

### Flippers



Resource – Actuation

flippers

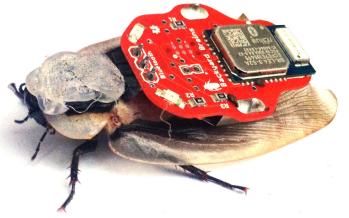
### Vacuum Gripper



Resource – Actuation

vacuum\_gripper

### Cyber-Cockroach



Resource – Actuation

cyber\_cockroach

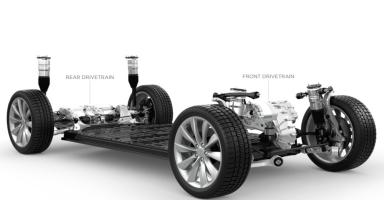
### Weasel ball



Resource – Actuation

weaselball

### Tesla Model X Chassis



Resource – Actuation

model\_x\_chassis

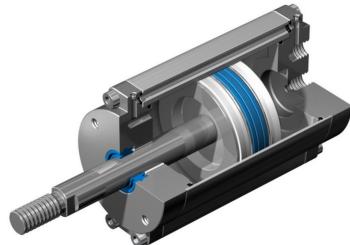
### One segway base



Resource – Actuation

segway\_base

### DDR



Resource – Actuation

ddr

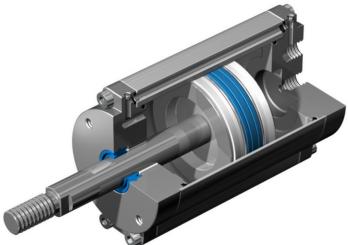
### Puppetry Wires



Resource – Actuation

puppetry\_wires

### 1 RGB LED



Resource – Actuation

led

### Christmas lights



Resource – Actuation

christmas\_lights

### Tracks



Resource – Actuation

tracks

### RC Car Chassis



Resource – Actuation

rc\_car\_chassis

### Circular Saw



Resource – Actuation

circular\_saw

### 2 Legs



Resource – Actuation

A basic humanoid leg kit sold by TrossenRobotics.

6359.90 USD 2legs

### One robotic finger

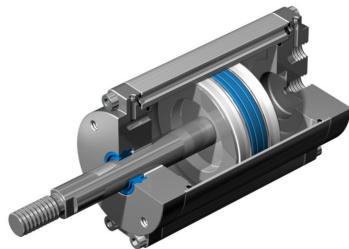


Resource – Actuation

*"When the finger points to the moon, the student looks at the finger."*

finger1

### Tesla Car Chassis



Resource – Actuation

tesla\_chassis

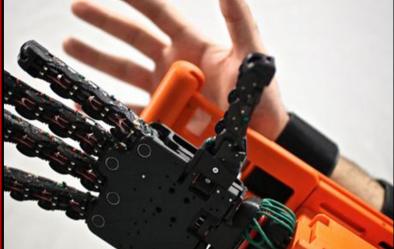
### DC Motor



Resource – Actuation

dcmotor

### One robotic hand



Resource – Actuation

1hand

### Lynxmotion Pan-tilt Kit



#### Resource – Actuation

A cheap pan-tilt kit made of two HiTec servos (HS-422) and two Lynx-motion servo brackets.

29 USD lynxmotion\_pan\_tilt\_kit

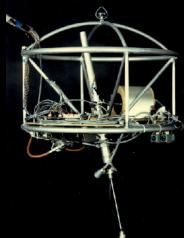
### Linear Actuator



#### Resource – Actuation

linear\_actuator

### 3D Hopper

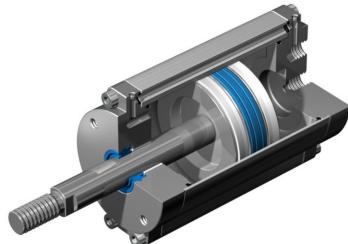


#### Resource – Actuation

The 3D Hopper was created in 1988 by Marc Raibert while at MIT. Successively, Raibert left MIT to found Boston Dynamics.

