

# General Relativity Animations

## The Inertial Balance

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## 1. Animation on Inertial Balance:

- The *weight* of an object depends on gravity
  - e.g. the same object weighs less on the Moon than on Earth; because the Moon's gravity is less.
- But *mass* is the same everywhere – an object has the same mass on the Moon, on Earth, or in space, etc.
- The *inertial balance* measures difference in *mass*.  
→ For a given spring, the frequency of oscillation is inversely proportional to the object's mass.

# Weight Depends on Where You Weigh it, But (Rest) Mass is Always the Same Value.

For an object which weighs 100 pounds on Earth:

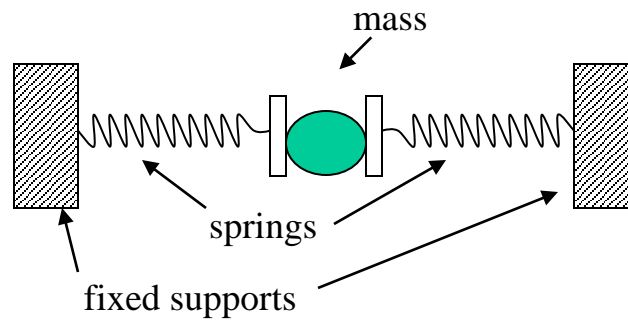
<u>Location</u>	<u>Weight</u>	<u>Mass</u>
Earth	100 pounds	45.5 kilograms
Mars	37.9 pounds	45.5 kilograms
Moon	16.6 pounds	45.5 kilograms
Outer Space	0	45.5 kilograms

# The Inertial Balance Scale\*

Oscillation Period =  $1/\text{freq} = K \cdot m$

where:  $m$  is mass, and

$K$  is spring constant



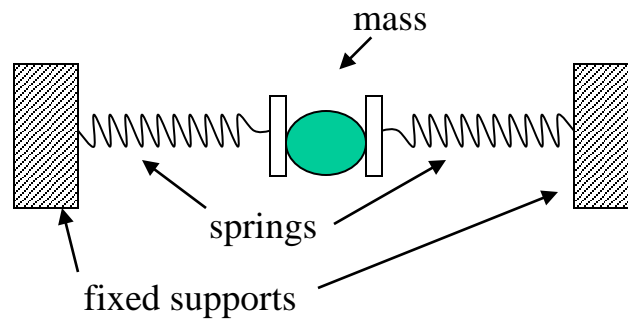
\* p. 65, 66, *Understanding Einstein's Theories of Relativity, Man's New Perspective on the Cosmos*, S. Gibilisco

# The Inertial Balance Scale\*

Oscillation Period =  $1/\text{freq} = \sqrt{K \cdot m}$

where:  $m$  is mass, and

$K$  is spring constant



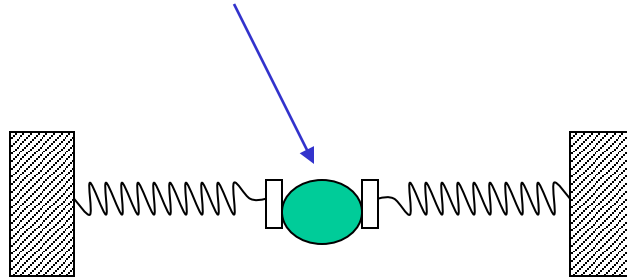
## An Inertial Balance Scale Measures:

- an object's *mass*
- not its weight

\* p. 65, 66, *Understanding Einstein's Theories of Relativity, Man's New Perspective on the Cosmos*, S. Gibilisco

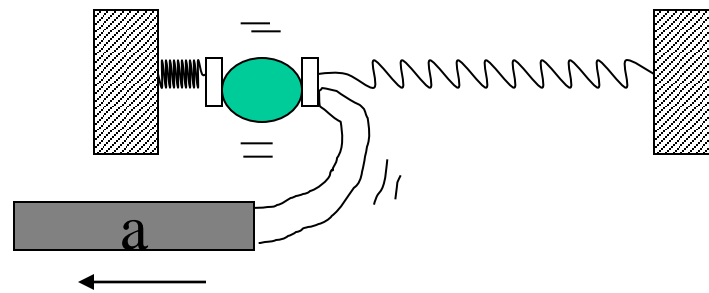
Assume a mass of:

**50 kilograms**



Assume a mass of:

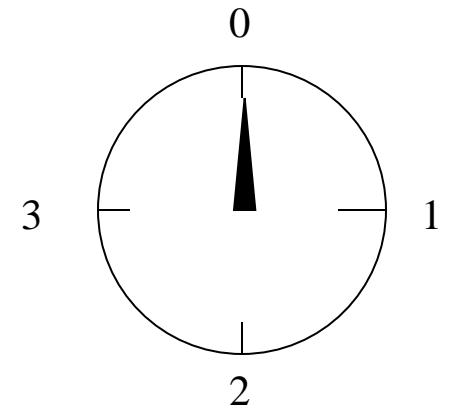
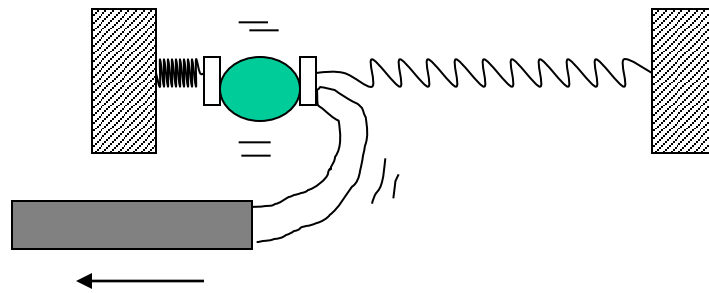
**50 kilograms**



Push mass to one side

Assume a mass of:

**50 kilograms**

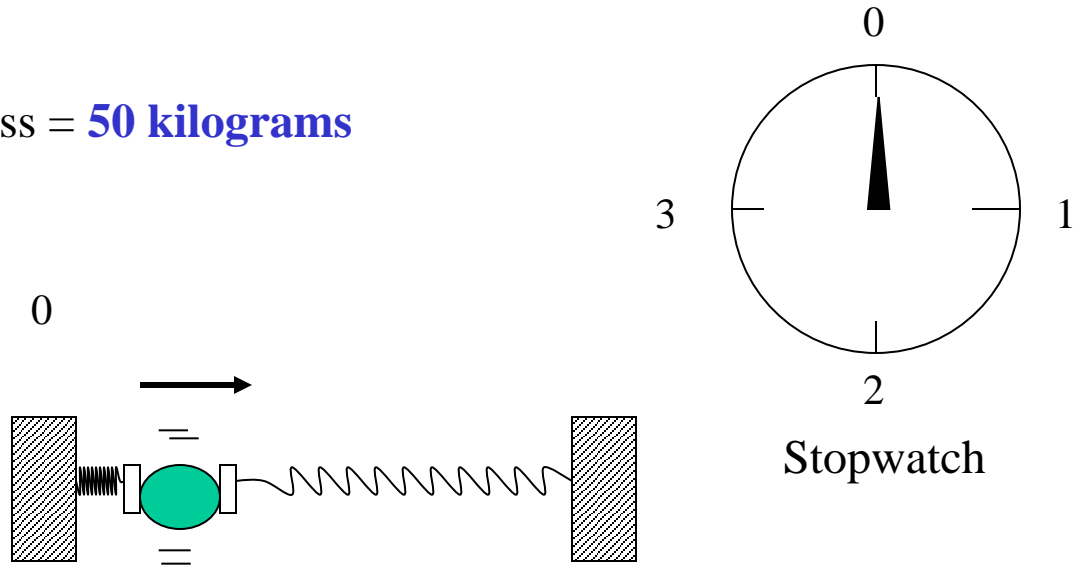


Stopwatch

Time with  
Stopwatch

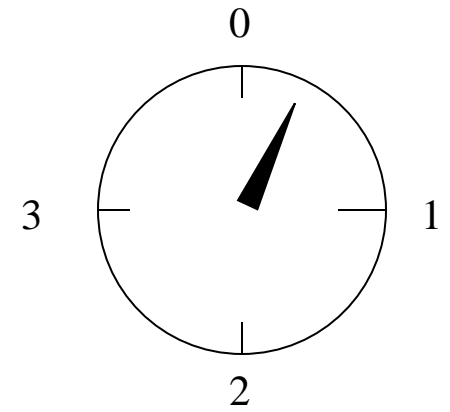


Mass = **50 kilograms**

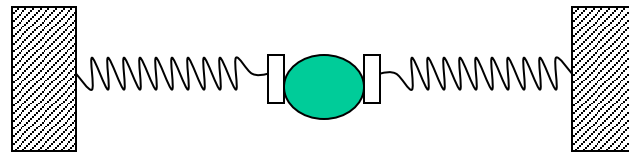


**Then let go!**

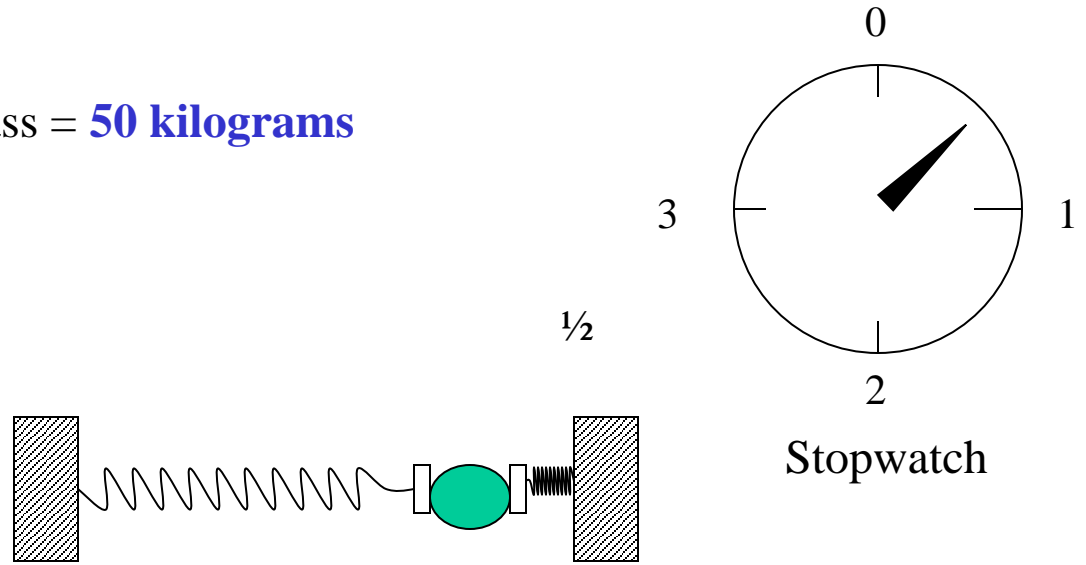
Mass = **50 kilograms**



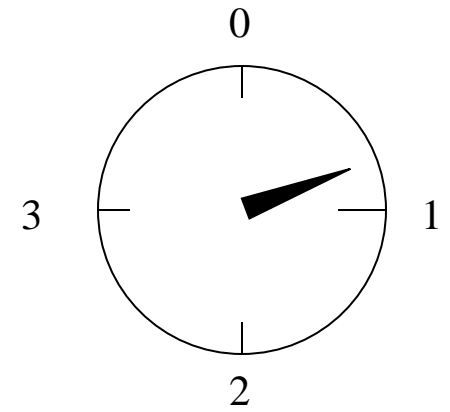
Stopwatch



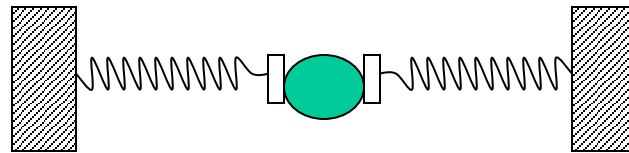
Mass = **50 kilograms**



Mass = **50 kilograms**

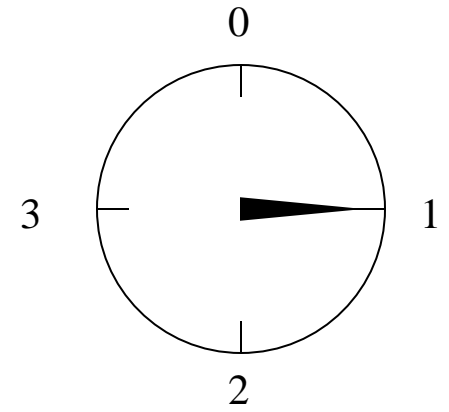
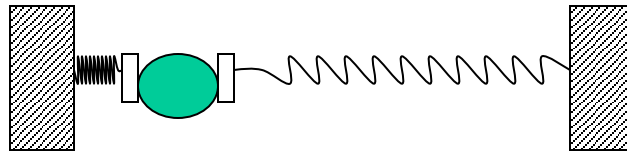


