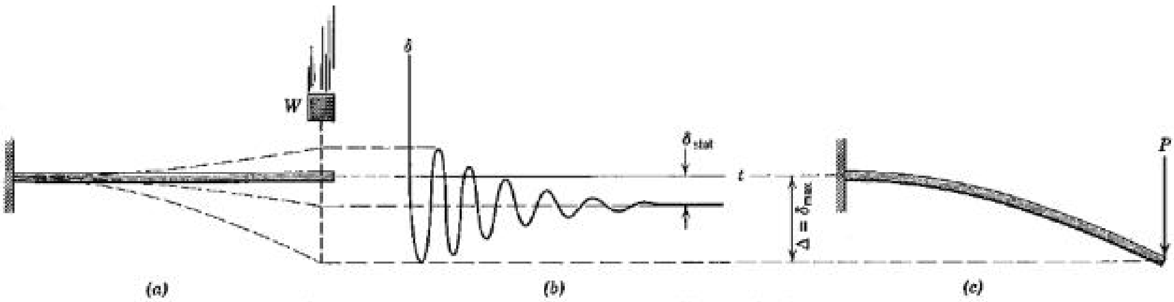
Part 22: Simplified Drop Test with a Impact Factor

With the new Add-On **DROPTEST** of the FEM System MEANS V11 (please visit company webite www.fem-infos.com) simple 3D drop tests of the falling body and impact surface can be calculated together in one FEM Simulation - provided that no plastic deformations such as e.g. in a Crash Impact.

A mass of known speed hits a rigid surface and creates an impact load. Instead of performing an explicit dynamic and non-linear FEM analysis with very expensive FEM systems, a linear static calculation is used here with an impact factor at the time of maximum amplitude.

In order to get a good approximation of the dynamics, an impact factor is calculated from the height of the fall and the mass. With hard elastic bodies, the impact factor for vertical impacts is always greater than or equal to two. The vertical impact factor can be more than 10, 100 or even greater. The following figure shows a static load P with an impact factor at the time of maximum amplitude.



A static force P approximates the dynamic effects of a falling weight W

The impact factor is determined from the difference between the impact force and the gravitational load

$$\text{Impact factor} = \frac{\textbf{Impact force}}{\textbf{Gravitational load}}$$

and is multiplied in the FEM model with the density of the falling body in order to take into account the impact energy in the FEM calculation.

Substitute Density = Density * Impact factor

Example 1: Car Tire falls on a Glass Plate

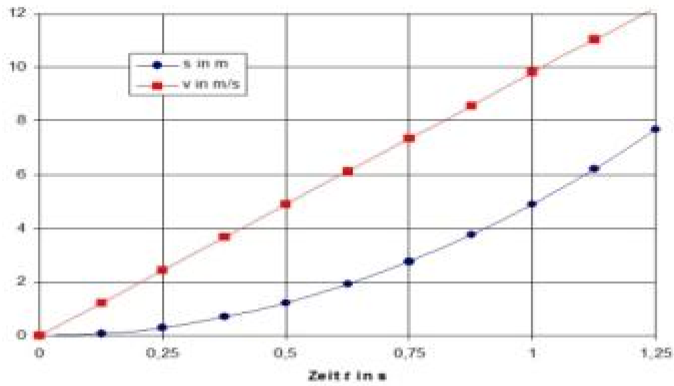
The deformations and stresses should be calculated when a 50 kg Car Tire falls from a height of 1 m, 3 m and 5 m onto a Glass Plate with a glass thickness of 15 mm. The yield point for technical glass is 45 N/mm² and must not be exceeded.

