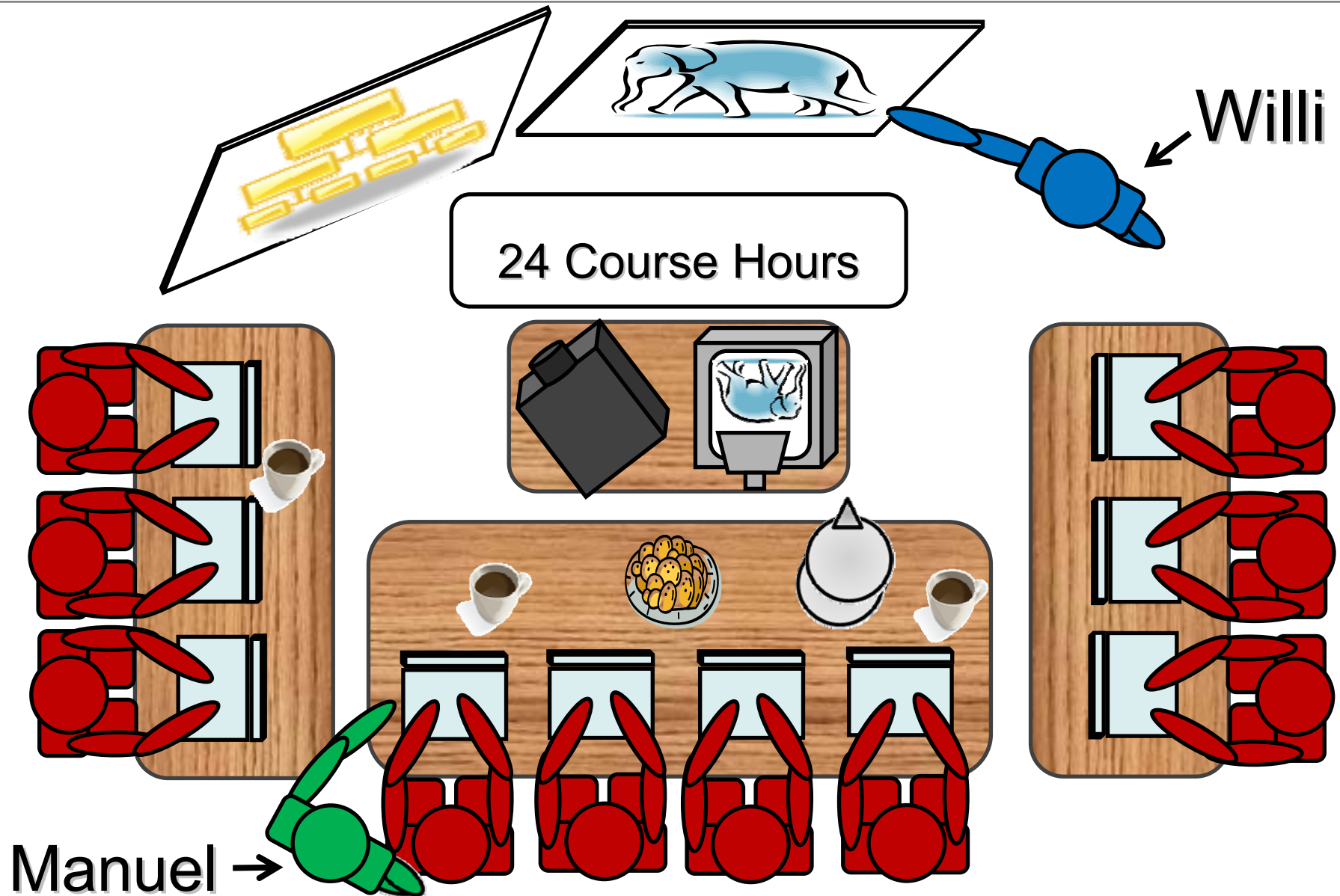


Teaching Modelica for Engineers at Technische Universität Braunschweig

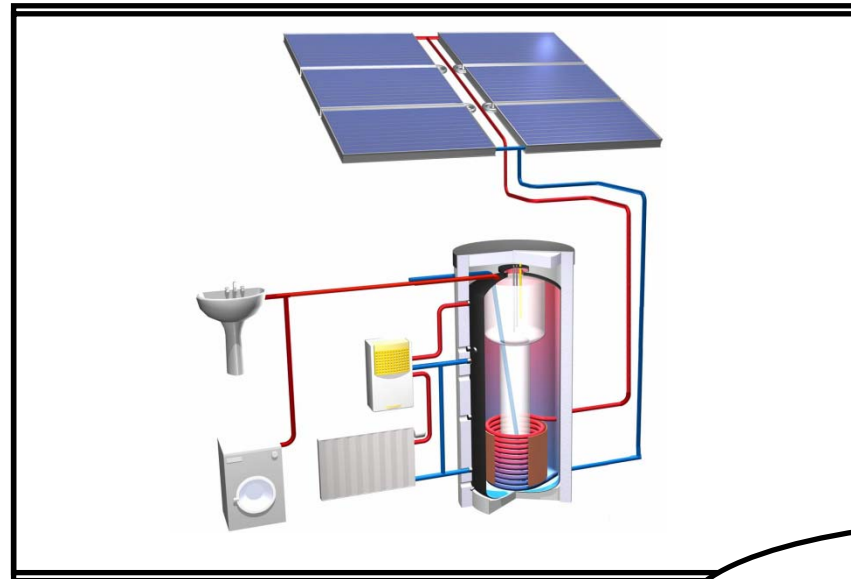
W. Tegethoff, M. Gräber, R. Kossel, C. Richter

1. Classroom and Exam
2. Thinking in Objects
3. Course Example: Refrigeration Cycle
4. Course Example: Tire Service Garage
5. Course Example: Lumped Capacitors
6. Conclusion

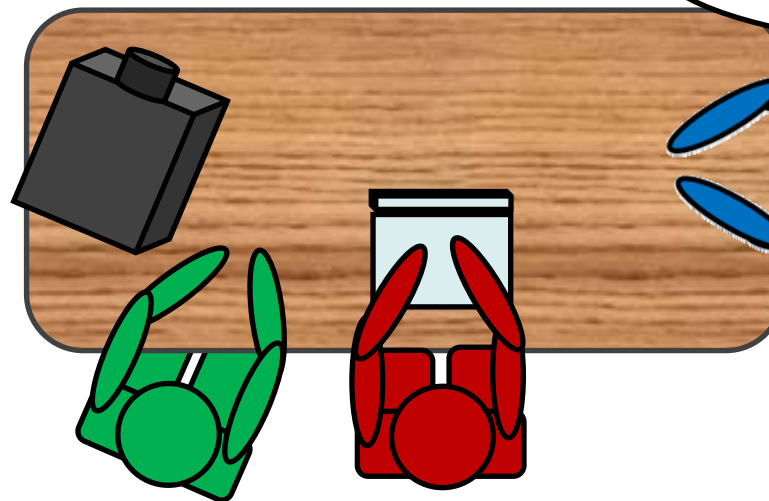


Learning targets:

- Modeling language Modelica
- Numeric for solving DAE-Systems (heuristic)
- Object-oriented analysis