Stopwatch



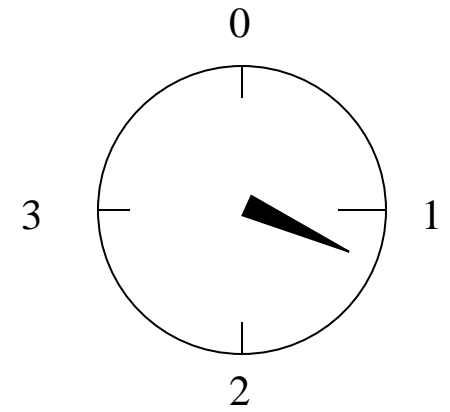
Mass = **50 kilograms**

1

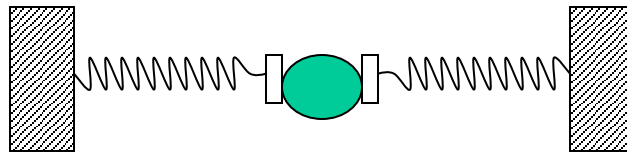


Stopwatch

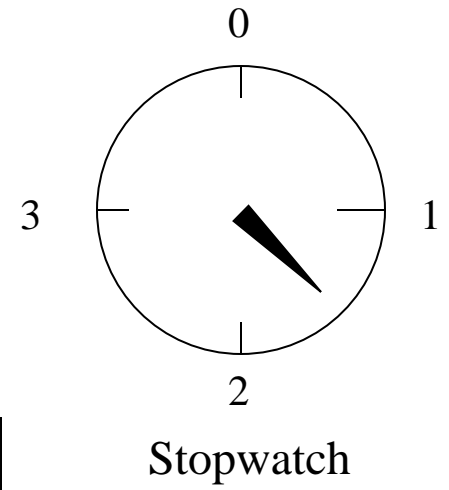
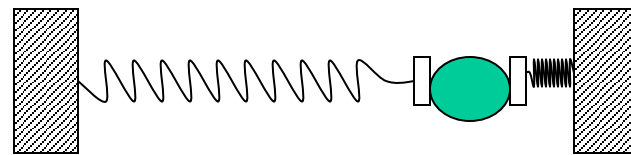
Mass = **50 kilograms**



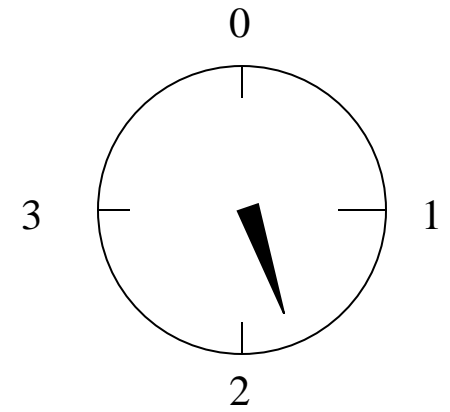
Stopwatch



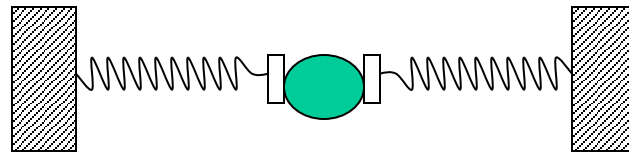
Mass = **50 kilograms**



Mass = **50 kilograms**



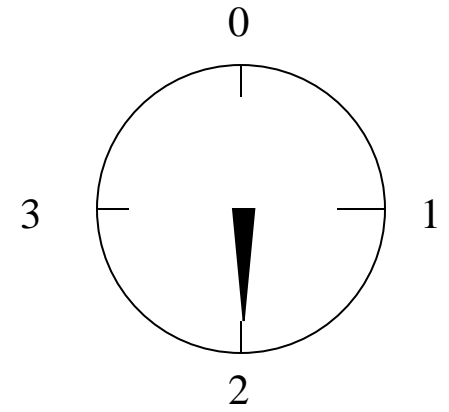
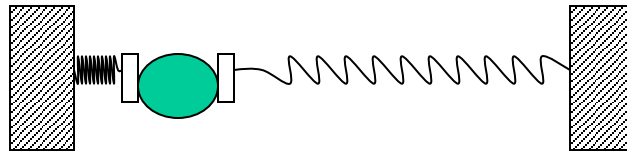
Stopwatch





Mass = **50 kilograms**

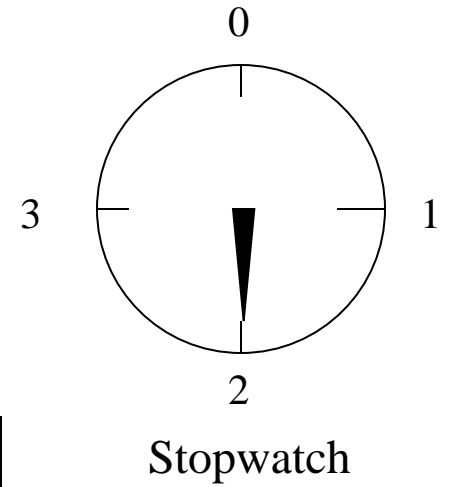
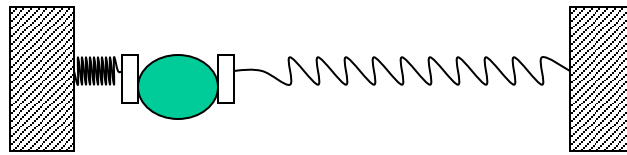
2



