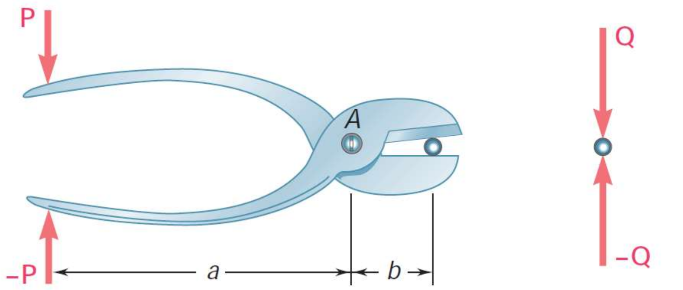
Analysis of Machines

Machines are structures designed to transmit and modify forces, whether they are simple tools or include complicated mechanisms.

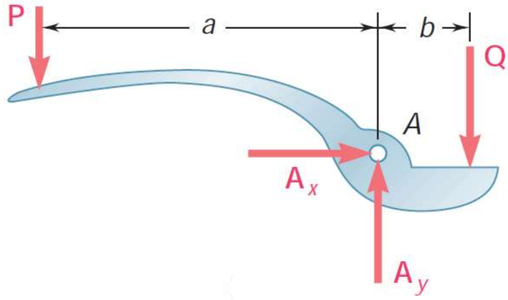
They simply transform input forces into output forces.



If we apply $\vec{P}$ & $-\vec{P}$ on the handle of this cutting plier, it will exert two equal & opposite forces $\vec{Q}$ & $-\vec{Q}$ on the wire.

To determine Q for a given P (or conversely), we draw a free body diagram of the plier. Note that the structure is nonrigid, hence we dismember it and analyse individual members.

Consider a FBD of one of the arms:-

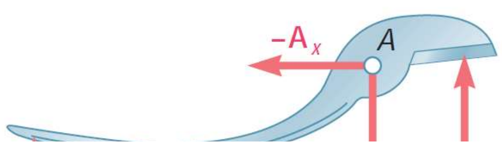


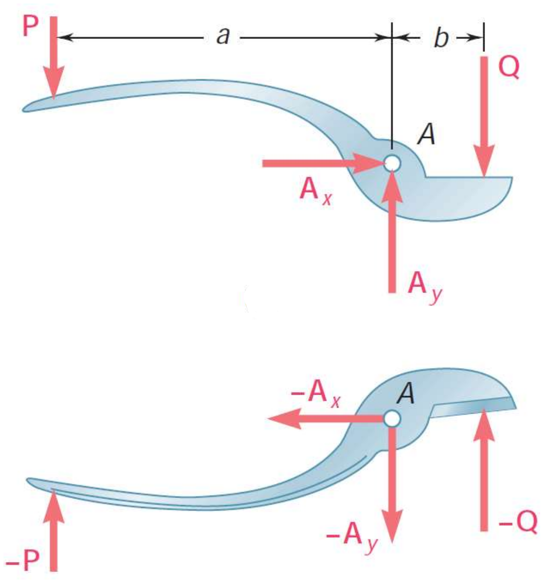
→ Taking moments about A:

$$P \cdot a = Q b$$

$$\Sigma f_x = 0 \Rightarrow A_x = 0$$

$$\Sigma f_y = 0 \Rightarrow A_y = P + Q$$





Taking moments about ...

