OBSOLETE DOCUMENT
Technical Reference Only

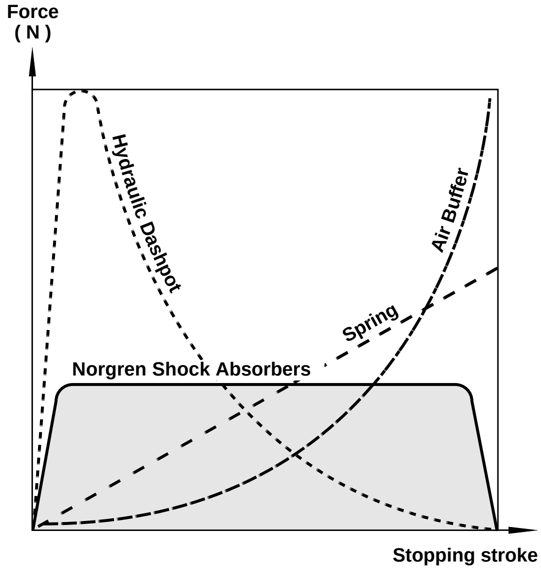
Formulae and Calculations
For Shock Absorbers

- **Uniform stopping force through the entire stroke**
- **Linearly absorbed energy of moving object**
- **Short stopping time**
- **Optimal deceleration of masses between 0,9 and 27200 kg**
- **Easy calculation and selection of shock absorbers by our PC-program PNEUCALC (Shock Absorbers)**

Please find our Shock Absorbers:
Miniature Shock Absorbers:
Page N **1.11.**007.01 and N **1.11.**011.01
Industrial Shock Absorbers:
Page N **1.11.**021.01 and N **1.11.**031.01

Ordering Information

For easier calculation and selection of Norgren shock absorbers we offer on request the PC calculation program Pneucalc (Shock Absorbers) quote: EDU/3020/1
Note: This program can be run on MS-DOS version 3.1 or higher.



Formulae and Calculations

Norgren shock absorbers provide linear deceleration and are therefore superior to other kinds of damping elements. Approximately 90% of applications can be easily calculated knowing only the following 4 parameters:

1) Mass to be decelerated (weight) m (kg)
2) Impact velocity v (m/s)
3) Propelling force F (N)
4) Cycles per hour C (/hr)

Key to Symbols used:

W_1	Kinetic Energy per cycle	(Nm)	ST	Stall torque factor (normally 2,5)	1 to 2,5
W_2	Propelling force Energy per cycle	(Nm)	M	Propelling torque	(Nm)
W_3	Total Energy per cycle (W_1+W_2)	(Nm)	g	Acceleration due to gravity = 9,81	(m/s ^{2})
W_4	Total Energy per hour ($W_3 \cdot C$)	(Nm/hr)	h	Drop height excl. shock absorber stroke	(m)
me	Effective weight	(kg)	L/R/r	Radius	(m)
m	Mass to be decelerated	(kg)	Q	Reaction force	(N)
v	Velocity of moving mass	(m/s)	m	Coefficient of friction	
V_D	Impact velocity at shock absorber	(m/s)	t	Deceleration time	(sec)
F	Propelling force	(N)	'g's	Deceleration rate	('g's)
C	Cycles per hour	(/hr)	s	S/A Stroke	(m)
P	Motor Power	(kW)			

V or V_D is the final impact velocity of the mass. With accelerating motion (propelling force) the final impact velocity can be 1,5 to 2 times higher than the average velocity. Please take this into account when calculating the kinetic energy (W_1).
The effective weight (me) is an imaginary weight.
It can either be - the same as the actual weight
- or a weight representing the propelling force plus the actual weight

This me figure is one of the parameters needed for choosing a shock absorber from the capacity chart.
There are 4 examples to calculate me:

Mass without propelling force

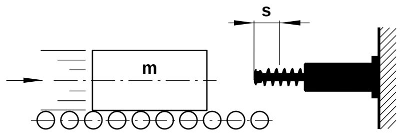
Formulae

$$me = \frac{2 \cdot W_3}{v^2} = m$$

Example:

m = 100 kg
v = 2 m/s
W_1 = 200 Nm
W_2 = 0
W_3 = 200 Nm

$$me = \frac{2 \cdot 200}{2^2} = 100 \text{ kg} = m$$



Mass with propelling force

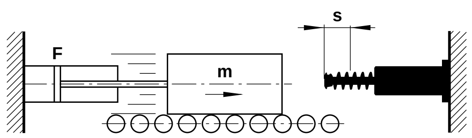
Formulae

$$me = \frac{2 \cdot W_3}{v^2}$$

Example:

m= 100 kg
F= 2000 N
v= 2 m/s
s= 0,1 m
W_1= 200 Nm
W_2= 200 Nm
W_3= 400 Nm

$$me = \frac{2 \cdot 400}{2^2} = 200 \text{ kg} \neq m$$



Mass without propelling force, directly on shock absorber

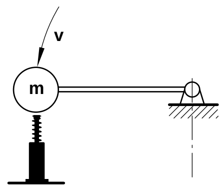
Formulae

$$me = \frac{2 \cdot W_3}{v^2} = m$$

Example:

m = 20 kg
v = 2 m/s
W_1 = 40 Nm

$$me = \frac{2 \cdot 40}{2^2} = 20 \text{ kg} = m$$



Mass without propelling force, indirectly on shock absorber

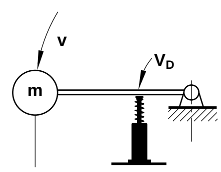
Formulae

$$me = \frac{2 \cdot W_1}{V_D^2}$$

Example:

m = 20 kg
v = 2 m/s
V_D = 0,5 m/s
W_1 = 40 Nm

$$me = \frac{2 \cdot 40}{0,5^2} = 320 \text{ kg} \neq m$$



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Examples how to choose a shock absorber:

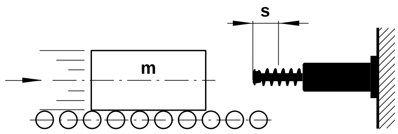
1 Mass without propelling force

Formulae

$W_1 = 0{,}5 \cdot m \cdot v^2$
$W_2 = \text{zero}$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$me = \frac{2 \cdot W_3}{v^2} = m$

Example 1

m = 20 kg	$W_1 = 0{,}5 \cdot 20 \cdot 1{,}5^2$	= 22,5 Nm
v = 1,5 m/s	$W_3 = W_1$	
C = 500/h	$W_4 = 22{,}5 \cdot 500$	= 11250 Nm/h
s = 0,012 m (nominal)	$me = 2 \cdot 22{,}5 : 2{,}25$	= 20 kg



Based upon W_3, W_4, me and the stroke s, the selection from the capecity chart is: M/59620/AX

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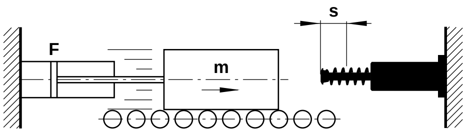
2 Mass with propelling force

Formulae

$W_1 = 0{,}5 \cdot m \cdot v^2$
$W_2 = F \cdot s$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$me = \frac{2 \cdot W_3}{}$

Example 2

m = 50 kg	$W_1 = 0{,}5 \cdot 50 \cdot 1^2$	= 25 Nm
v = 1 m/s	$W_2 = 1500 \cdot 0{,}025$	= 37,5 Nm
F = 1500 N	$W_3 = 25 + 37{,}5$	= 62,5 Nm
C = 800/h	$W_4 = 62{,}5 \cdot 800$	= 50000 Nm/h
s = 0,025 m (nominal)	$me = 2 \cdot 62{,}5 : 1^2$	= 125 kg



Note:
2.1 For vertically upward moving mass $W_2 = (F - m \cdot g) \cdot s$
2.2 For vertically downward moving mass $W_2 = (F + m \cdot g) \cdot s$
Selected from the capecity chart is: M/59625/AX/25

