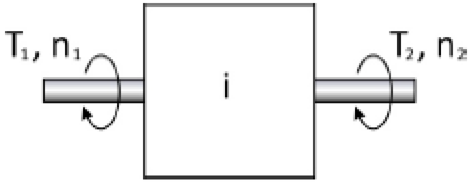
Aalto University
School of Engineering

Mechatronics Basics

Exercise session 7.11.2015 | Solutions round 1 | Tips round 2

Mechanics 1

Calculate the gear ratio i, when $n_1 = 597\ rpm$ and $n_2 = 205\ rpm$.



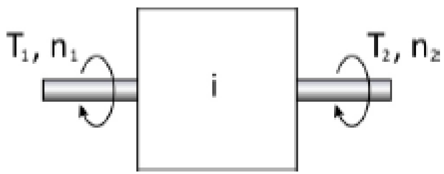
Answer:

Check

Correct formula is $i = n_1/n_2$.

Mechanics 2

What is the angular velocity (rad/s) of shaft 2, when $i = 8.09$ and $n_1 = 1651.9 rpm$



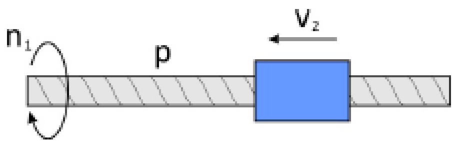
Answer:

Check

Correct equation is $\omega_2 = (2\pi n_1/60i)$.

Mechanics 3

What is the pitch of the screw, if the sledge moves with velocity $v = 2.79\ cm/s$ and angular velocity of the shaft is $\omega = 30.35\ rad/s$? Give your answer in unit mm/rev.



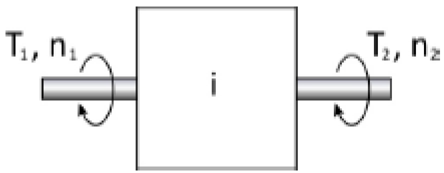
Answer:

Check

The correct equation is $p = 2\pi v/\omega$.

Mechanics 4

What is the torque output T_2 of shaft 2, if the angular velocities of the shafts are $\omega_1 = 62.75\ rad/s$ and $\omega_2 = 21.54\ rad/s$, torque $T_1 = 156.6\ Nm$ and efficiency rate $\eta = 0.83$?



Answer: ✗

Check

The correct equation is $T_2 = \eta(\omega_1/\omega_2)T_1$.

Mechanics 5

Calculate the kinetic energy of a mass $m = 9.88\ kg$ with linear velocity $v = 59.4\ km/h$. Give your answer in unit kJ.

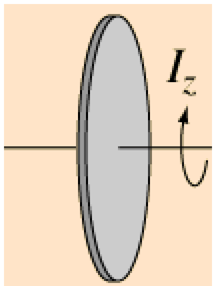
Answer: ✗

Check

The correct equation is $E = (1/2)mv^2$. Remember to convert km/h to m/s before calculating the energy.

Mechanics 6

Calculate the kinetic energy of a rotating solid disc. The dimensions are: radius $r = 10.54\ cm$, length $l = 12.2\ mm$, mass $m = 8.45\ kg$ and the rotating speed $n = 971.4\ rpm$. Give the answer in unit J.



Answer:

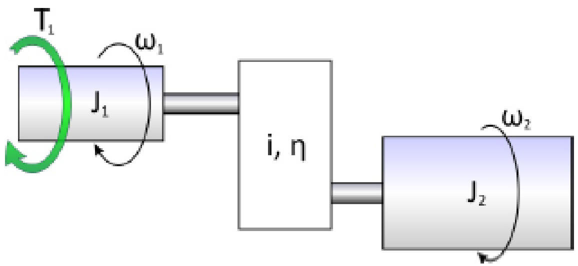
Check

The moment of inertia: $I = 0.5mr^2$. The kinetic energy: $0.5I\omega^2$. Remember to be careful with units!

Mechanics 7

Calculate the reduced moment of inertia for whole system reduced on shaft 1, given the properties:

- $J_1 = 1.43\ kgm^2$
- $J_2 = 0.69\ kgm^2$
- $i = 6.73$
- $\eta = 0.82$



Answer:

Check

The right equation is $J_r = J_1 + J_2/(\eta i^2)$.

Mechanics 8

An electric motor produces a torque of $T = 83.6\ Nm$. What is the highest torque the gear-motor system can produce, when the rotating speed of the electric motor is reduced with a gearbox of efficiency $\eta = 0.95$ and gear ratio $i = 6.44$?