Stopwatch

Mass = **50 kilograms**

2

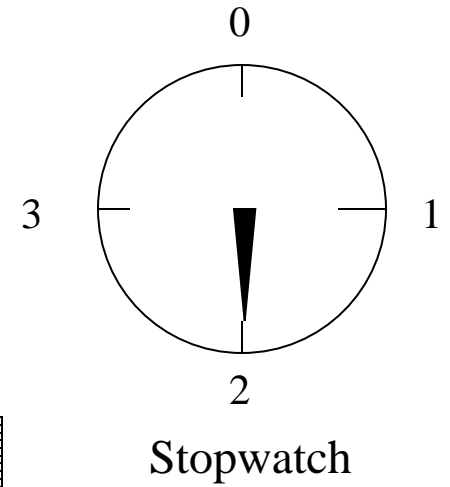
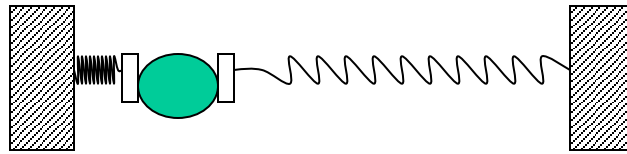


Makes *two* complete cycles back and forth

- **in 2 seconds**

Mass = **50 kilograms**

2

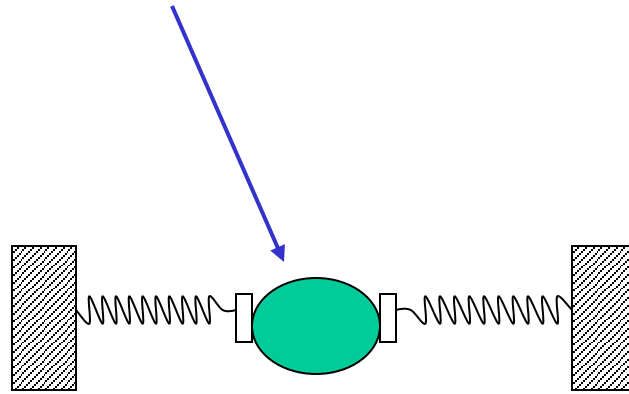


Makes *two* complete cycles back and forth

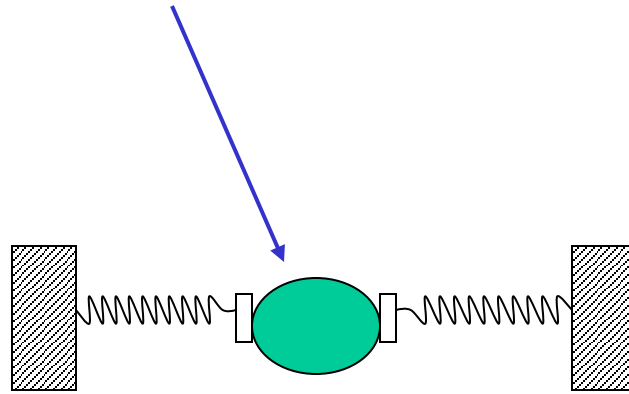
- **in 2 seconds**

Frequency: **One cycle per second**

Replace with twice the mass  
or **100 kilograms**

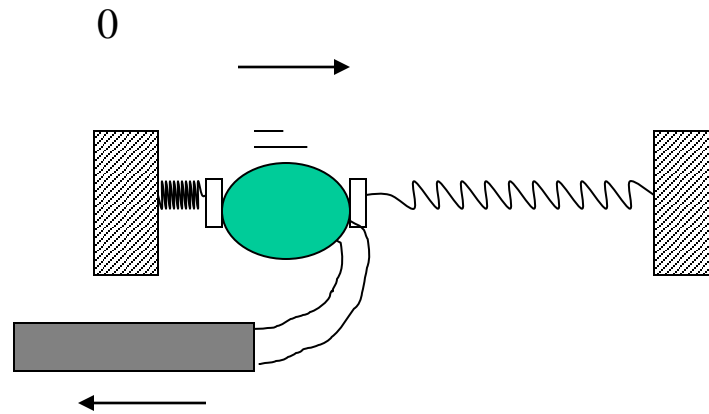


Replace with twice the mass  
or **100 kilograms**



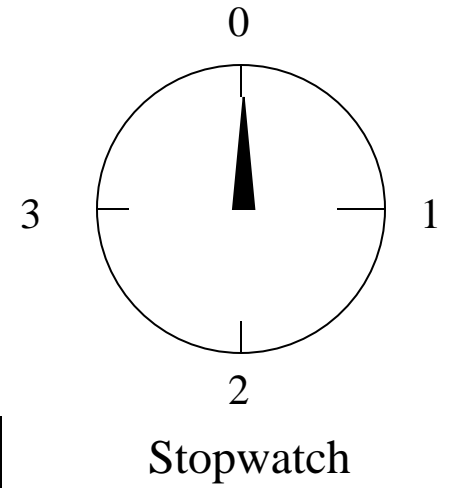
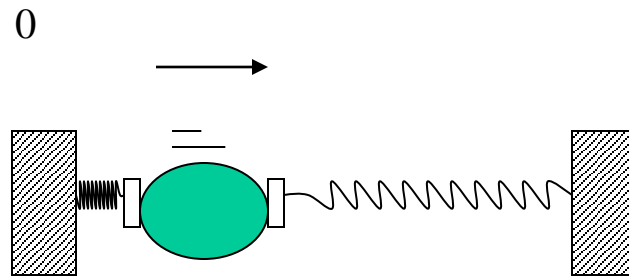
**What is *its* frequency?**