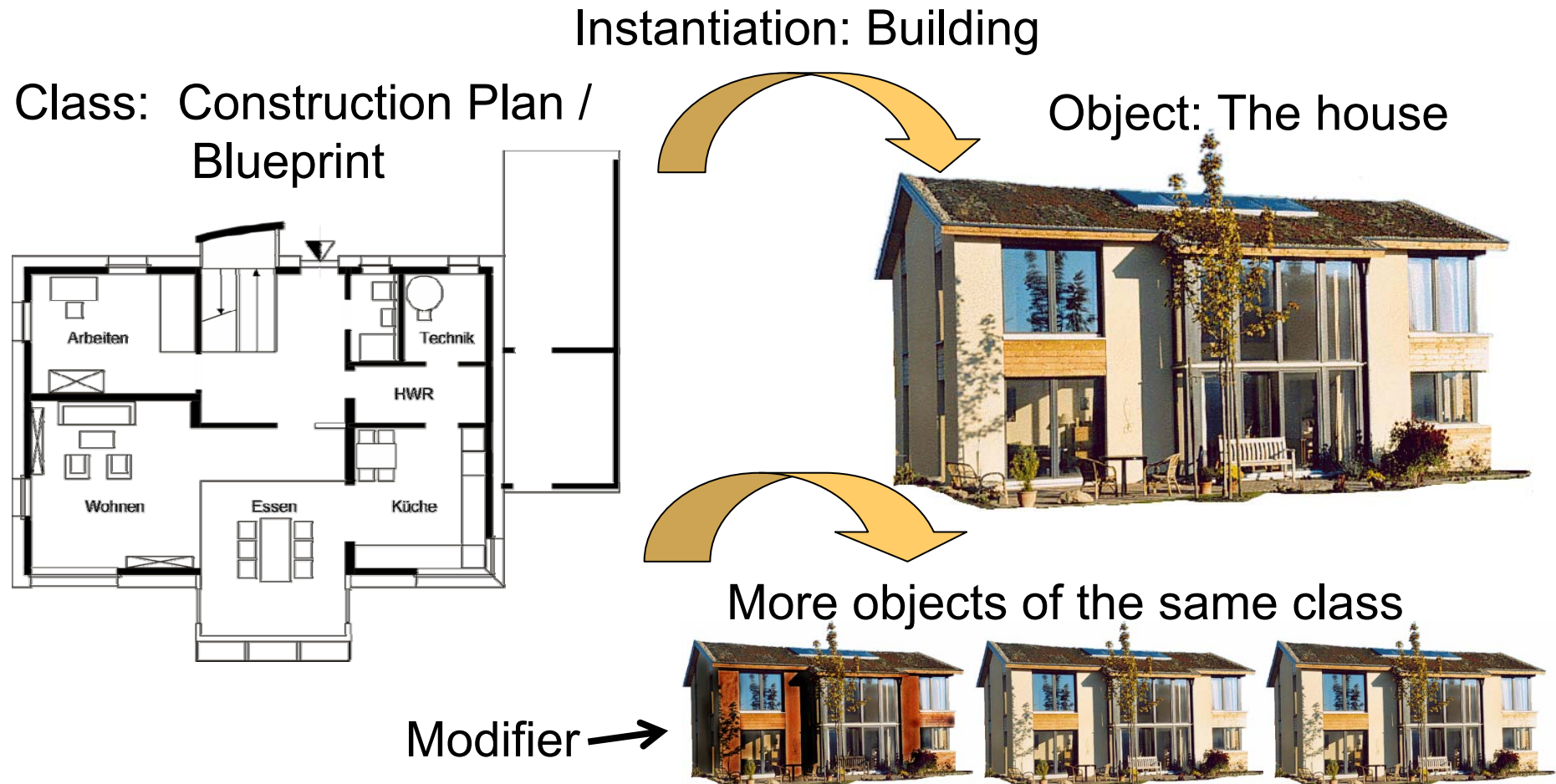
Exam Time:
30 Minutes



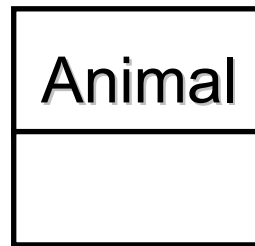
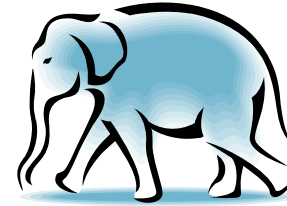
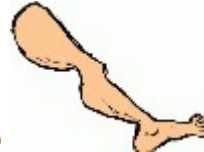
What is Polymorphism?

1. Classroom and Exam
- 2. Thinking in Objects**
3. Course Example: Refrigeration Cycle
4. Course Example: Tire Service Garage
5. Course Example: Lumped Capacitors
6. Conclusion

What is a class? What is an object?



Object-oriented Analysis

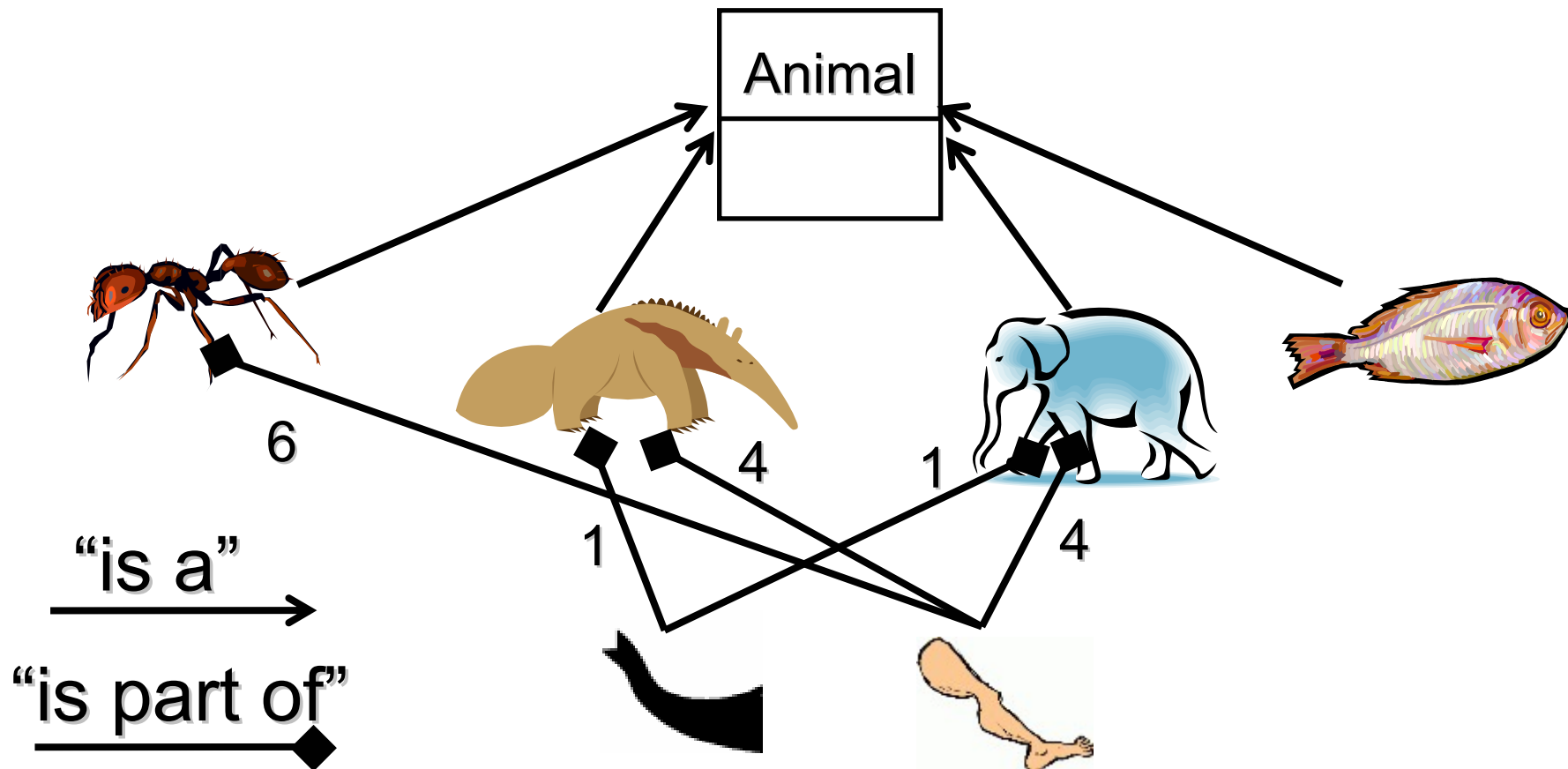


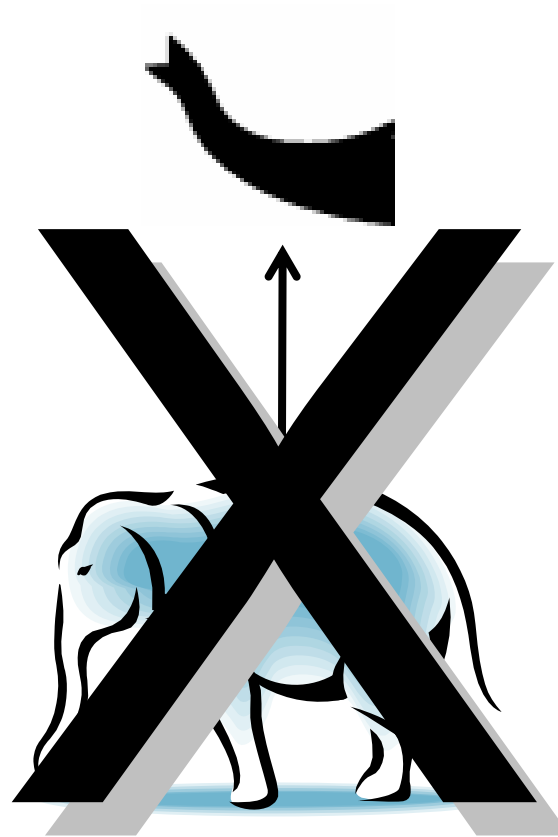
“is a”