3D\_hopper

### Magnetic field



#### Resource – Actuation

magnetic\_field

### Servocity PT-2100 Pan-tilt Kit



#### Resource – Actuation

This professional pan-tilt kit can move a payload of up to 10 kg.

8.5 lbs; 1,199.99 USD servocity\_pt2100\_pan\_tilt\_kit

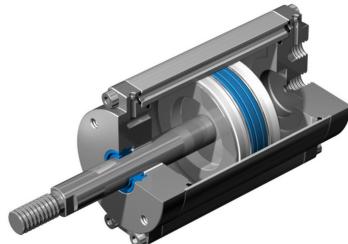
### Balloon



#### Resource – Actuation

balloon

### Five links for a robot snake



#### Resource – Actuation

5\_snake\_links

### PR2 Gripper



#### Resource – Actuation

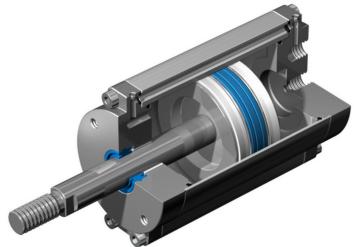
pr2\_gripper

### One tentacle

#### Resource – Actuation

1tentacle

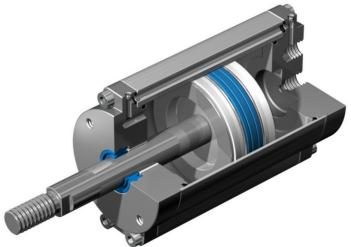
### Prismatic Joint



Resource – Actuation

prismatic\_joint

### Wheel



Resource – Actuation

wheel

### Loudspeaker



Resource – Actuation

loudspeaker

### 2 Propellers



Resource – Actuation

2propellers

### Steerable Needle



Resource – Actuation

steerable\_needle

### 100 USD (better)



Resource – Budget

USD 100

100USD

### 1 USD (better)



Resource – Budget

USD 1

1USD

### USD 10,000



Resource – Budget

You have 10,000 USD to buy all components.

+ 10000 USD 10KUSD

### Smoke Signals



Resource – Communication

smoke\_signal

### Communication tether



Resource – Communication

comm\_tether

### WiFi 802.11 NIC



Resource – Communication

wifi\_802\_11

### Carrier Pigeon



Resource – Communication

carrier\_pigeon

### Acoustic Modem



Resource – Communication

10 bit/s

acoustic\_modem

### The Ansible



Resource – Communication

You have an infinite communication channel at zero power consumption

ansible

### Random Number Generator



Resource – Computation

rng

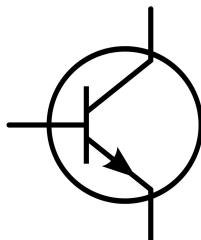
### Arduino Uno



Resource – Computation

20 USD arduino\_uno

### 1 transistor



Resource – Computation

1transistor

### NVidia Jetson TK1



Resource – Computation

199 USD jetson\_tk1

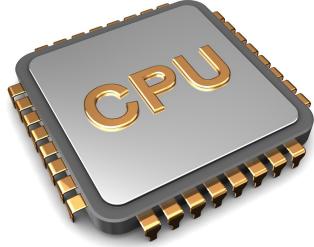
### Raspberry PI 2



### Resource – Computation

35 USD raspberry\_pi\_2

### Infinite Computation



### Resource – Computation

infinite\_computation

### The Cloud



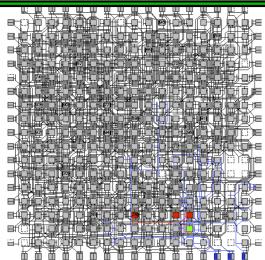
### Resource – Computation

You have infinite computation – but not necessarily infinite bandwidth.