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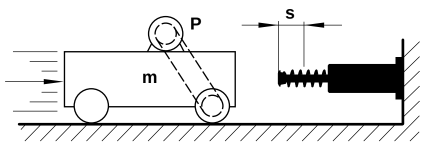
3 Mass with motor drive

Formulae

$W_1 = 0{,}5 \cdot m \cdot v^2$
$W_2 = \frac{1000 \cdot P \cdot ST \cdot s}{v}$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$me = \frac{2 \cdot W_3}{v^2}$

Example 3

m = 200 kg	$W_1 = 0{,}5 \cdot 200 \cdot 0{,}8^2$	= 64 Nm
v = 0,8 m/s	$W_2 = 1000 \cdot 0{,}5 \cdot 2{,}5 . 0{,}025 : 0{,}8$	= 39 Nm
ST = 2,5	$W_3 = 64 + 39$	= 103 Nm
P = 0,5 kW	$W_4 = 103 \cdot 100$	= 10300 Nm/h
C = 100/h	$me = 2 \cdot 103 : 0{,}8^2$	= 322 kg
s = 0,025 m (nominal)		



Selected from the capecity chart is: C/59838/1

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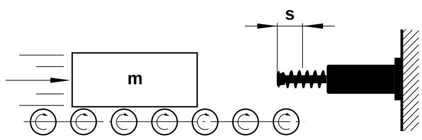
4 Mass on driven rollers

Formulae

$W_1 = 0{,}5 \cdot m \cdot v^2$
$W_2 = \mu \cdot m \cdot g \cdot s$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$me = \frac{2 \cdot W_3}{v^2}$

Example 4

m = 55 kg	$W_1 = 0{,}5 \cdot 55 \cdot 1{,}5^2$	= 62 Nm
v = 1,5 m/s	$W_2 = 55 \cdot 0{,}2 \cdot 9{,}81 \cdot 0{,}025$	= 3 Nm
C = 1000/h	$W_3 = 62 + 3$	= 65 Nm
µ = 0,2 (steel/steel)	$W_4 = 65 \cdot 1000$	= 65000 Nm/h
s = 0,025 m (nominal)	$me = 2 \cdot 65 : 1{,}5^2$	= 57,8 kg



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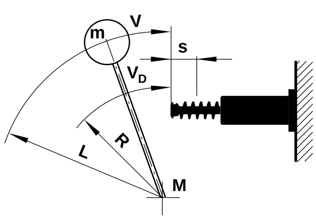
5 Swinging mass with propelling force

Formulae

$W_1 = 0{,}5 \cdot m \cdot v^2$
$W_2 = \frac{M \cdot s}{R}$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$V_D = \frac{V \cdot R}{L}$
$me = \frac{2 \cdot W_1}{V_D^2}$

Example 5

m = 150 kg	$W_1 = 0{,}5 \cdot 150 \cdot 1^2$	= 75 Nm
v = 1 m/s	$W_2 = 200 \cdot 0{,}025 : 0{,}5$	= 10 Nm
M = 200 Nm	$W_3 = 75 + 10$	= 85 Nm
R = 0,5 m	$W_4 = 85 \cdot 250$	= 21250 Nm/h
L = 0,8 m	$V_D = 1 \cdot 0{,}5 : 0{,}8$	= 0,6 m/s
C = 250/h	$me = 2 \cdot 85 : 0{,}6^2$	= 472 kg
s = 0,025 m (nominal)		



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6 Free falling mass

Formulae

$W_1 = m \cdot g \cdot h$
$W_2 = m \cdot g \cdot s$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$V_D = \sqrt{2 \cdot g \cdot h}$
$me = \frac{2 \cdot W_3}{V_D^{2}}$