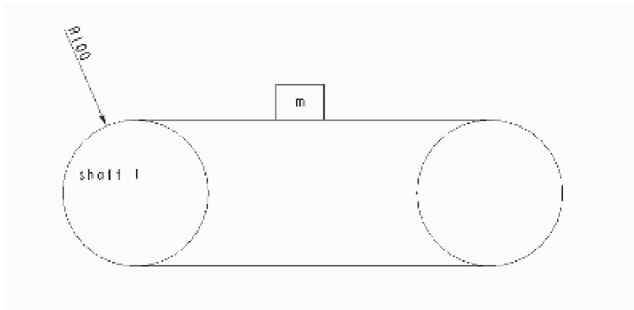
Answer:

Check

The correct formula is $T_2 = T\eta i$

Mechanics 9

What is the moment of inertia of the mass, $m = 14.0\ kg$, moving linearly on the conveyor when belt reduced on the shaft 1 of radius $r = 100\ mm$?



Answer:

Check

Consider the kinetic energy: $(1/2)mv^2 = (1/2)I\omega^2$.

The right equation to use is: $I_r = mr^2$. Notice: You should not need the velocity information. Notice2: Compare this equation with the inertia of a particle rotating around an axis.

Mechanics 10

A car first accelerates with a constant acceleration rate $a_1 = 2.67\ m/s^2$ for $t_1 = 8.3\ s$. Then it drives $s = 103.2\ m$ with the achieved speed. Lastly, the car brakes to the final velocity of 0. The whole procedure takes $t_s = 17.5\ s$.

What is the whole distance travelled?

Answer: ✕

Check

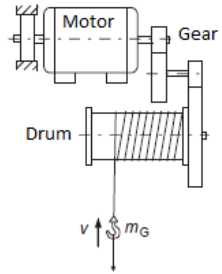
Time elapsed during final deceleration: $t_2 = t_s - t_1 - s/(at_1)$.

Final deceleration (abs.) $a_2 = at_1/t_2$.

Distance travelled: $\cancel{s + 1/2at_1 + 1/2at_1t_2}$. **Correction:** $s + \frac{1}{2}a_1t_1^2 + \frac{1}{2}a_1t_1t_2$

Mechanics 11

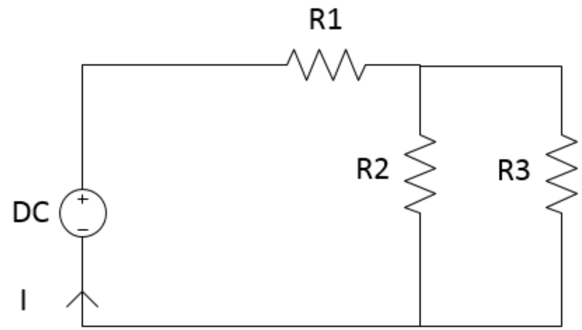
A lifting device consists of an electric motor, a gearbox and a drum for lifting a rope. The lifting speed after the initial acceleration is $v = 0.4\ m/s$, gear efficiency $\eta = 0.85$, maximum motor torque is $T = 13.5\ Nm$, motor inertia $I_m = 0.0047\ kgm^2$, drum diameter $d = 0.5\ m$, and motor rotating speed $n = 2752\ rpm$. The inertia of the drum is considered small and thus neglected. Calculate the acceleration time of the mass $m_G = 480.1\ kg$. Remember to consider the effect of the mass on the accelerating torque.



- Linear mass reduced on motor shaft: $I_r = \frac{m}{\eta}\left(\frac{v}{\omega}\right)^2$
- Inertia: $I = I_m + I_r$
- Gear ratio: $i = \frac{2\pi\frac{n}{60}}{\frac{v}{d/2}}$
- Torque left for accelerating the mass: $T = T - \frac{T_m}{\eta}\frac{\omega_2}{\omega_1} = T - \frac{mgd}{2\eta i}$
- Motor shaft angular acceleration: $\alpha = \frac{T}{I}$
- Acceleration time: $t = \frac{\omega}{\alpha} = \frac{2\pi n}{60\alpha}$

Electrics 1

The voltage source is adjusted to $V = 11.4\ V$ and the resistors are $R1 = 1.0\ k\Omega$, $R2 = 0.4\ k\Omega$ and $R3 = 1.6\ k\Omega$. Calculate the current I. Give your answer in unit mA.