*"Somewhere, over the rainbow!"*

cloud

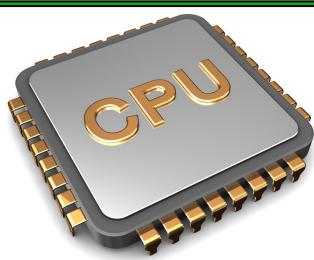
### FPGA



### Resource – Computation

fpga

### 100-state DFA



### Resource – Computation

100dfa

### TrueNorth Processor



### Resource – Computation

The neuromorphic processor created by IBM.

truenorth

### Macbook Pro



### Resource – Computation

macbook\_pro

### Oracle



### Resource – Computation

This oracle answers one 1 bit question per second.

oracle

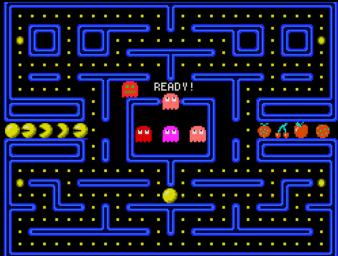
### Underwater



### Environment

underwater

### Pacman's maze



Environment

pacman\_maze

### Lake Michigan



Environment

lake\_michigan

### The Bates Motel



Environment

bates\_motel

### Intel Lab in Seattle



Environment

intel\_lab

### Mount Etna



Environment

etna

### Deep Space



Environment

deep\_space

### Bat Cave



Environment

batcave

### Mars



Environment

mars

### Hoth



Environment

hoth

### In the mall



Environment

in\_the\_mall

### The Dagobah Swamps



Environment

dagobah

### The Endor Forest



Environment

endor

### Tatooine



Environment

tatooine

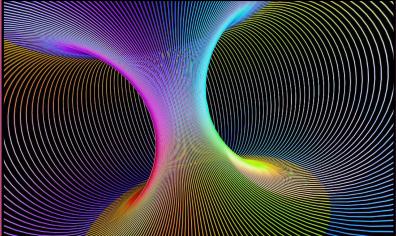
### Ice Rink



Environment

ice\_rink

### In a toroidal office space



Environment

torus

### On a ski slope



Environment

ski\_slope

### Theory of Everything



Special

A reviewer can use this card to dismiss the paper as over-reaching.

*The results should be more concrete.*

everything16

### Fundamental Theorem



Special

This card can be played by a reviewer to reject a paper by appealing to authority.

*The Fundamental Theorem of Robotics (Egerstedt, 2001) subsumes all subsequent results.*

fundamental01

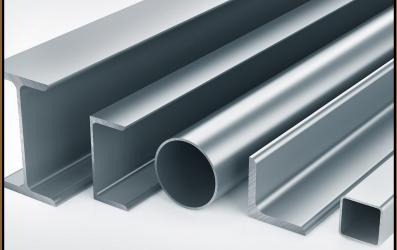
### Color-changing material



Resource – Materials

color\_changing\_material

### All the aluminum you need



Resource – Materials

aluminum

### A bag containing 300 duckies



Resource – Materials

bag\_of\_duckies

### One standard duckie



Resource – Materials

duckie

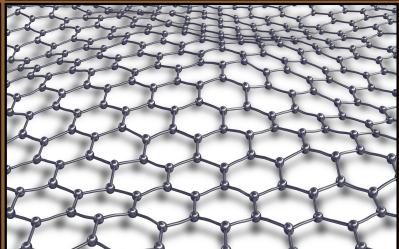
### Shovel



Resource – Materials

shovel

### All the graphene you need



Resource – Materials

graphene

### All the balsa you need



Resource – Materials

balsa

### A giant rubber duckie



Resource – Materials

giant\_rubber\_duckie

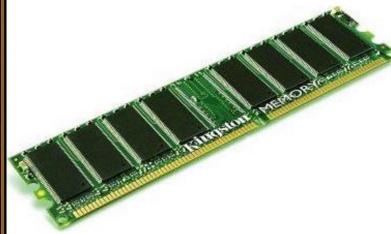
### 640 KB



Resource – Memory

640K ought to be enough for anybody.