Example 6

m = 20 kg	W_1= 20 · 9, 81· 0,5	= 98 Nm
h = 0,5 m	W_2= 20 · 9,81 : 0,025	= 5 Nm
C = 500/h	W_3= 98 + 5= 103 Nm	
s = 0,025 m	W_4= 103 · 500	= 51500 Nm/h
	$V_D = \sqrt{2 \cdot 9{,}81 : 0{,}5}$	= 3,13 m/s
	$me = \frac{2 \cdot 103}{3{,}13^{2}}$	= 21 kg

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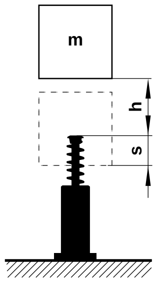
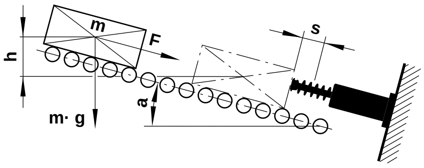


6.1 Mass rolling/sliding down incline

Formulae

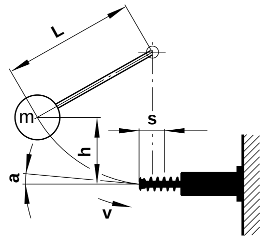
$F = m \cdot g \cdot \sin\alpha$
$W_1 = m \cdot g \cdot h$
$W_2 = m \cdot g \cdot \sin \cdot \alpha\, s$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$V_D = \sqrt{2 \cdot g \cdot h}$
$me = \frac{2 \cdot W_3}{V_D^{2}}$



6.2 Mass free falling about a pivot point

Calculation as per example 6.1
Check side load

Arctan α = s/L



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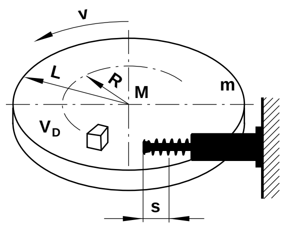
7 Rotary index table with propelling torque

Formulae

$W_1 = 0{,}25 \cdot m \cdot v^2$
$W_2 = \frac{M \cdot s}{R}$
$W_3 = W_1 + W_2$
$W_4 = W_3 \cdot C$
$V_D = \frac{v \cdot R}{L}$
$me = \frac{2 \cdot W_3}{V_D^{2}}$

Example 7

m = 250 kg	W_1= 0,25 · 250 · 1,1 ^{2}	= 76 Nm
v = 1,1 m/s	W_2= 1000 · 0,025 : 0,8	= 31 Nm
M = 1000 Nm	W_3= 76 + 31	= 107 Nm
s = 0,025 m	W_4= 107 · 600	= 64200 Nm/h
L = 1,25 m	V_D= 1,1 · 0,8 : 1,25	= 0,7 m/s
R = 0,8 m	me= 2 · 107 : 0,7 ^{2}	= 437 kg
C = 600/h		



Note:
Formulae given are only correct for circular table with uniform weight distribution.
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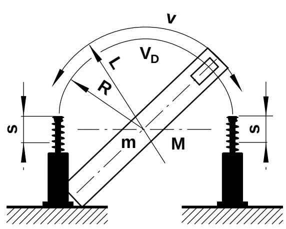
8 Swinging Arm with propelling torque

Formulae

$W_1 = 0{,}5 \cdot m \cdot (v \cdot 0{,}6)^2$
$W_2 = \frac{M \cdot s}{R}$
$W_3 = W_1 + W_2$
$W_4 = W_3 . C$
$V_D = \frac{v \cdot R}{L}$
$me = \frac{2 \cdot W_3}{V_D^{2}}$

Example 8

m = 50 kg	W_1= 0,5 · 50 · (2·0,6) ^{2}	= 36 Nm
v = 2 m/s	W_2= 500 · 0,025 : 0,8	= 16 Nm
M = 500 Nm	W_3= 36 + 16	= 52 Nm
s = 0,025 m	W_4= 52 . 950	= 49400 Nm/h
L = 1,5 m	V_D= 2 · 0,8 : 1,5	= 1,1 m/s
R = 0,8 m	me= 2 · 52 : 1,1 ^{2}	= 86 kg
C = 950/h		