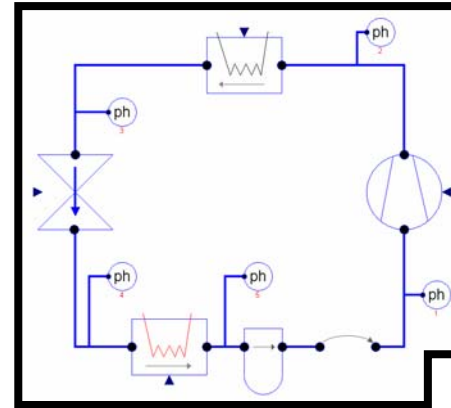
“is part of”







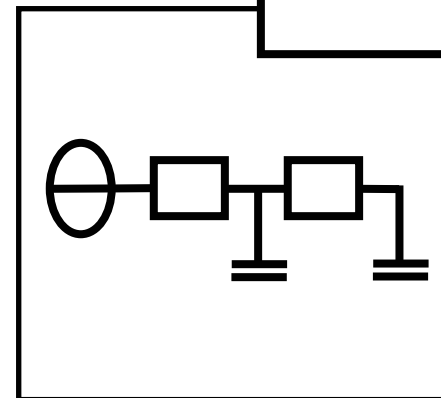
Refrigeration Cycle



Tire Service Garage

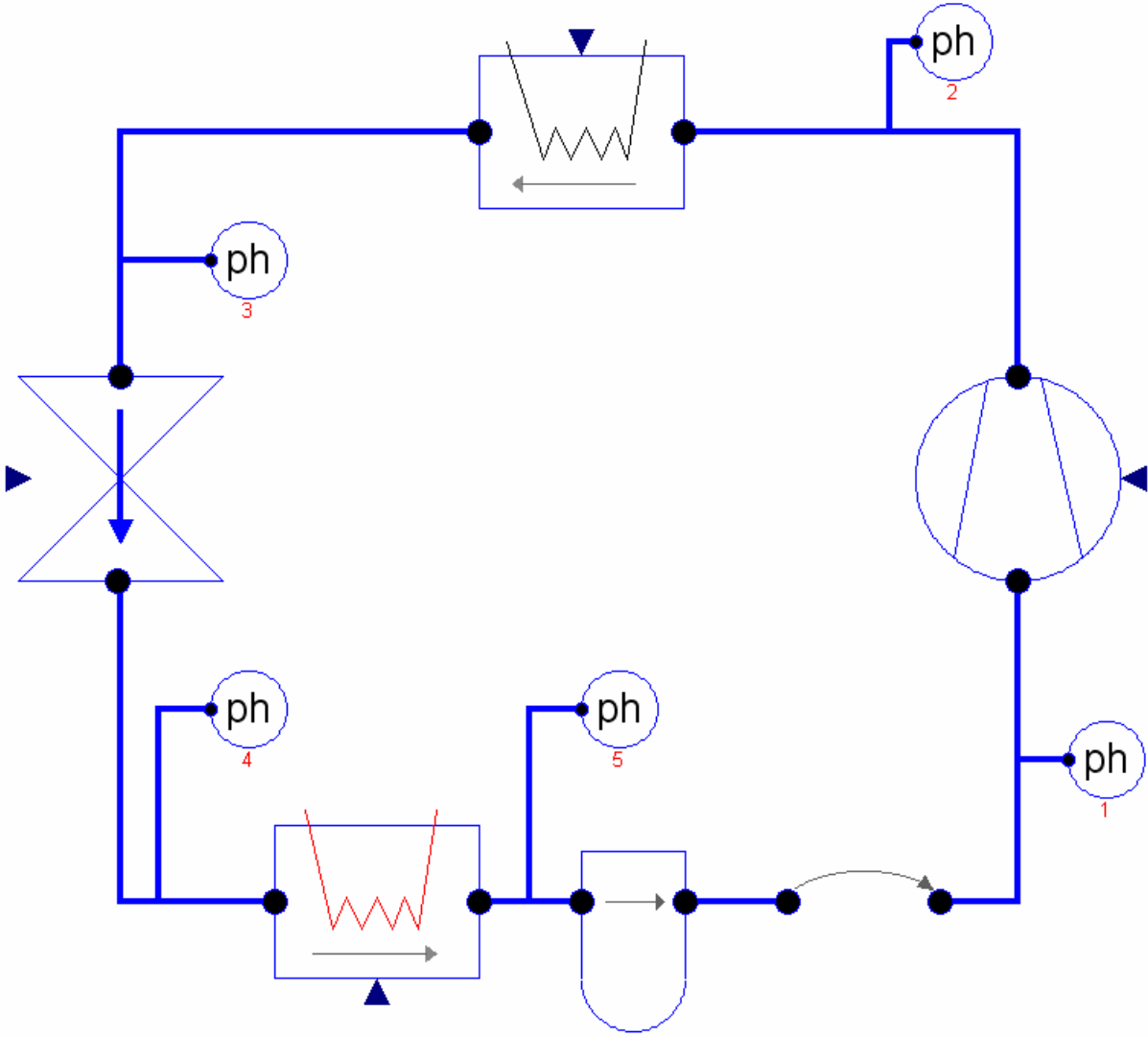


Lumped Capacitors



1. Classroom and Exam
2. Thinking in Objects
- 3. Course Example: Refrigeration Cycle**
4. Course Example: Tire Service Garage
5. Course Example: Lumped Capacitors
6. Conclusion

Refrigeration Cycle



Solving Non-linear Algebraic Equations

```
gascooler.idealOutletRefrigerant.p = 1E+007
```

```
receiver.refrigerant.p = 0
```

```
Residual:
```

```
{ -0.0654391, 92922.9 }
```

```
gascooler.idealOutletRefrigerant.p = -1E+009
```

```
receiver.refrigerant.p = -1.41559
```

```
Residual:
```

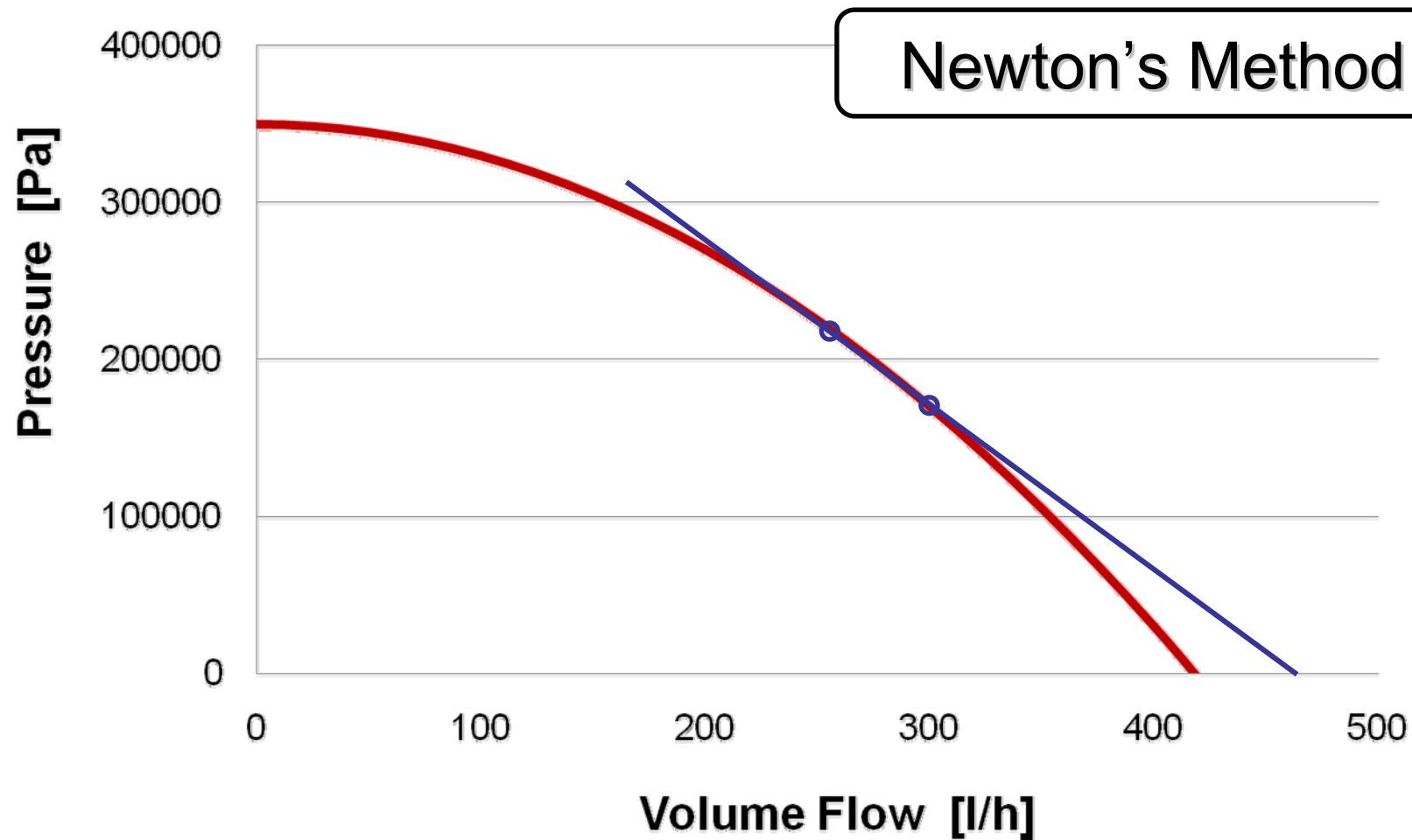
```
{ -0.101224, -9024.99 }
```

```
gascooler.idealOutletRefrigerant.p = -9.17831E+008
```