640KB

**Infinite memory**

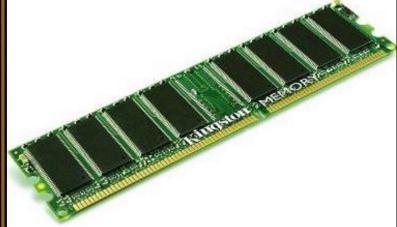
Resource – Memory

infinite\_memory

**One pebble**

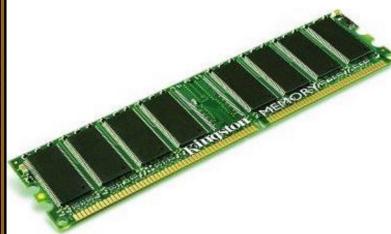
Resource – Memory

pebble

**Ideal Stack**

Resource – Memory

stack

**1 bit**

Resource – Memory

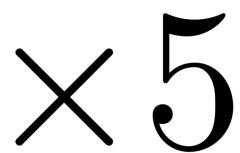
1bit

**2x multiplier**

Special

A chosen resource can be multiplied by 2.

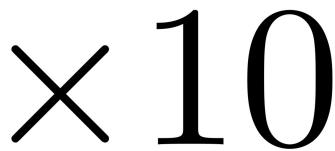
mult2

**5x multiplier**

Special

A chosen resource can be multiplied by 5.

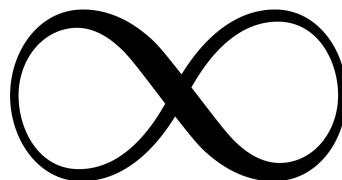
mult5

**10x multiplier**

Special

A chosen resource can be multiplied by 10.

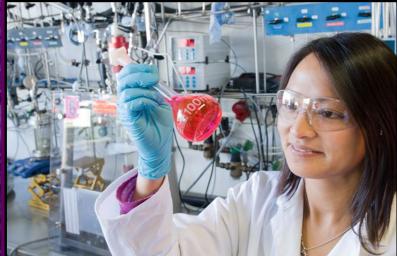
mult10

 **$\infty$  multiplier**

Special

A chosen resource can be multiplied by  $\infty$ .

multinf

**Very Dedicated Grad Student**

Resource – Collaborator

Use this resource as you wish.

dedicated\_grad\_student

**Steve Lavalle****Resource – Collaborator**

Thanks to an optimal design of the filter, you can *handwave away* all the concerns regarding the computation requirements of the proposed solution.

lavalle

**Friend at IRB committee****Resource – Collaborator**

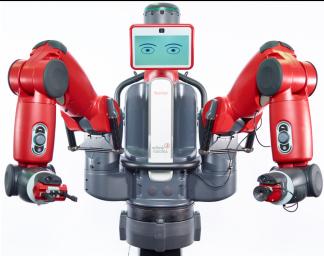
The IRB will approve your project in spite of its questionable ethics. This card is especially useful in conjunction with *Very Dedicated Grad Student*.

irb\_approval

**Titan XIII****Resource – Platform**

The newest sprawling-type quadruped robot from the Fukushima laboratory at TokyoTech.

titanXIII

**Baxter****Resource – Platform**

baxter

**KUKA Youbot****Resource – Platform**

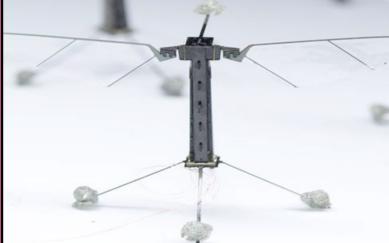
kuka\_youbot

**Gimball****Resource – Platform**

gimball

**R2D2****Resource – Platform**

r2d2

**Robobee****Resource – Platform**

robobee

**Dragon Runner****Resource – Platform**

A compact remote-controlled robot used by the British army.