The following data are known:

Mass m of the car tire = 50 kg

Fall height s s_1 = 1 m, s_3 = 3 m, s_5 = 5 m

Speed v v_1 = 4.4 m/s, v_3 = 7.7 m/s, v_5 = 10 m/s (see diagramm)



Gravitational acceleration a = 9.81 m/s²

Impact time t = 0.1 s (is assumed to be a short contact time in the entire kinetic energy is converted into deformation energy)

Gravitational load = m * a = 50 kg * 9.81 m / s² = 490.5 N

Impact force

Impulse = mass * speed

Impulse$_1$ = 50 kg * 4.4 m/s = 220 kg * m/s
Impulse$_3$ = 50 kg * 7.7 m/s = 385 kg * m/s
Impulse$_5$ = 50 kg * 10 m/s = 500 kg * m/s

Impact force = Impulse / Impact time

F_{I1} = 220 kg * m/s / 0.1 s = 2 200 N
F_{I3} = 385 kg * m/s / 0.1 s = 3 850 N
F_{I5} = 500 kg * m/s / 0.1 s = 5,000 N

Impact factor

f = Impact force / Gravitational load

f_1 = 2 200 N / 490.5 N = 4.48
f_3 = 3 850 N / 490.5 N = 7.84
f_5 = 5,000 N / 490.5 N = 10.19

Substitute densities

Substitute density at 1 m height = 4.48 * 1.1340 kg/mm³ * 10^{-6} = 5.08E-06 kg/ mm³
Substitute density at 3 m height = 7.84 * 1.1340 kg/mm³ * 10^{-6} = 8.89E-06 kg / mm³
Substitute density at 5 m height = 10.19 * 1.1340 kg/mm³ * 10^{-6} = 1.15E-05 kg/mm³