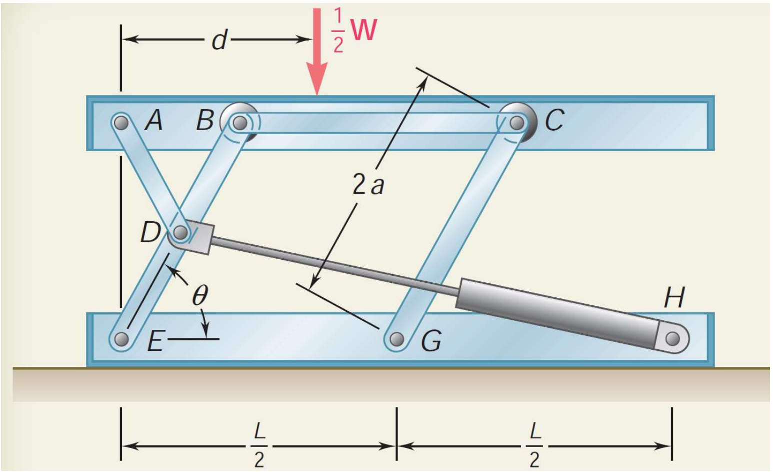
$$P \cdot a = Q\,b$$

$\Sigma F_x = 0 \Rightarrow A_x = 0$

$\Sigma F_y = 0 \Rightarrow A_y = P + Q$

Example:

$W = 1000$ kg



The hydraulic lift consists of two identical linkages on which hydraulic cylinder exert forces.

One one linkage & cylinder is shown.

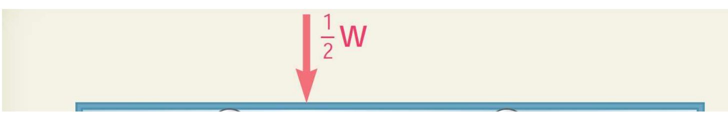
Members EDB & CG are of length $2a$ each.

AD is a pinned at midpoint of EDB.

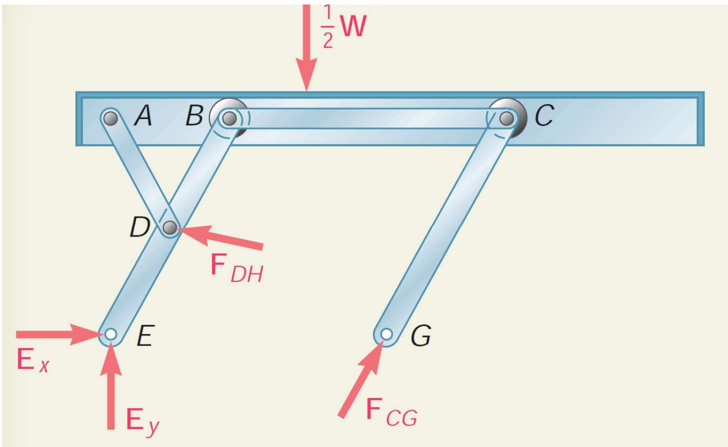
Determine forces exerted by the cylinder in raising the crate for $\theta = 60^\circ$, $a = 0.7$ m, $L = 3.20$ m.

Is the result independent of d?

Soln: FBD of the machine:



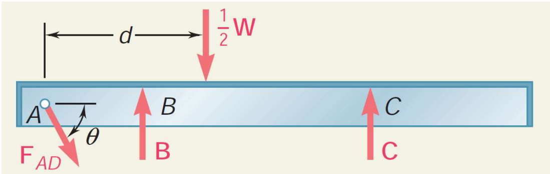
FBD of machine:

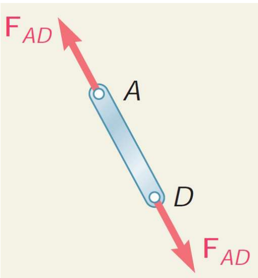


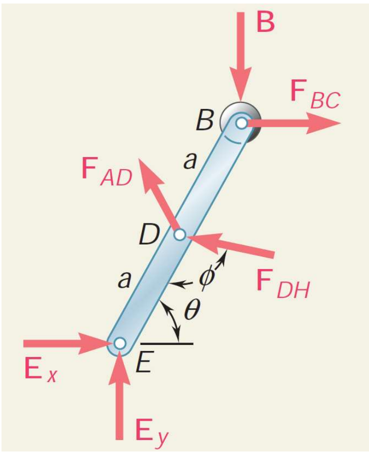
There are more than 3 unknowns, hence we need to dismember the machine.