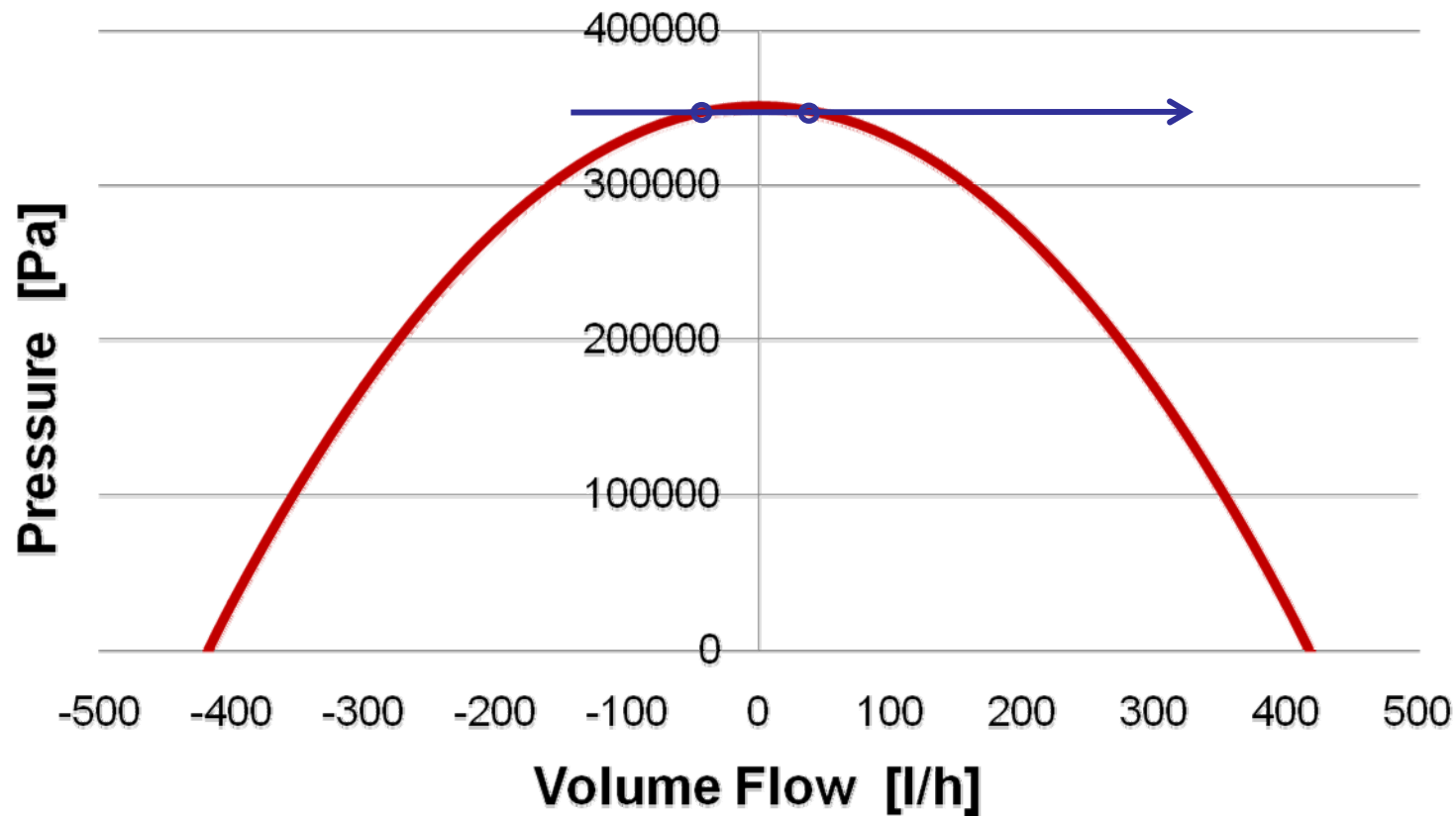
```
receiver.refrigerant.p = -1.28344
```

```
Residual:
```