Note:
Formulae are for arm with uniform weight distribution
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9 Swinging Arm with propelling force

Formulae

$W_1 = 0{,}5 \cdot m \cdot (v \cdot 0{,}6)^2$

$W_2 = \frac{F \cdot r \cdot s}{R} = \frac{M \cdot s}{R}$

$W_3 = W_1 + W_2$

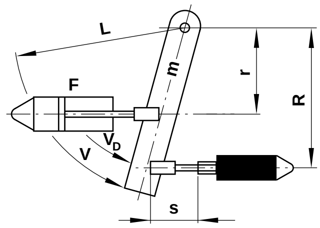
$W_4 = W_3 \,.\, C$

$V_D = \frac{v \cdot R}{L}$

$me = \frac{2 \cdot W_3}{V_D^{\,2}}$

Example 9

$m = 40$ kg	$W_1 = 0{,}5 \cdot 40 \cdot (2 \cdot 0{,}6)^2$	= 28,8 Nm
$v = 2$ m/s	$W_2 = 700 \cdot 0{,}6 \cdot 0{,}05 : 0{,}8$	= 26,2 Nm
$F = 700$ N	$W_3 = 28{,}8 + 26{,}2$	= 55 Nm
$M = 420$ Nm	$W_4 = 55 \cdot 1800$	= 99000 Nm/h
$s = 0{,}05$ m	$V_D = 2 \cdot 0{,}8 : 1{,}2$	= 1,3 m/s
$r = 0{,}6$ m	$me = 2 \cdot 55 : 1{,}3^2$	= 62 kg
$R = 0{,}8$ m		
$L = 1{,}2$ m		
$C = 1800$/h		



Note:
Formulae are for arm with uniform weight distribution
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10 Mass lowered at controlled speed

Formulae

$W_1 = 0{,}5 \cdot m \cdot v^2$

$W_2 = m \cdot g \cdot s$

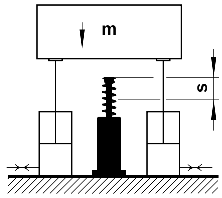
$W_3 = W_1 + W_2$

$W_4 = W_3 \cdot C$

$me = \frac{2 \cdot W_3}{v^2}$

Example 10

$m = 100$ kg	$W_1 = 100 \cdot 0{,}8^2 \cdot 0{,}5$	= 32 Nm
$v = 0{,}8$ m/s	$W_2 = 100 \cdot 9{,}81 \cdot 0{,}025$	= 24,5 Nm
$s = 0{,}025$ m (nominal)	$W_3 = 32 + 24{,}5$	= 56,5 Nm
$C = 5$/h	$W_4 = 56{,}5 \cdot 5$	= 282,5 Nm/h
	$me = 2 \cdot 56{,}5 : 0{,}8^2$	= 176,6 kg



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Reaction Force Q (N)

$Q = \frac{1{,}2 \cdot W_3}{s}$

Stopping time t (s)

$t = \frac{2{,}6 \cdot s}{V_D}$

Deceleration Rate 'g's (m/s²)

$\text{'g's} = \frac{0{,}6 \cdot V_D^{\,2}}{g \cdot s}$

These formulae are valid for all examples. For adjustable shock absorbers these values only apply when the shock absorbers are correctly adjusted. Add safety margin if necessary

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Warning

These products are intended for use in industrial compressed air systems only. Do not use these products where pressures and temperatures can exceed those listed under **'Technical Data'**.

Before using these products with fluids other than those specified, for non-industrial applications, life-support systems, or other applications not within published specifications, consult NORGREN.

Through misuse, age, or malfunction, components used in fluid power systems can fail in various modes.

The system designer is warned to consider the failure modes of all component parts used in fluid power systems and to provide adequate safeguards to prevent personal injury or damage to equipment in the event of such failure.
System designers must provide a warning to end users in the system instructional manual if protection against a failure mode cannot be adequately provided.
System designers and end users are cautioned to review specific warnings found in instruction sheets packed and shipped with these products.

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