Mass = **100 kilograms**



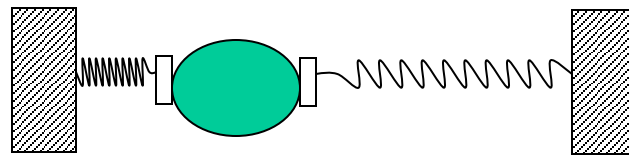
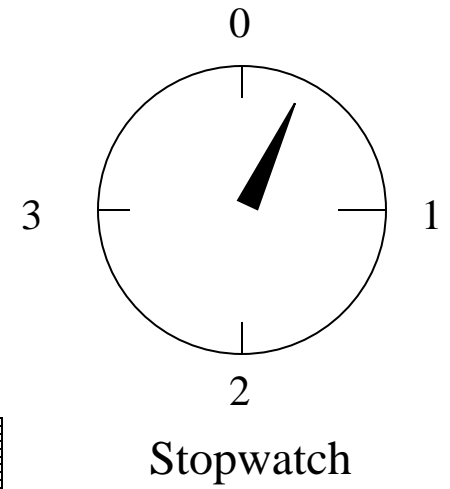
Push mass to one side

Mass = **100 kilograms**



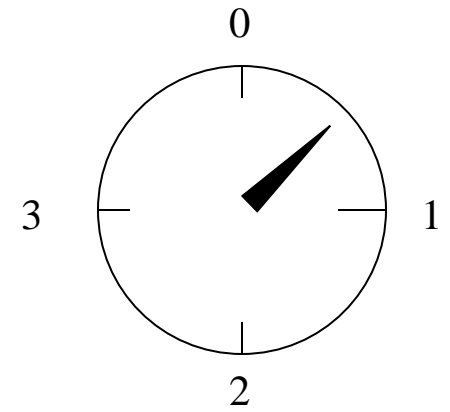
Let go

Mass = **100 kilograms**

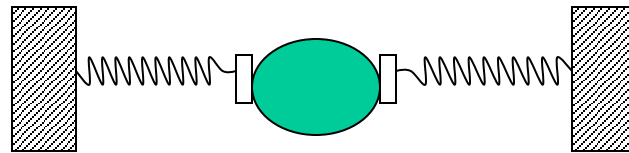




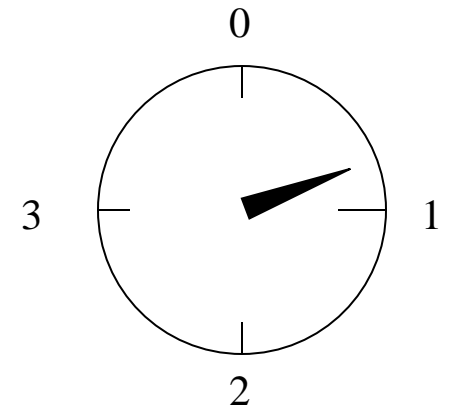
Mass = **100 kilograms**



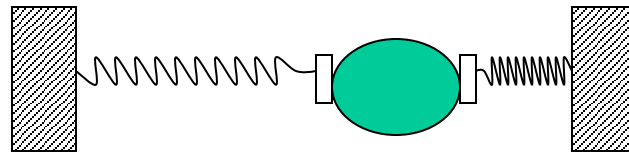
Stopwatch



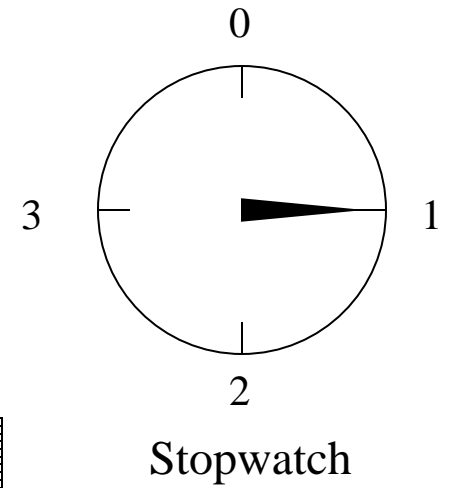
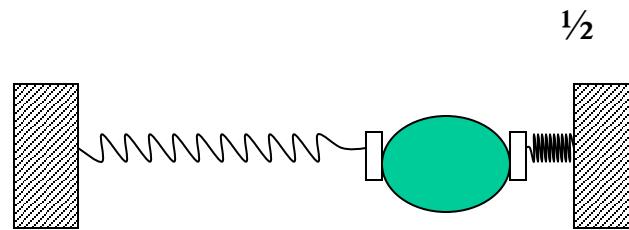
Mass = **100 kilograms**