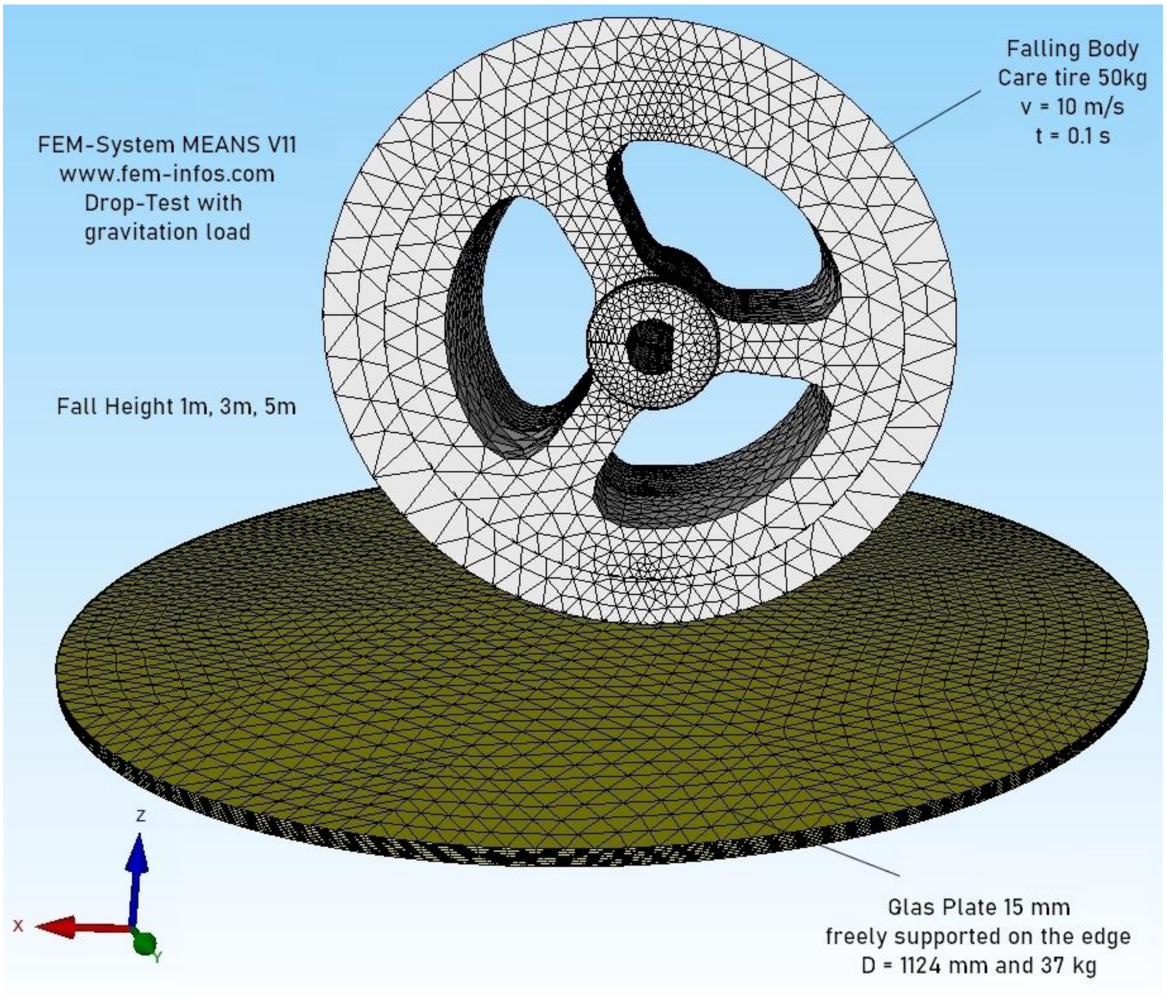
Impact masses

Impact mass at 1 m height = 50 kg * 4.48 = 224 kg
Impact mass at 3 m height = 50 kg * 7.84 = 392 kg
Impact mass at 5 m height = 50 kg * 10.19 = 510 kg

FEM model

The finite element model consists of 154 062 solid elements, 228 469 nodes and the following 3 element groups:

Element group 1: Car Tires with 58,460 TET10 elements with local refinement
Element group 2: Glass Plate with 95 232 TET10 elements
Element group 3: with 370 MPC-Elements