20 lbs; 120,000 USD dragon\_runner

**PR2**

Resource – Platform

pr2

**DJI Phantom 4**

Resource – Platform

400 USD dji\_phantom\_4

**Duckiebot**

Resource – Platform

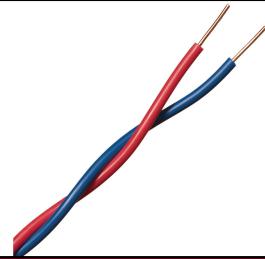
duckiebot

**Li-ion AA Battery**

Resource – Power

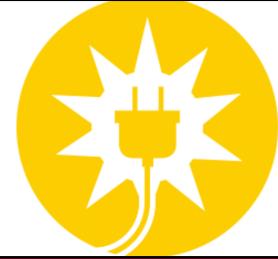
A rechargeable battery.

30 g aa\_battery

**A 1 km Power Tether**

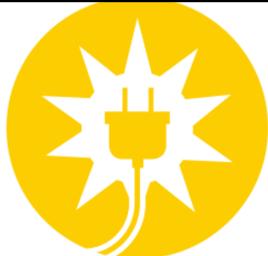
Resource – Power

+∞ W power\_tether

**1 megawatt**

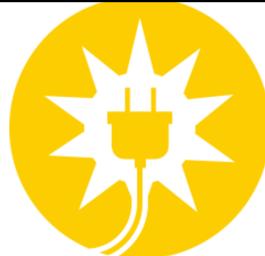
Resource – Power

1 MW megawatt

**100 watt**

Resource – Power

100 W 100watt

**1 milliwatt**

Resource – Power

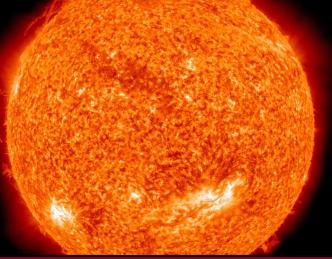
1 mw milliwatt

**Rechargeable AAA Battery**

Resource – Power

aaa\_battery

### The power of the sun

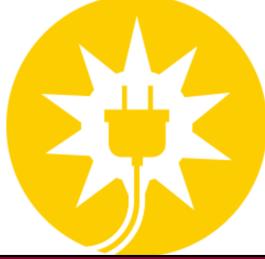


#### Resource – Power

You can channel all the power irradiated by the sun into supporting your robotic system.

$3.828 \times 10^{26}$  W the\_power\_of\_the\_sun

### 1 watt



#### Resource – Power

1 W watt

### Name recognition

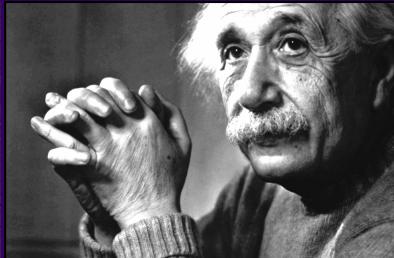


#### Rewards

Each of these cards count as a positive reviewer.

name\_recognition

### Name recognition



#### Rewards

Each of these cards count as a positive reviewer.

name\_recognition2

### Bitterness



#### Rewards

Your negative opinion as a reviewer counts double.

bitterness

### Bitterness



#### Rewards

Your negative opinion as a reviewer counts double.

bitterness2

### Military-grade Fibre-Optic IRU



#### Resource – Sensing

The Astrix 1090 is a 3-axis fiber-optic gyroscope produced by Airbus. It is designed to work for >20 years in small satellites.