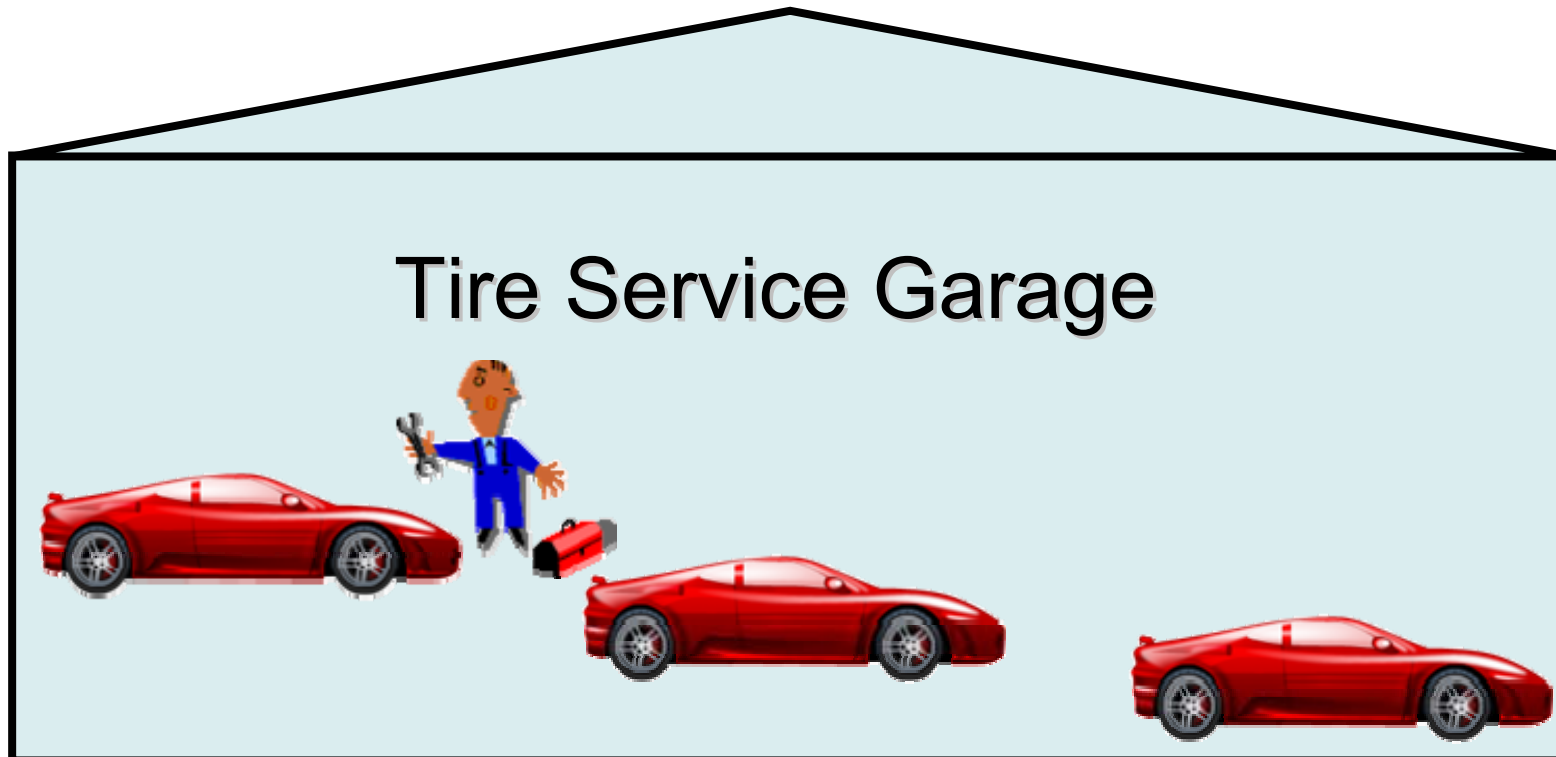
```
{ -0.0970766, -9024.99 }
```

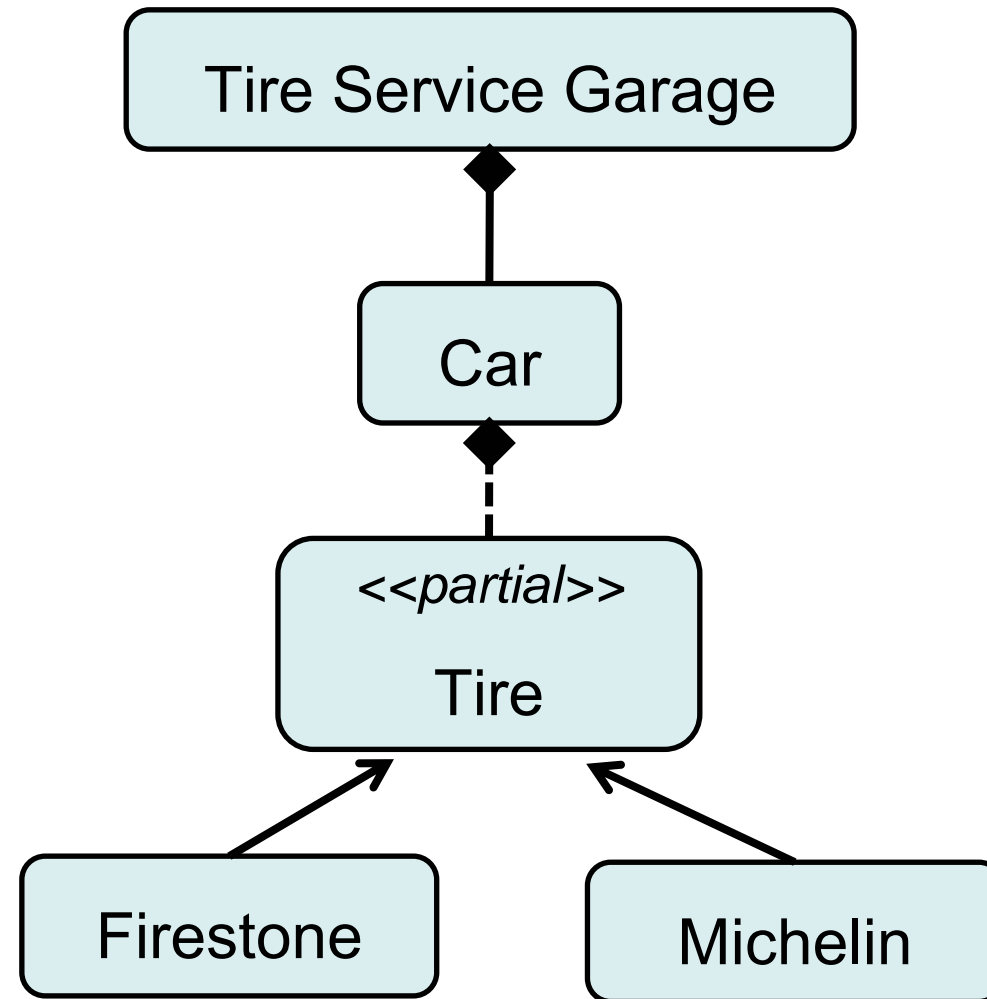


Pitfalls:



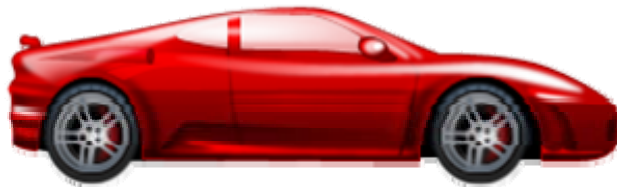
1. Classroom and Exam
2. Thinking in Objects
3. Course Example: Refrigeration Cycle
- 4. Course Example: Tire Service Garage**
5. Course Example: Lumped Capacitors
6. Conclusion



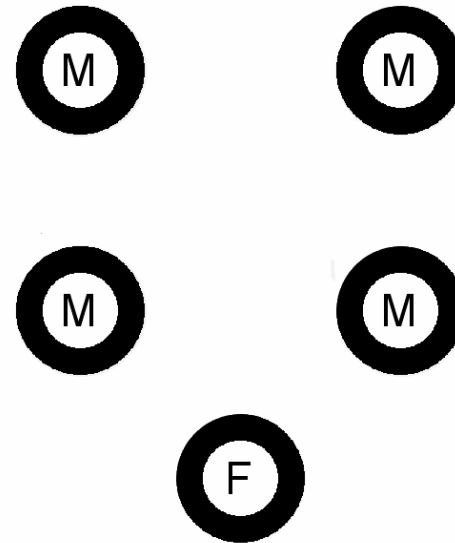


Car

Icon



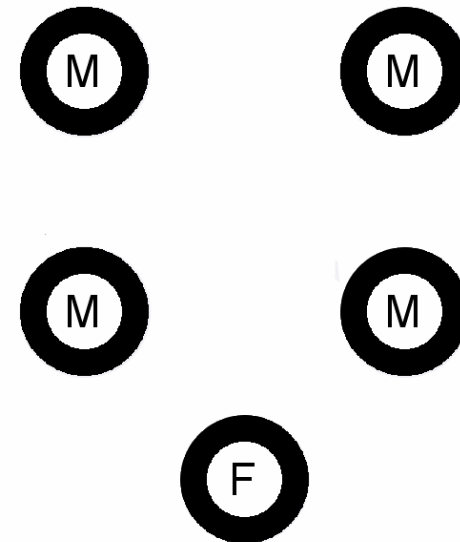
Object Diagram



Car

```
model Car
  Firestone spareTire;
  Michelin frontRightTire;
  Michelin frontLeftTire;
  Michelin backRightTire;
  Michelin backLeftTire;
end Car;
```