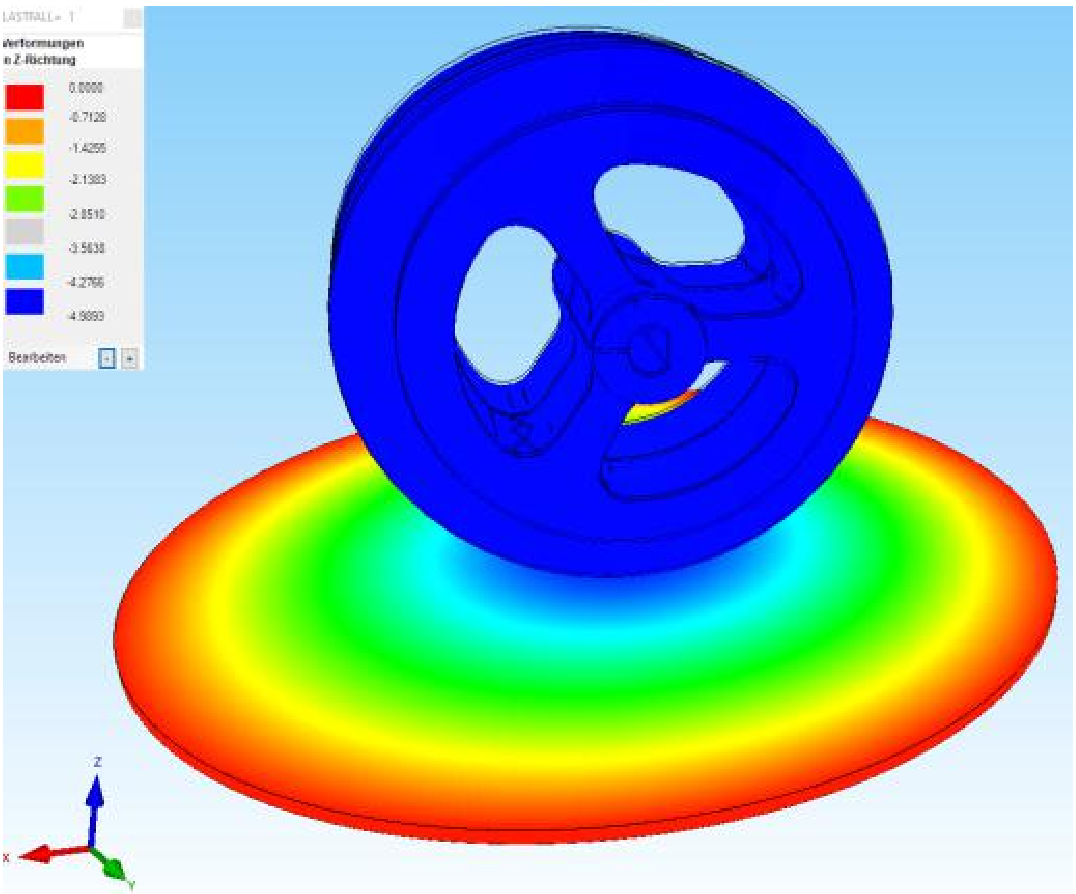


Stress results of different heights

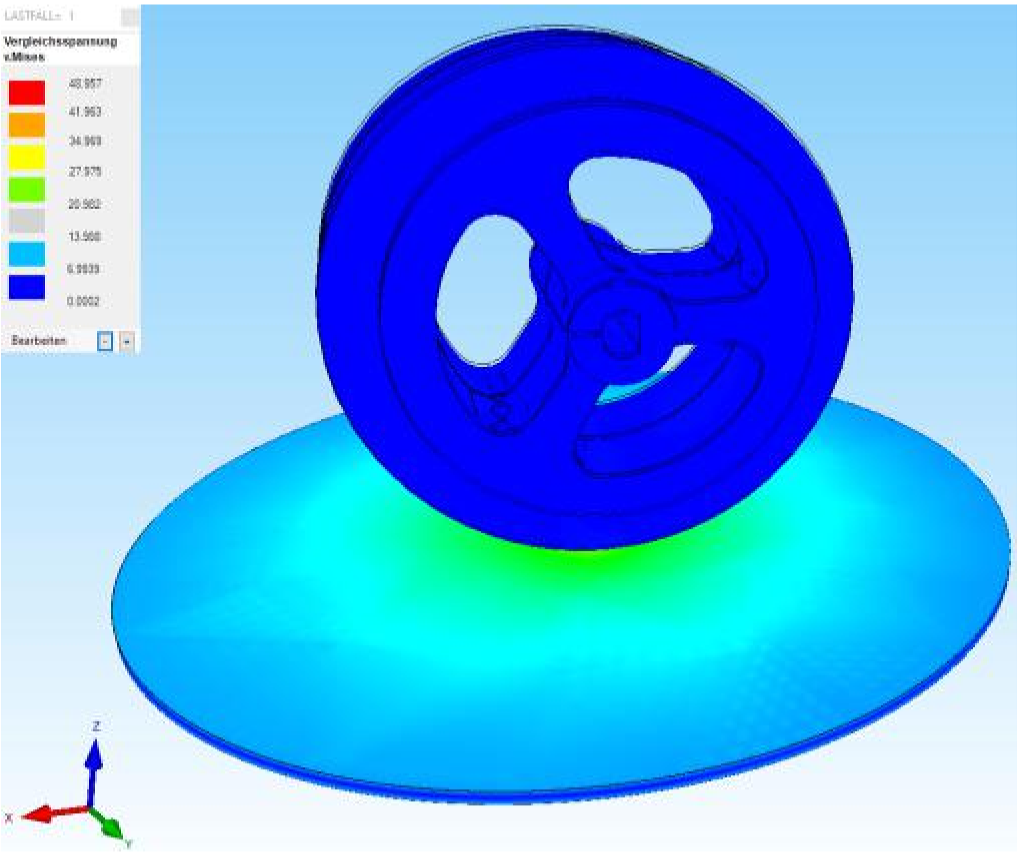
The following results are calculated with the FEM model:

	v.Mises stress (N/mm²)	
<u>Fall height 0 m</u>		
Tire	1	
Glass plate	6	
<u>Fall height 1 m</u>		
Tire	3	
Glass plate	14	
<u>Fall height 3 m</u>		
Tire	5	
Glass plate	27	
<u>Fall height 5 m</u>		
Tire	8	
Glass plate	48	(no permissible because > 45 N / mm²)

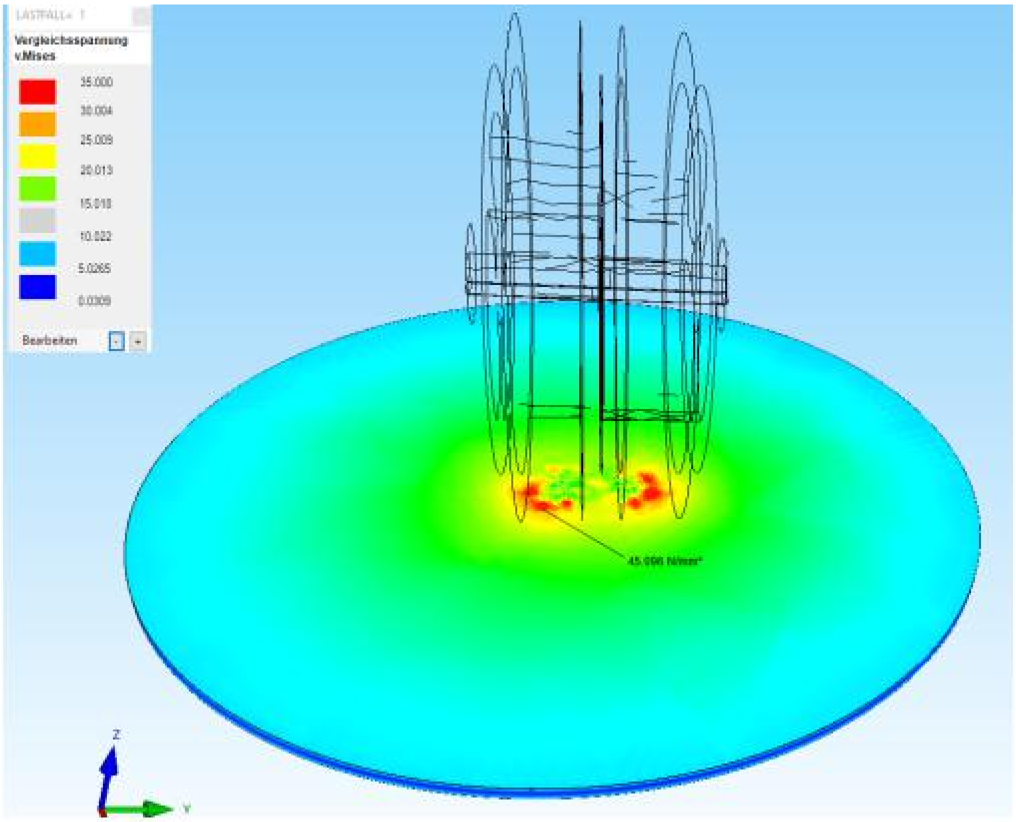
Max. Displacements in Z-direction with a Fall height of 5 m = - 4.9 mm



