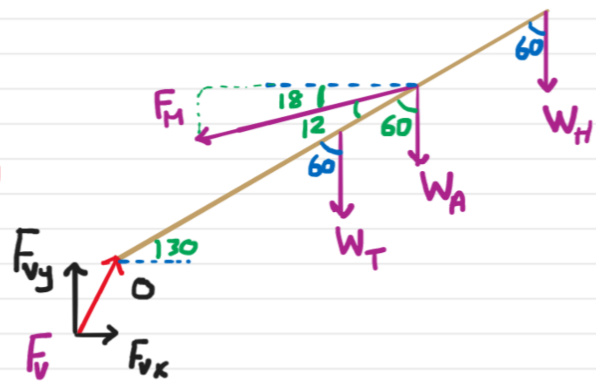
$$(F_M \sin 12)(0.48) - (W_T \sin 60)(0.36) - (W_A \sin 60)(0.48) - (W_H \sin 60)(0.72) = 0$$

$$\therefore F_M \approx 2.37\ w$$

For a 60 kg person $\Rightarrow W = 60(9.8) = 588$ N

$\therefore F_M \doteq 1394$ N !!

Find F_V.



$\overset{+}{\rightarrow} \Sigma F_x = 0$

$F_{vx} - F_M \cos 18 = 0 \Rightarrow F_{vx} \sim 2.25W$

$\therefore F_{vx} \sim 1326$ N

$\overset{+}{\uparrow} \Sigma F_y = 0$

$F_{vy} - W_T - W_A - W_H - F_M \sin 18 = 0$

$\therefore F_{vy} = W_T + W_A + W_H + (2.37W)\sin 18$

$= 0.46W + 0.12W + 0.07W + 2.37W \sin 18$

$F_{vy} \doteq \underline{1.38W} \simeq 812$ N.

$\therefore F_V = \sqrt{F_{vx}^2 + F_{vy}^2} \sim 2.7W$!!!

$F_V \sim 1552$ N!! too big a force to act on the fifth lumbar vertebra.

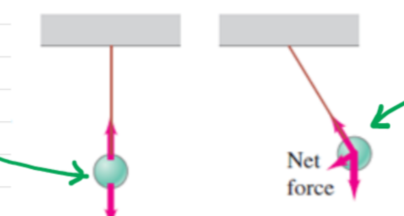
To NOT hurt our spinal cord, we we carry objects we must minimize the distance between our bodies and the load.

9-4] Stability and balance

For an object in stable equilibrium ($\Sigma \vec{F} = 0$, $\Sigma \tau = 0$) will remain in this condition. If it is displaced slightly from its equilibrium position, we have three possible outomes:

i) Object returns to its equilibrium position after being slightly displace $\Rightarrow$ Stable Equilibrium

Equilibrium position

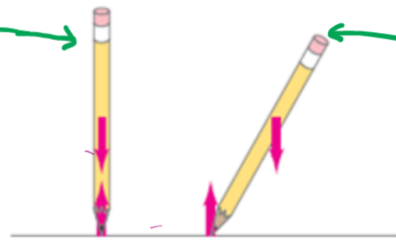


(a)

ball goes back to equilibrium position.

ii) Object moves further from its equilibrium position (does NOT return to its equilibrium position ⇒ Unstable Equilibrium

Equilibrium position



(b)

pencil does NOT return to its equilibrium position.

unstable eq.

stable eq.

bowl

(iii) Neutral Equilibrium

Equilibrium position

motion

does Not return to its equilibrium position.