12 W; 4.2 kg; 100,000 USD astrix\_1090

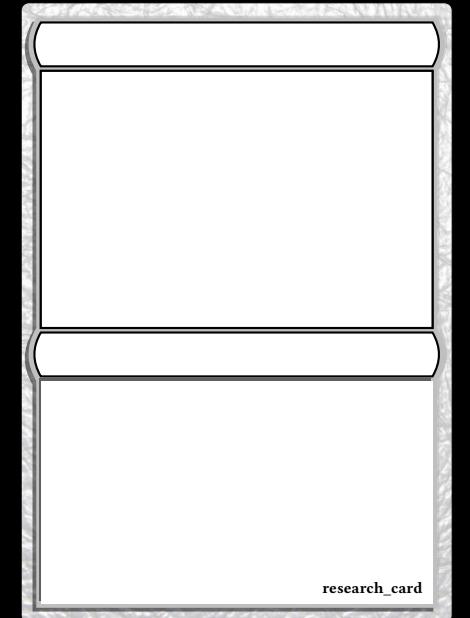
### GelSight



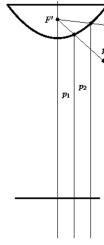
#### Resource – Sensing

An image-based tactile sensor that works by sensing the deformation of a thin film in contact with the object.

gelsight



### Parabolic mirror

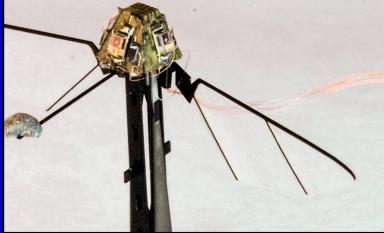


### Resource – Sensing

Turns a camera into an omnidirectional camera.

? W; ? USD parabolic\_mirror

### Artificial Ocelli sensor



### Resource – Sensing

ocelli

### Sick LMS511 Range Finder



### Resource – Sensing

A 2D, 190 deg, range finder with 0.25 deg resolution per ray. The maximum range is 80m.

22 W; 3.7 kg; 7000 USD Sick\_LMS511\_11100\_Lite

### Odour sensor



### Resource – Sensing

odour\_sensor

### CURVACE sensor



### Resource – Sensing

CURVACE

### Sonar



### Resource – Sensing

sonar

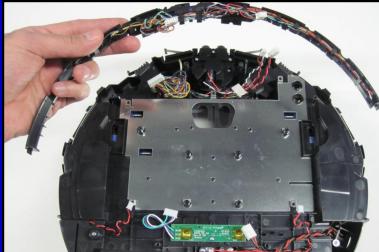
### Cheap IMU



### Resource – Sensing

9.90 USD cheap\_gyro

### Bump Sensor



### Resource – Sensing

? W; ? USD bump\_sensor

### Pressure Sensor



### Resource – Sensing

A pressure to voltage transducer.

? W; 235 USD pressure\_sensor\_PX302

### Thermal imaging camera



Resource – Sensing

thermal\_imaging\_camera

### Earth GPS Receiver



Resource – Sensing

earth\_gps\_receiver

### Compass



Resource – Sensing

? W; ? USD compass

### Velodyne HDL-64E



Resource – Sensing

60 W; 29 lbs; 6000 USD velodyne\_HDL\_64E

### Linear Odometer



Resource – Sensing

? W; ? USD linear\_odometer

### Hokuyo range-finder



Resource – Sensing

A reliable sensor. Maximum range is 8m.

5 W; 2000 USD hokuyo\_urg

### 1-point Range Finder



Resource – Sensing

? W; ? USD 1point\_range\_finder

### Kinect



Resource – Sensing

kinect

### Camera



Resource – Sensing

? W; ? USD camera

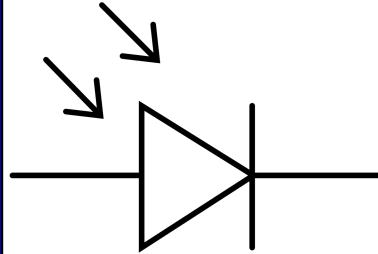
### Microphone



### Resource – Sensing

? W; ? USD microphone

### Photoreceptor



### Resource – Sensing

photodiode

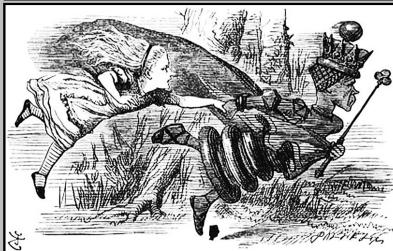
### Dynamic Vision Sensor



### Resource – Sensing

dvs

### Goal posts have moved



### Special

You can change the current goal by changing either the *Task* or the *Environment* card.