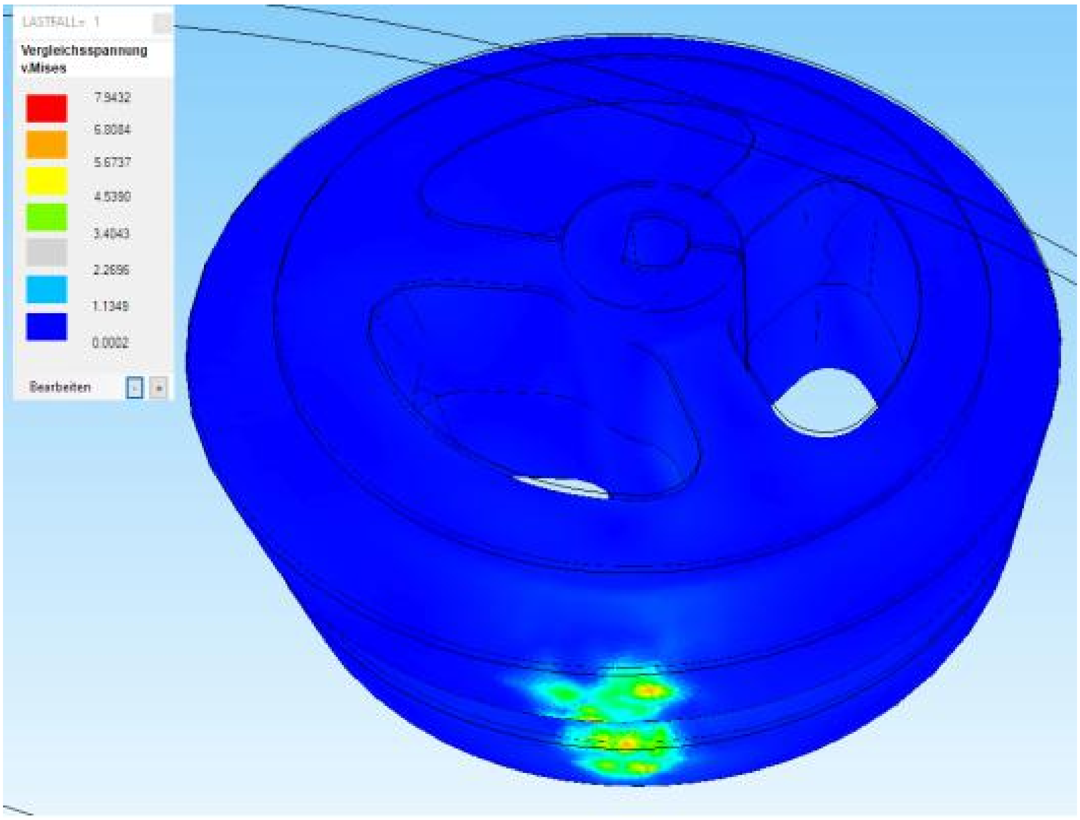
v.Mises Stress at a Fall height of 5 m = 48 N/mm²



