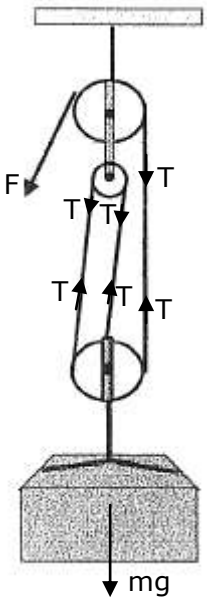
Q- (a) What force F is required to lift the mass of 200 kg by the tackle shown in the figure?
(b) The mass and the tackle are mounted on the ceiling by a hook made out of a 5mm steel rod with a tensile strength of $500*10^6$ Nm^{-2}. Will the hook be able to support the arrangement?
(c) Sketch the new arrangement to reduce the force required further.

(a) The force F applied at the end of the string will create the tension T in the string which is having magnitude equal to F.



As nothing is given, we will consider the string and the pulley as light and frictionless, and hence the tension in the string is throughout same T.

As in the figure the block and its pulley is supported be three parts of the string, the net upward force on the block is provided by these three parts and equal to 3T.

Hence for equilibrium the weight mg must balanced by the upward force or net force must be zero. This gives

$3T = mg$

Or $T = F = mg/3 = 200*9.8/3 = 653.33$ N

The tensile stress is the maximum tension in the rod per unit area hence the maximum load supported by the rod is given by

F_{max} = Tensile stress*Area of cross-section

$= 500*10^6*\pi R^2$

$= 500*10^6*3.14*\left(\frac{5}{2}*10^{-3}\right)^2$

$= 9812.5$ N

The forces acting down on the uppermost pulley are the tensions in the applied force F, hence the total tensile force in the rod of the tackle will be

$F + 3T = 4F = 4*653.33 = 2613.33$ N

As this force is much less than the maximum tensile force in the rod the rod can support the system.

For further reduction of the force F the number of pulleys should be increased by same number on each pulley block as in the sketch on right.