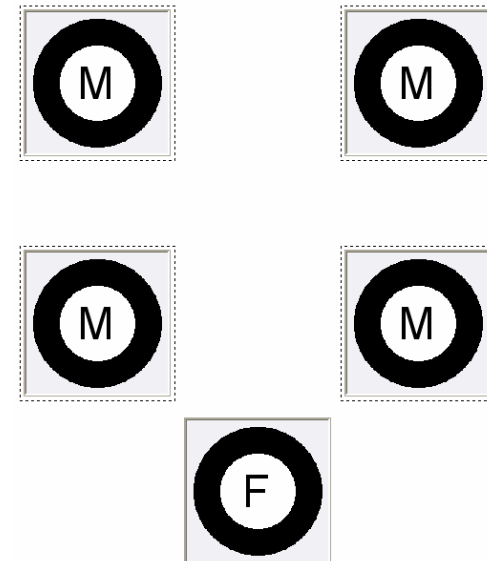
Object Diagram

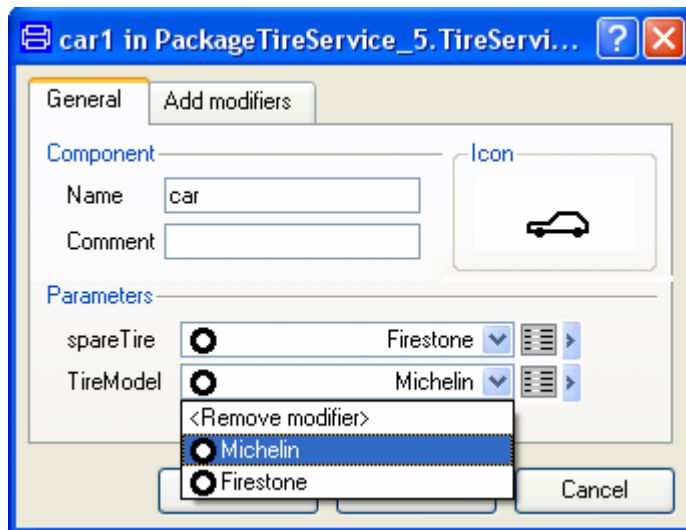
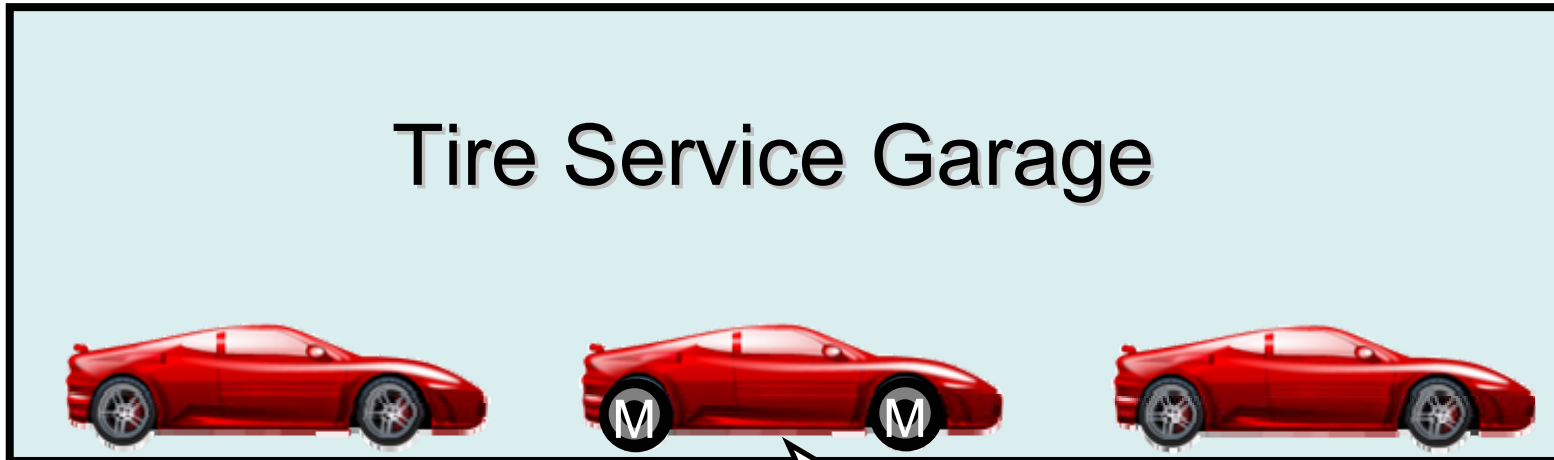


Car

```
model Car
  replaceable Firestone spareTire extends Tire
    annotation (choicesAllMatching=true);
  replaceable model TireModel = Michelin extends Tire
    annotation (choicesAllMatching=true);
  TireModel frontRightTire;
  TireModel frontLeftTire;
  TireModel backRightTire;
  TireModel backLeftTire;
end Car;
```

Object Diagram

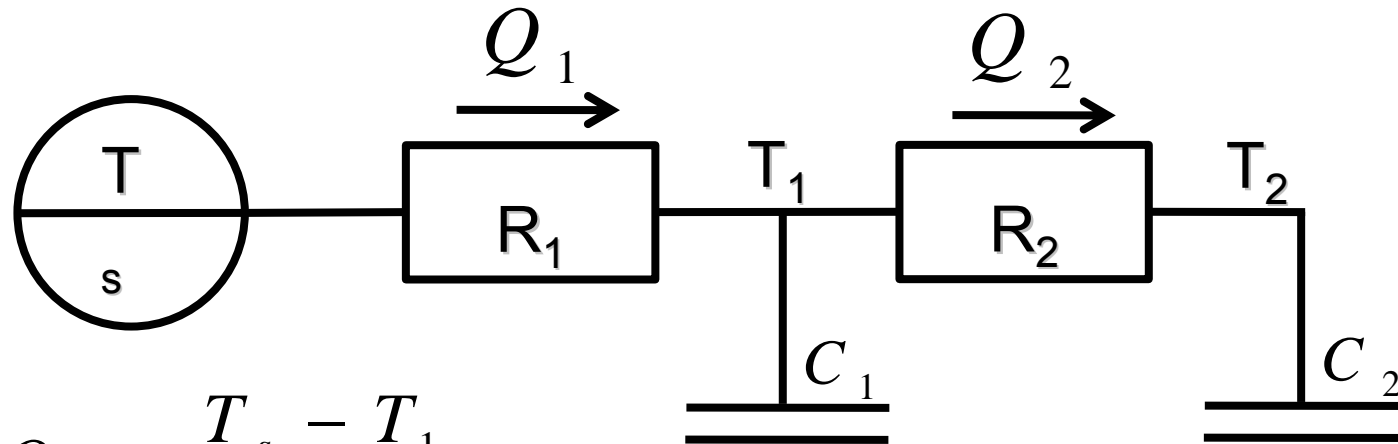




redeclare model TireModel =

Michelin;

1. Classroom and Exam
2. Thinking in Objects
3. Course Example: Refrigeration Cycle
4. Course Example: Tire Service Garage
- 5. Course Example: Lumped Capacitors**
6. Conclusion