*"We must run as fast as we can, just to stay in place. And if you wish to go anywhere you must run twice as fast as that."*

goal\_posts

### 3D printer



### Special

You can 3D print a piece for your robot.

3dprinter

### The Power of Friendship

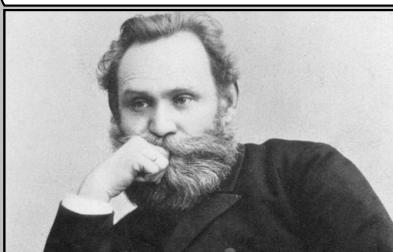


### Special

Use a card belonging to somebody else.

the\_power\_of\_friendship

### A Russian did it in the 1960s



### Special

The paper under review is rejected.

russian

### Do research!



### Special

Create a new card using one of the empty cards. Put it randomly in the deck.

do\_research

### Sort fruits by color



### Task

sort\_fruits

### Find all Easter Eggs



Task

find\_easter\_eggs

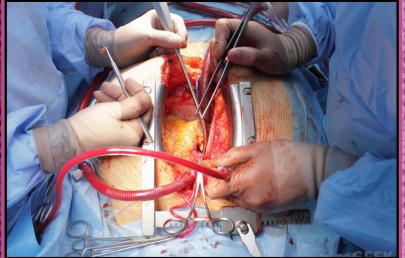
### Assemble IKEA furniture



Task

assemble\_ikea

### Perform surgery



Task

surgery

### Rescue all survivors



Task

rescue\_survivors

### Change diaper



Task

diaper

### Play chess



Task

chess

### Track ???



Task

track

### Find and disarm an IED



Task

IED\_disposal

### 1 week

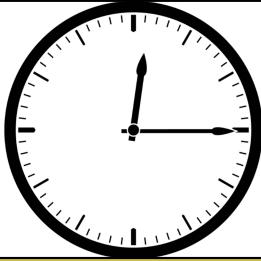


Resource – Time

1 week to perform the task

1week

**1 day**

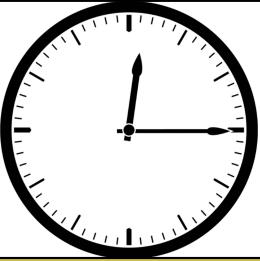


**Resource – Time**

1 day to perform the task

1day

**1 hour**

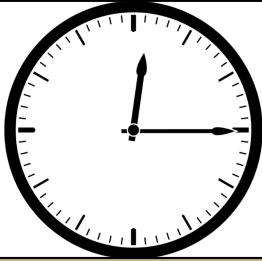


**Resource – Time**

1 hour to perform the task

1hour

**1 year**

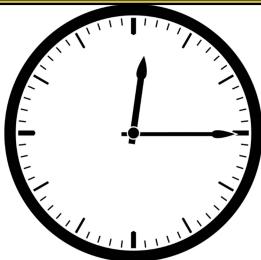


**Resource – Time**

1 year to perform the task

1year

**All the time in the world**



**Resource – Time**

You have all the time in the world to perform the task.

all\_the\_time

**Perfect parameter tuning**



**Resource – Data**

perfect\_parameter\_tuning

**Infinite training data**



**Resource – Data**

You have infinite training data.

infinite\_data

**8000 robot-hours of training data**



**Resource – Data**

8000\_hours

**Lazy graduate student**



**Resource – Data**

The lazy graduate student will only collect 2 hours of training data.

lazy\_graduate\_student