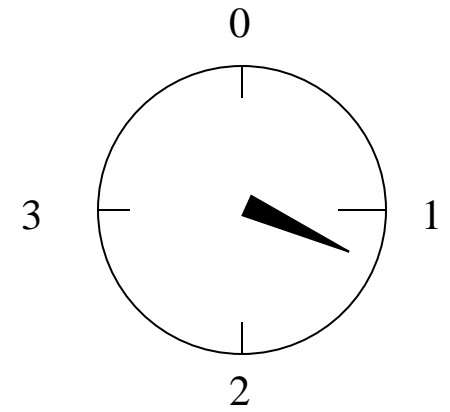
Stopwatch



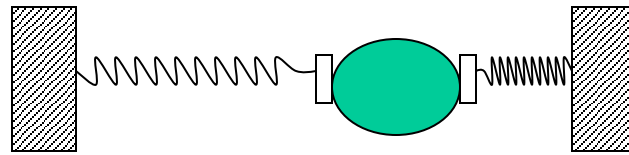
Mass = **100 kilograms**



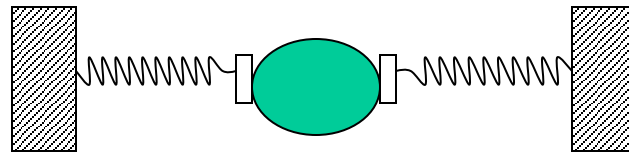
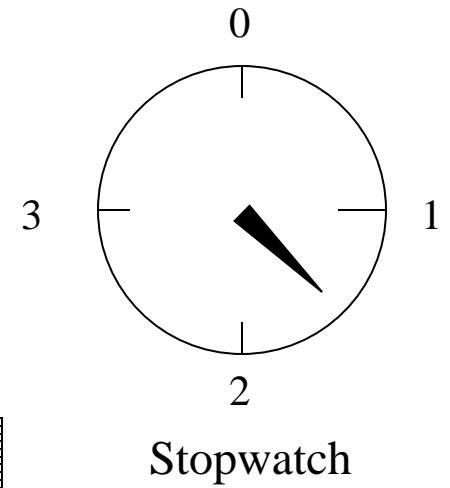
Mass = **100 kilograms**



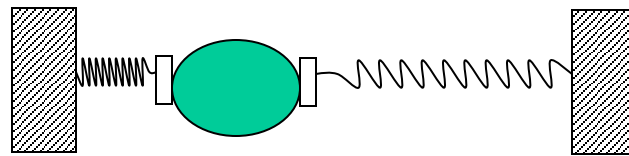
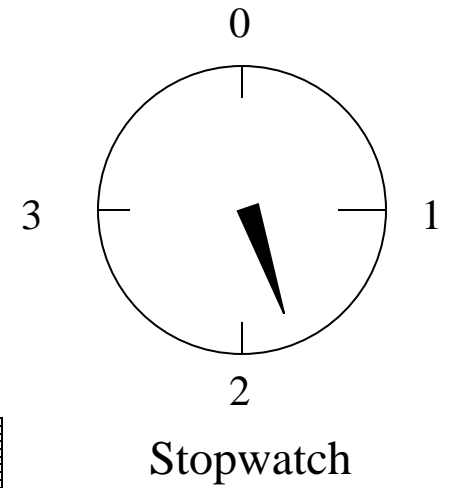
Stopwatch



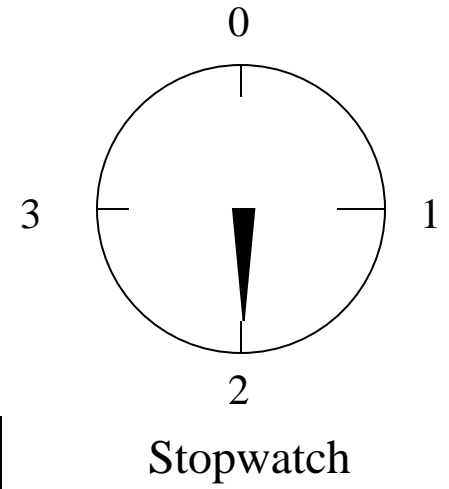
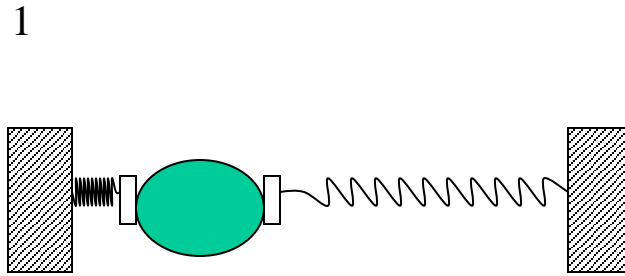
Mass = **100 kilograms**