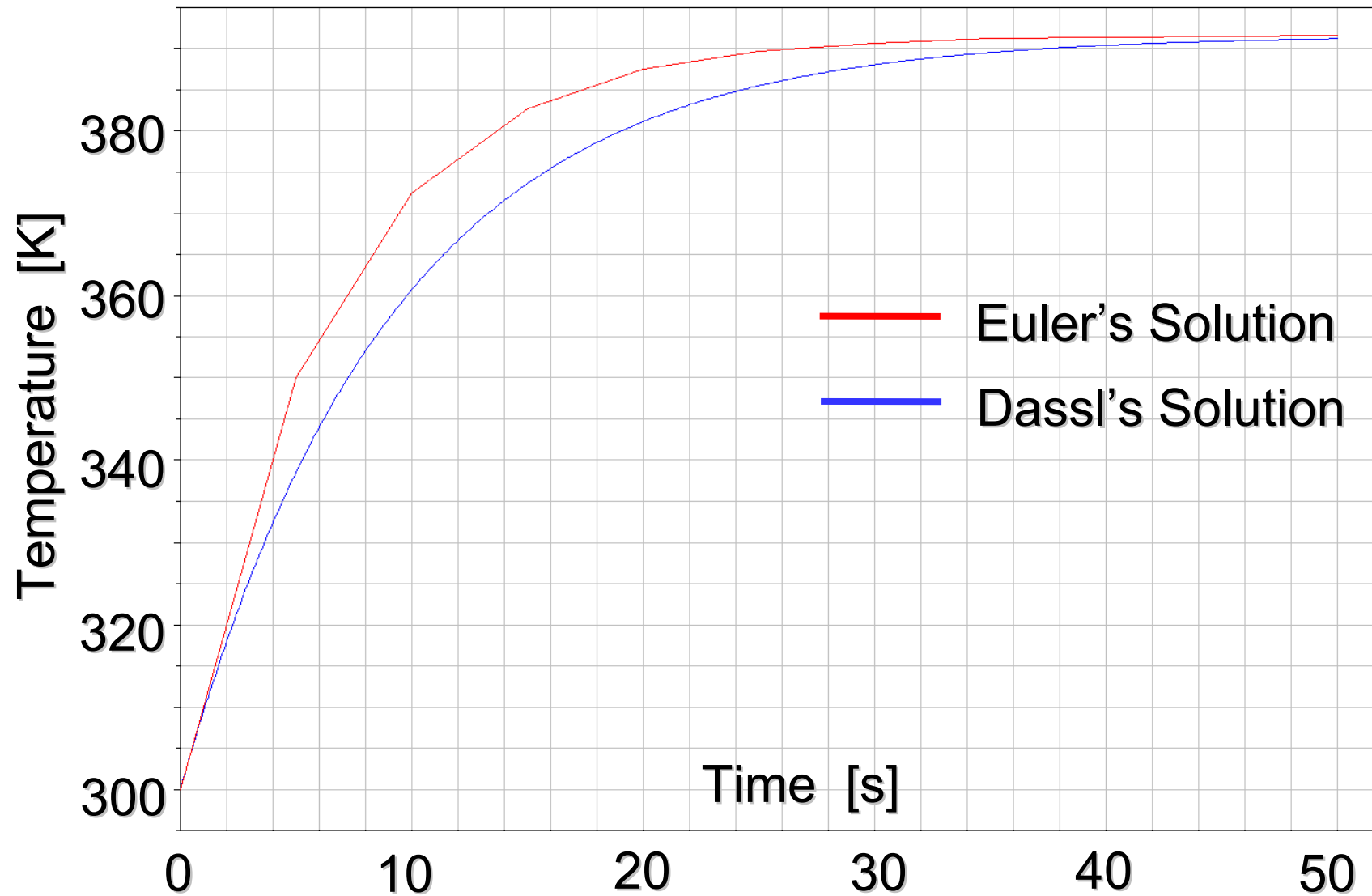
$$Q_1 = \frac{T_s - T_1}{R_1}$$

$$Q_2 = \frac{T_1 - T_2}{R_2}$$

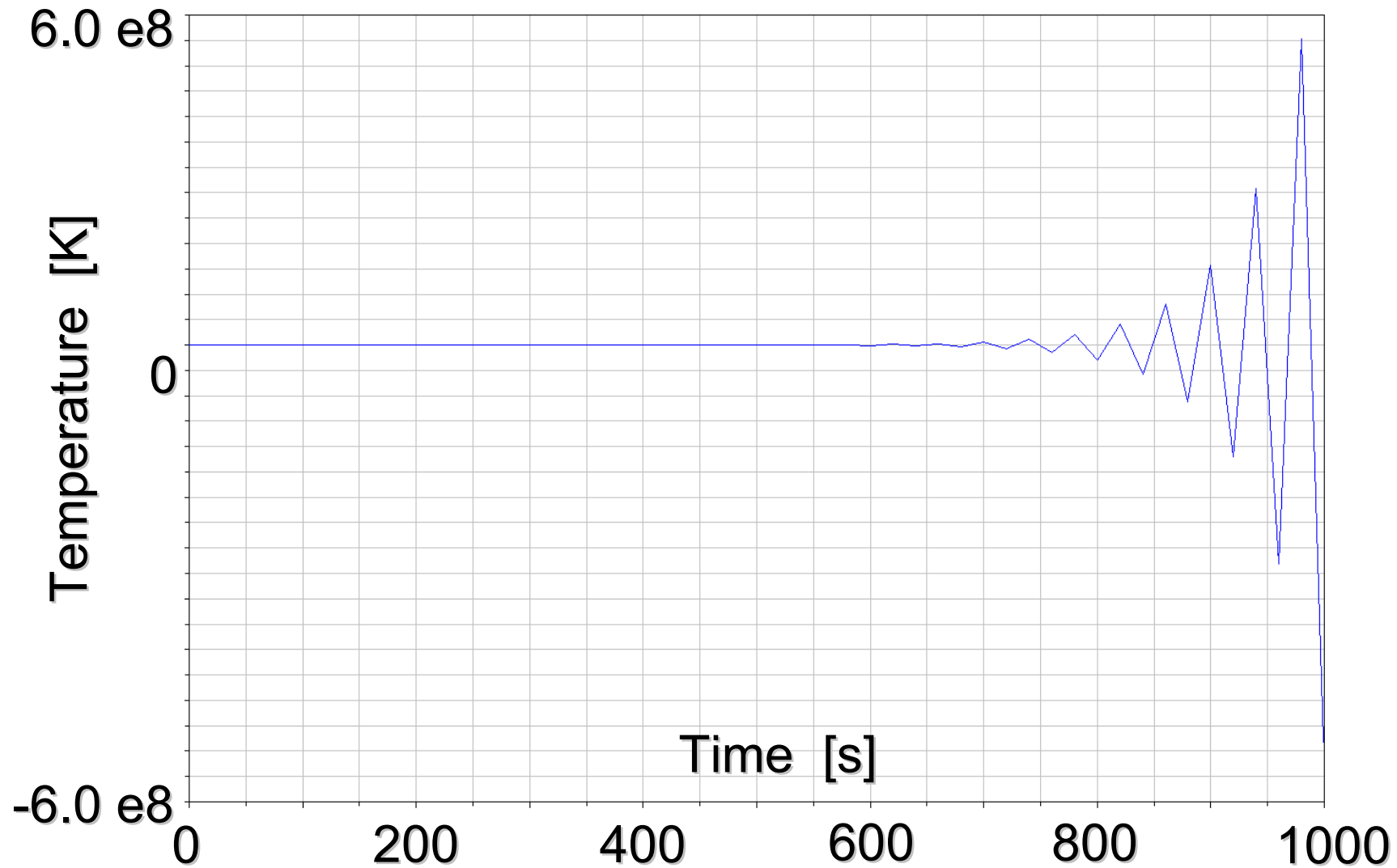
$$C_1 \cdot \frac{dT_1}{dt} = Q_1 - Q_2$$

$$C_2 \cdot \frac{dT_2}{dt} = Q_2$$

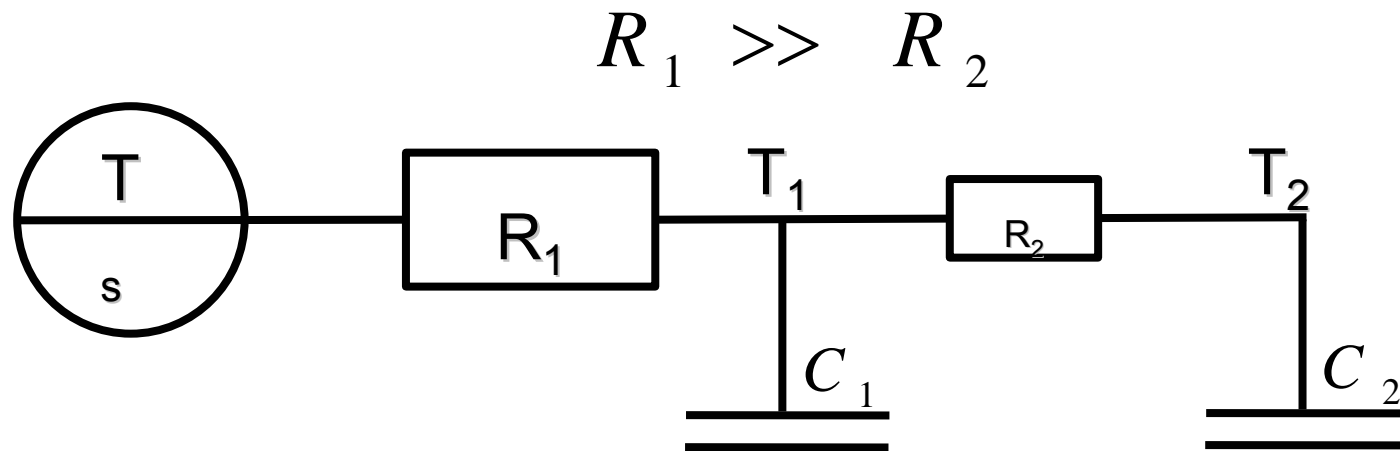
$\frac{dT_1}{dt} = \frac{T_s - T_1}{C_1 R_1} - \frac{T_1 - T_2}{C_1 R_2}$
$\frac{dT_2}{dt} = \frac{T_1 - T_2}{C_2 R_2}$



