1. A figure skater goes into a spin, keeping her arms up and close to her body, illustrating conservation of angular momentum. In a classroom demonstration of the above effect, a student is standing on a rotating platform, which is spinning with $2 \mathrm{rev} / \mathrm{s}$. The student is holding two heavy dumbbells, 5 kg each, originally tightly pressed to his/her body at a negligible distance from the axis of rotation. The student then extends the arms horizontally, bringing each dumbbell 80 cm from the axis of rotation. Assume the student (without dumbbells) and the platform have a combined rotational inertia of $I=8 \mathrm{~kg} \cdot \mathrm{~m}^{2}$ and (unlike the case of the figure skater) neglect the rotational inertia of extended arms.
(a) find the original $\omega$
(b) find the angular momentum $\mathcal{L}$
(c) find the final $I^{\prime}$ (note: there are two arms)
(d) find the final $\Omega$; convert to rev $/ \mathrm{s}$
(e) find the change in kinetic energy
2. $m=1 \mathrm{~kg}, r=5 \mathrm{~mm}, R=25 \mathrm{~cm}$. Equilibrium. Find $M$.

3. The rod-disk system is brought from $\omega_{0}=0$ to $\omega=1000 \mathrm{rad} / \mathrm{s}$ in $t=10 \mathrm{~s}$. Find $T\left(M_{\text {rod }}=4 \mathrm{~kg}, M_{\text {disk }}=1 \mathrm{~kg}, r=5 \mathrm{~mm}, R=25 \mathrm{~cm}\right)$

4. A solid disk with $r=1 \mathrm{~m}$ and $M=1 \mathrm{~kg}$ falls from unwinding string (as in a primitive yo-yo).

(a) write the linear 2nd Law (for $T, M g$ and $a$ )
(b) write the torque due to $T$ about the CM
(c) write the rotational 2nd Law (for $\tau, I$ and $\alpha$ )
(d) use constrain $\alpha=a / r$ to eliminate $\alpha$, and then $T$
(e) find $a$
(f) find $\alpha$


Figure 1: Two twins, masses $m=30 \mathrm{~kg}$ (left, $d=1 \mathrm{~m}$ each) against their dad with mass $M=75 \mathrm{~kg}$. Force of gravity on the seesaw and reaction of the fulcrum are not shown since they produce no torque. Find $D$.
5.


Figure 2: Horizontal beam of mass $M=100 \mathrm{~kg}$ and length $L=2 \mathrm{~m}$ supported by a blue cord making angle $\theta=30^{\circ}$ with horizontal. Only forces with non-zero torque about the pivot (tension $\vec{T}$-blue- and gravity $M \vec{g}$-black) are shown. Find $T$


Figure 3: Horizontal beam of mass $M=100 \mathrm{~kg}$ and length $L=4 \mathrm{~m}$ with additional mass $m=60 \mathrm{~kg}$ at the end. The rod is pivoted at the left end, and there is a support at a distance $d=1 \mathrm{~m}$. Find the force $N$.
7.


Figure 4: A beam of mass $M=10 \mathrm{~kg}$ and length $L=3 \mathrm{~m}$ with additional mass $m=500 \mathrm{~kg}$ at the end. The rod is pivoted at the left end and makes an angle $\phi_{1}=30^{\circ}$ with vertical. There is a supporting cord which makes an angle $\phi_{2}=45^{\circ}$ with vertical. Find the tension $T$.
9. A beam with $M=100 \mathrm{~kg}$ makes an angle $45^{\circ}$ with horizontal, and is supported by a cable which makes $30^{\circ}$ with the beam. Find $T$.