Mass = **100 kilograms**

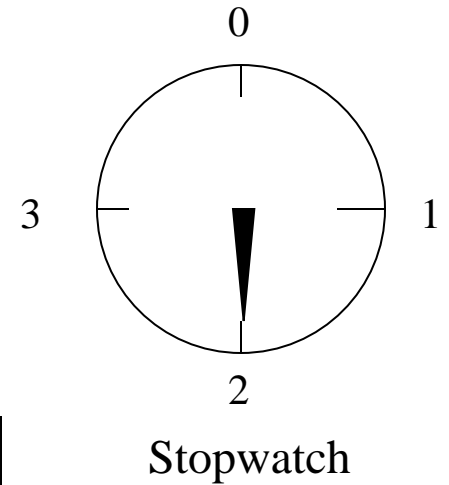
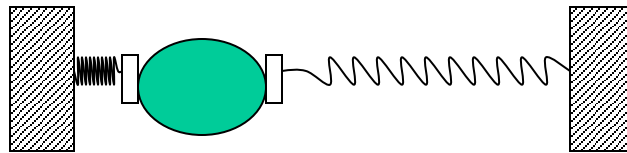


Mass = **100 kilograms**



Mass = **100 kilograms**

1



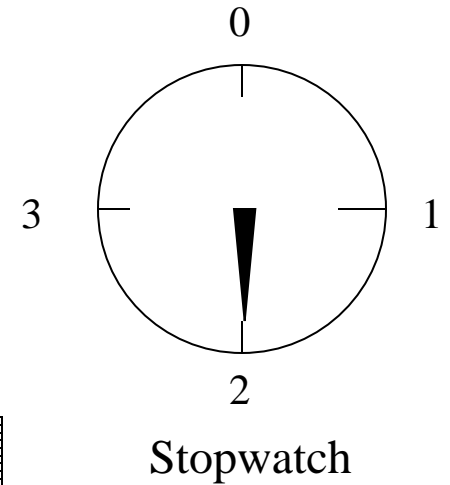
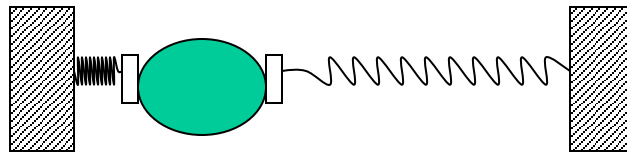
Makes only *one* complete cycle back and forth

- **in 2 seconds**



Mass = **100 kilograms**

1



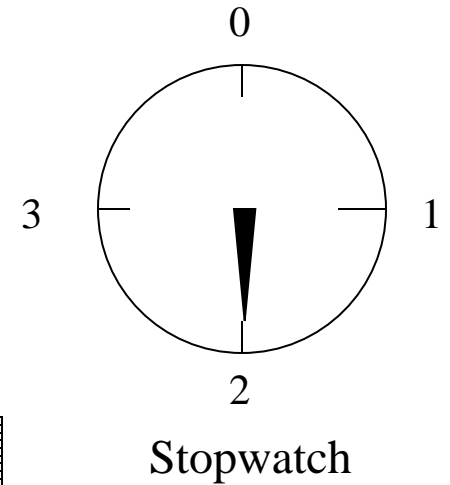
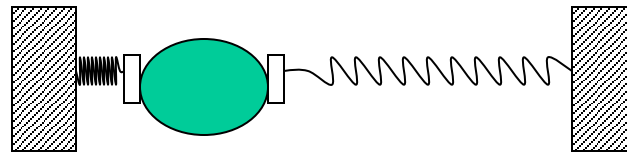
Makes only *one* complete cycle back and forth

- **in 2 seconds**

Frequency: **One-half cycle per second**

Mass = **100 kilograms**

1



Makes only *one* complete cycle back and forth

- **in 2 seconds**

Frequency: **One-half cycle per second**

**More mass means *slower* period**

# Inertial Balance Summary

<u>MASS</u>	<u>FREQUENCY</u> (cycles per second)	<u>PERIOD</u> (time to make one cycle)
50 kg.	1 Hz	1 second
100 Kg.	$\frac{1}{2}$ Hz	2 second
200 kg	$\frac{1}{4}$ Hz	4 seconds

(A Hertz (Hz) is one cycle per second)

# Inertial Balance Summary

	<u>MASS</u>	<u>FREQUENCY</u> (cycles per second)	<u>PERIOD</u> (time to make one cycle)	
	50 kg.	1 Hz	1 second	
<b>Heavier</b>	100 Kg.	$\frac{1}{2}$ Hz	2 second	<b>Slower</b>
	200 kg	$\frac{1}{4}$ Hz	4 seconds	

(A Hertz (Hz) is one cycle per second)

**The heavier the mass, the slower it cycles**

End of Animation