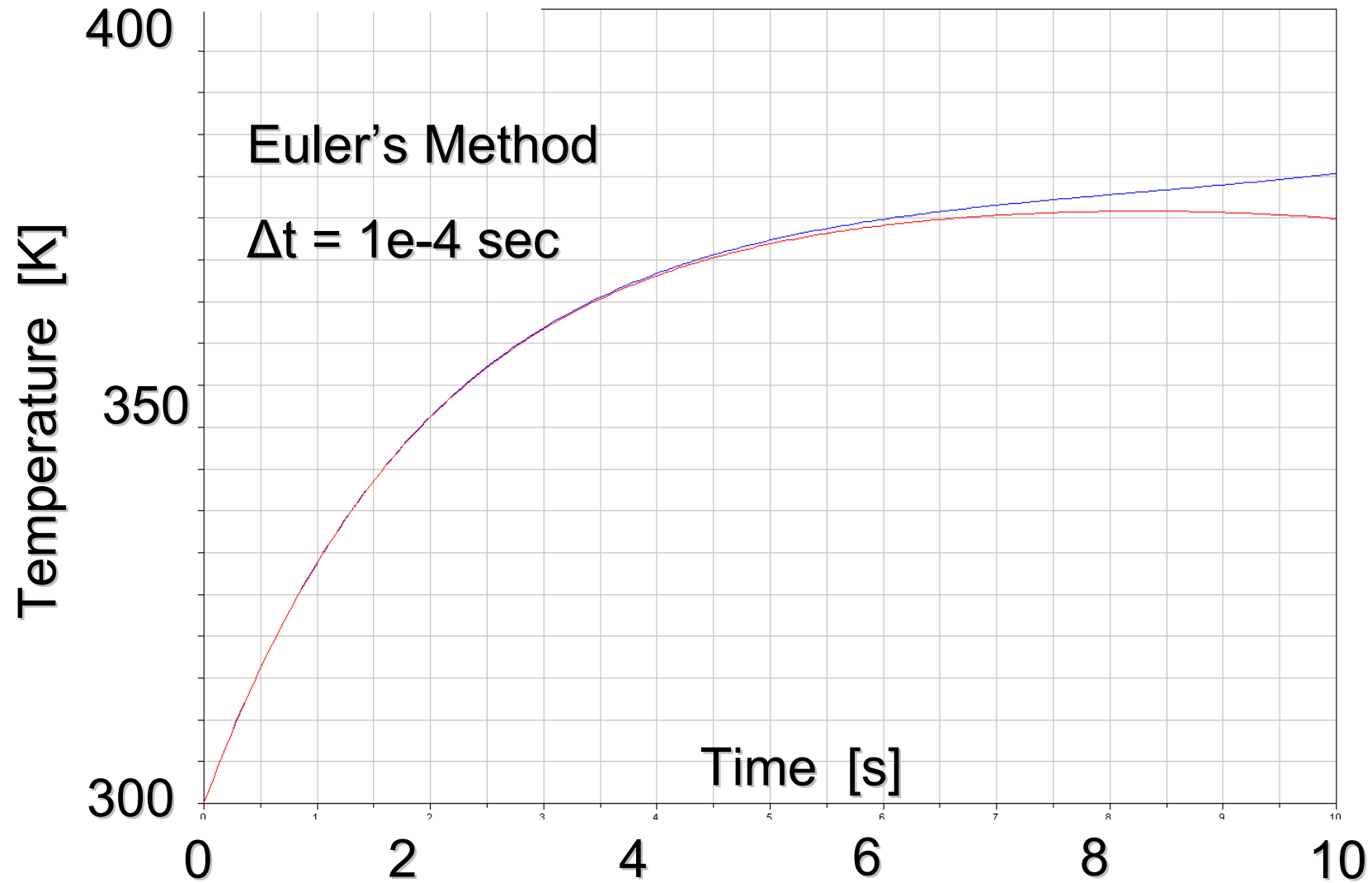
Lumped Capacitors - Stiffness

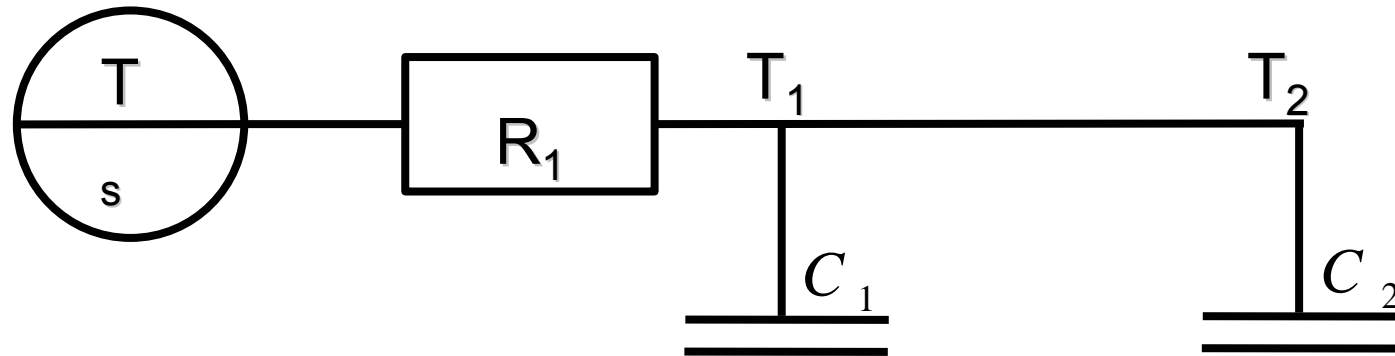


Lumped Capacitors - Stiffness



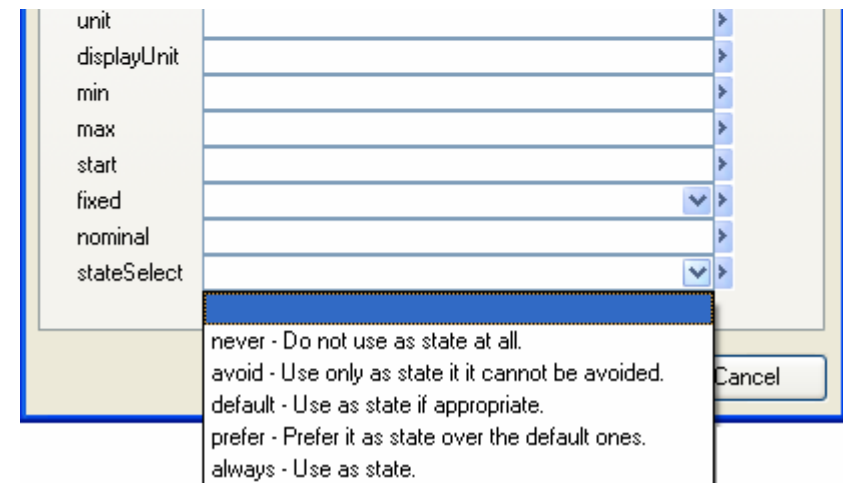
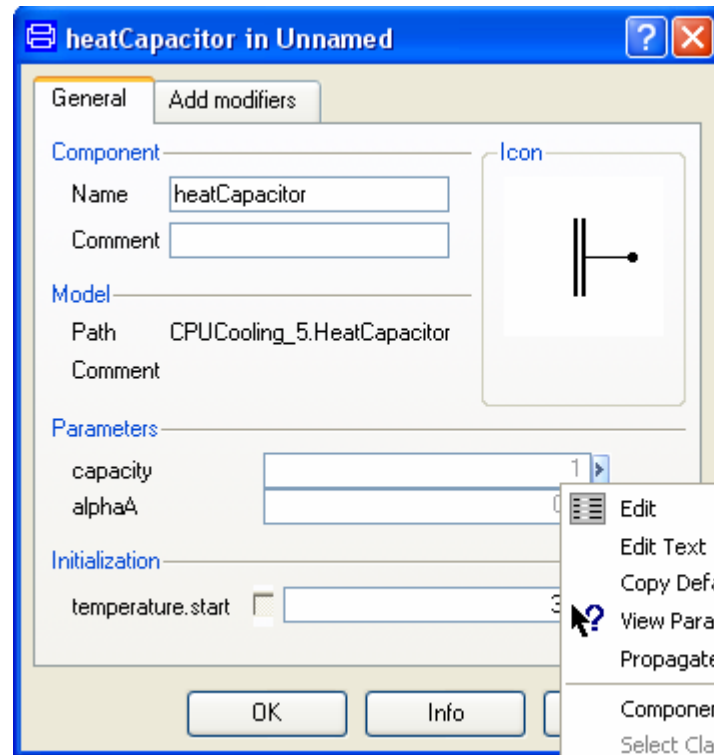
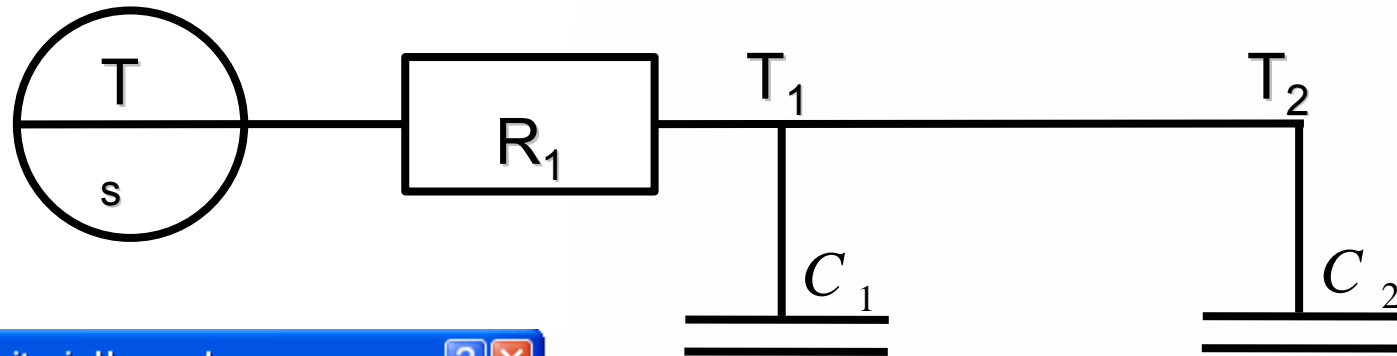
Lumped Capacitors - Stiffness





$$\frac{d}{dt} \Big|_{Q_1} = \frac{T_s - T_1}{R_1}$$
$$\frac{d}{dt} \Big|_{Q_2} = \frac{T_1 - T_2}{R_2}$$

Lumped Capacitors – State Selection



1. Classroom and Exam
2. Thinking in Objects
3. Course Example: Refrigeration Cycle
4. Course Example: Tire Service Garage
5. Course Example: Lumped Capacitors
- 6. Conclusion**

Students typically have to learn thinking in objects

Students learn modelling in Modelica by

- Carefully selected didactical concepts
- Well assisted assignments
- Final projects

In thermo-fluid systems, good knowledge about numerical solving of DAE-Systems is necessary