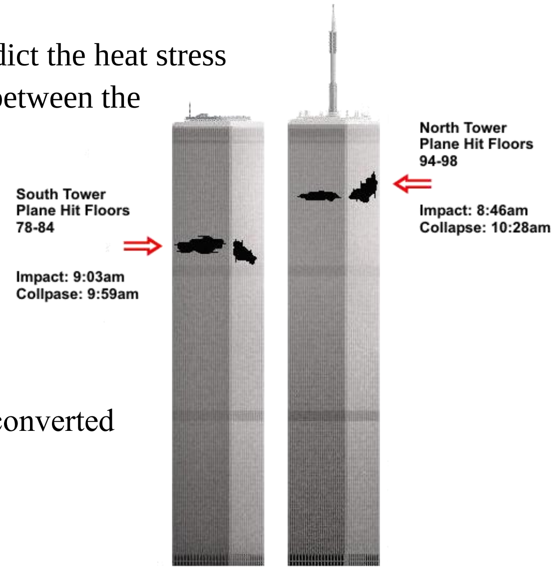
More Review Questions for June 2010

After the attacks of September 11, 2001, investigators had to predict the heat stress which the tower's steel had to endure as a result of the collision between the plane and the tower and the ensuing fire of all the fuel aboard. Especially important was the stress of the supportive but poorly fireproofed truss steel supports that collapsed and led to a domino effect in bringing down each tower. We will consider only one plane since only one plane crashed into each tower of the World Trade Center.



We will assume that all of the energy of the plane's motion was converted into heat.

Total weight of **Boeing 707-320** = 1.46×10^6 N

Speed upon collision = 960 km/h

In addition we have to consider the additional heat released from the combustion of jet fuel. The weight of unused fuel on board each plane = 310 000 N. Although jet fuel consists of a mixture of alkanes with 9 to 17 carbons, we will use the average number in the following equation to reveal how much heat is released by the combustion of jet fuel:

$C_{13}H_{28} + 20\ O_2 \rightarrow 13\ CO_2 + 14\ H_2O + 7912$ kJ

Facts about Steel	
Weight of steel in the area near the impact of the plane	50 000 N
specific heat	450 J/(kg^{o}C)
Increase in temperature needed to deform steel tress supports	600^{o}C

Question: Was the maximum temperature that the steel could have attained enough to stress the steel? Assume an initial temperature of 20^{o}C and that only 1% of the energy from the plane's motion and combustion of fuel was absorbed by the steel tresses.

Answer: First we need mass in kg and speed in m/s:

$F_g = mg$

$m = F_g/g$

$= 1.46 \times 10^6$ N /(9.8N/kg) =148979.5918 kg

v = 960 km/h(1000m/km)(1h/3600 s) = **266.67 m/s**

$E_k = 0.5mv^2$

$= 0.5(148979.5918\ kg)(266.67\ m/s)^2$

5 297 184 580 J = 5.29718458×10^7 kJ

From $C_{13}H_{28} + 20\ O_2 \rightarrow 13\ CO_2 + 14\ H_2O$ + 7912 kJ, we notice that each mole of $C_{13}H_{28}$ releases 7912 kJ. But we had more than 1 mole burning:

$m = F_g/g$
= 310 000 N/(9.8N/kg) = 31632.65306 kg
31632.65306 kg = 31 632 653.06 g of $C_{13}H_{28}$
31 632 653.06 g of $C_{13}H_{28}$ / (184 g/mole) = 171916.5927 moles

171916.5927 moles* 7912 kJ/mole = 1 360 204 081 kJ

Total amount of heat = 1 360 204 081 kJ + 5.29718458 X 10^7 kJ = 1 413 175 927.kJ
= 1 413 175 927000 J
The tresses only absorbed 1% of the heat: 0.01(1 413 175 927000) = 1 413 175 9270 J
$Q = mc\Delta T$
1 413 175 9270 J = 50000N/(9.8N/kg)* 450 J/(kg^{o}C)(x – 20)

= 6175. ^{o}C

Temperature exceeds 600 ^{o}C ,so, yes, the steel tresses could have been stressed. We are also ignoring all the heat released by everything else that burnt!