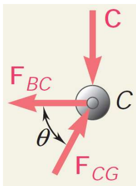
AD, BC, CG : Two force members

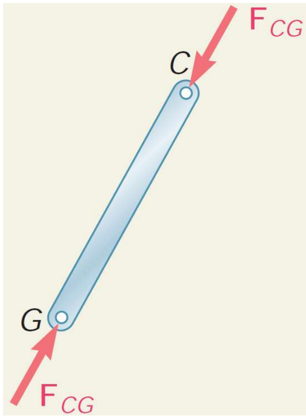
CG : Assumed to be in compression.



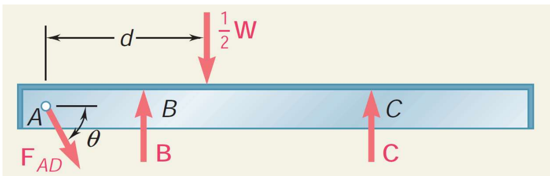








Platform ABC:

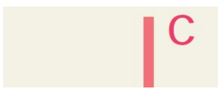


$\sum F_x = 0$

$\Rightarrow F_{AD} \cos\alpha = 0 \Rightarrow F_{AD} = 0$

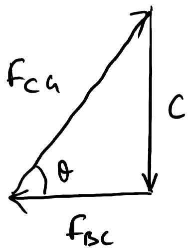
$\sum F_y = 0 \Rightarrow B + C = \frac{1}{2} W$

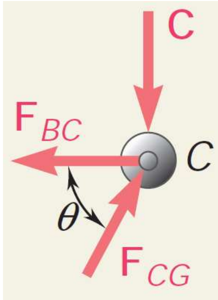
Roller C:



Roller C.

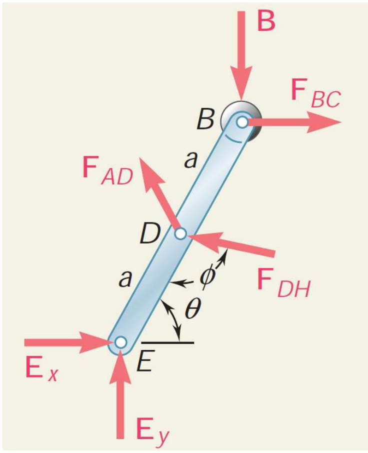
We can draw a force triangle:





$$\tan\theta = \frac{C}{F_{BC}} \Rightarrow \boxed{F_{BC} = C\cot\theta}$$

Member BDE:



$$\sum M_E = 0$$

$$\Rightarrow F_{DH}\cos(\phi - 90^\circ)\, a - B(2a\cos\theta) - F_{BC}(2a\sin\theta) = 0$$

$$\Rightarrow F_{DH}\sin\phi - 2(B+C)\cos\theta = 0$$

Using $B + C = \frac{1}{2}W$, we get

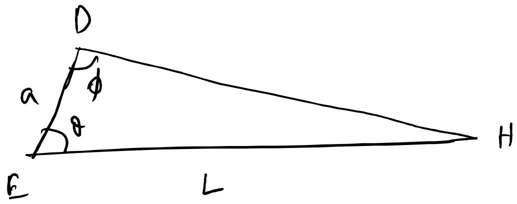
$$\boxed{F_{DH} = W\frac{\cot\theta}{\sin\phi}}$$

$\therefore$ F_{DH} is independent of d.

Using law of cosines: $(DH)^2 = a^2 + L^2 - 2aL\cos\theta$

$$\Rightarrow DH = 2.91 \text{ m}$$

Law of sines: $\frac{\sin\phi}{EH} = \frac{\sin\theta}{DH} \Rightarrow \sin\phi = \frac{EH}{DH}\sin\theta$



$F_{DH} =$