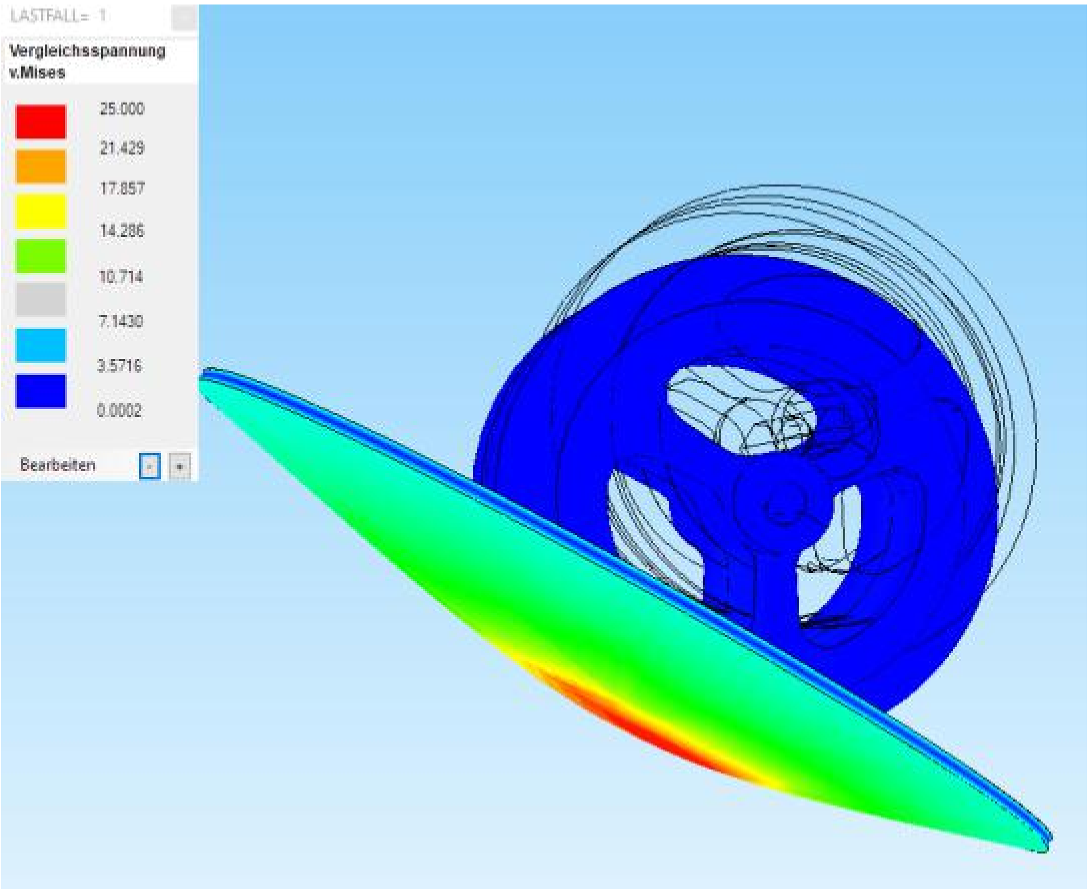
v.Mises Stress of Glass Plate at a Fall height of 5 m = 48 N/mm²



v.Mises Stress of Tire at a Fall height of 5 m = 8 N/mm²



v.Mises Stress Plate bottom with a Displacment-Factor of 22



Example 2: Glass bottle falls on glass table

The deformations and stresses are to be calculated when a 0.23 kg glass bottle falls from a height of 80 m onto a 15 mm glass plate.

Mass m of glass bottle = 0.23 kg

Density of glass = 2.48E-6 kg / mm³

Height of fall = 80 m

Speed = 40 m / s (from the following table with final speeds from free fall without air resistance)

	erreichte Endgeschwindigkeit		
sec	m/sec	km/h	Fallhöhe
1	9,8	35,3	4,91
2	19,6	70,6	19,62
3	29,4	105,9	44,15
4	39,2	141,3	78,48
5	49,1	176,6	122,63
6	58,9	211,9	176,58
7	68,7	247,2	240,35
8	78,5	282,5	313,92
9	88,3	317,8	397,31
10	98,1	353,2	490,50

Acceleration due to gravity a = 10 m / s²

Impact time t = 0.1 s

Gravitational load = m * a = 0.23 kg * 10 m / s² = 2.3 N

Impulse = mass * speed = 0.23 kg * 40 m / s = 9.2 kg * m / s

Impact force = impulse / impact time = 9.2 kg * m / s / 0.1 s = 92 N

Impact factor = impact force / gravitational load = 92 N / 2.3 N = 40

Substitute density = 40 * 2.48 kg / mm³ * 10-6 = 9.92E-05 kg / mm³

Impact mass = 40 * 0.23 kg = 9.2 kg

FEM model

The finite element model consists of 147 721 solid elements, 233 981 nodes and the following 3 element groups:

Element group 1: car tires with 58,460 TET10 elements
Element group 2: glass plate with 95 232 TET10 elements
Element group 3: MPC elements