Answer:

Check

R2 and R3 parallel: $R23 = (R2R3)/(R2 + R3)$.

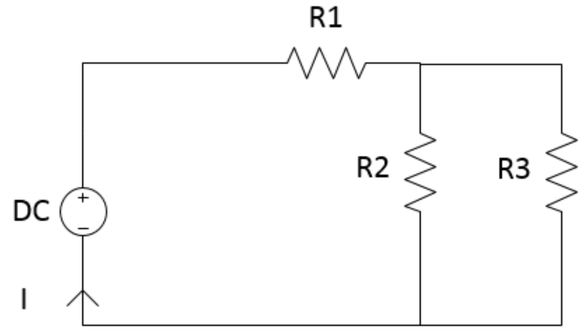
R1 and R23 in series: $R123 = R1 + R23$.

$I = U/R123$

The correct answer is: 8.64

Electrics 2

The voltage source is adjusted to $V = 11.1\ V$ and the resistors are $R1 = 0.9\ k\Omega$, $R2 = 0.5\ k\Omega$ and $R3 = 1.4\ k\Omega$. Calculate how much electrical power is dissipated as heat. Give your answer in unit mW.



Answer: ✗

Check

R2 and R3 parallel: $R23 = (R2R3)/(R2 + R3)$.

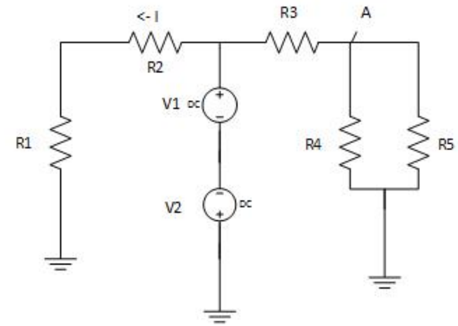
R23 and R1 in series: $R123 = R1 + R23$.

$P = VI = V^2/R123$.

The correct answer is: 97.14

Electrics 3

For the following circuit, with $R1 = 0.6\ k\Omega$, $R2 = 9.4\ k\Omega$, $R3 = 10.5\ k\Omega$, $R4 = 1.0\ k\Omega$, $R5 = 1.4\ k\Omega$, $V1 = 4.0\ V$ and $V2 = 9.7\ V$, find the voltage at node A respective to the ground.



Answer:

Check

R4 and R5 parallel: $R45 = (R_4 R_5)/(R_4 + R_5)$

R3 and R45 in series: $R345 = R3 + R45$

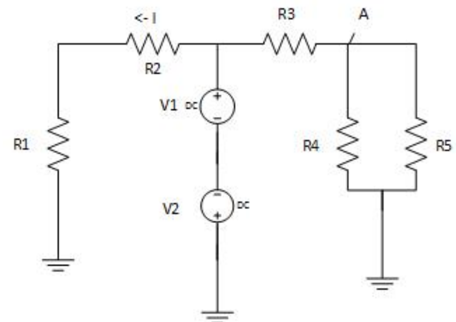
Voltage sources: $V_t = -V_2 + V_1$

Voltage at node A: $V_A = (V_t/R345) * R45$

The correct answer is: -0.30

Electrics 4

For the following circuit, with $R1 = 0.6\ k\Omega$,$R2 = 9.4\ k\Omega$, $R3 = 10.5\ k\Omega$, $R4 = 1.0\ k\Omega$, $R5 = 1.4\ k\Omega$, $V1 = 4.0\ V$ and $V2 = 9.7\ V$, find the current I. Give your answer in unit mA.



Answer:

Check

Voltage sources: $V_t = -V2 + V1$.

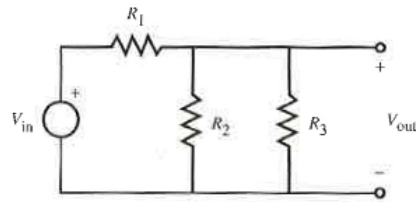
R1 and R2 in series: $R12 = R1 + R2$.

Current: $I = V_t/R12$

The correct answer is: -0.57

Electrics 5

Solve V_o in terms of V_i from the following circuit. $R1 = 97.1\ \Omega$, $R2 = 10.0\ k\Omega$, $R3 = 0.9\ M\Omega$. The solution is of form $V_o = kV_i$. Give only factor k as your answer.



Answer:

Check

R2 and R3 parallel: $R23 = (R2R3)/(R2 + R3)$.

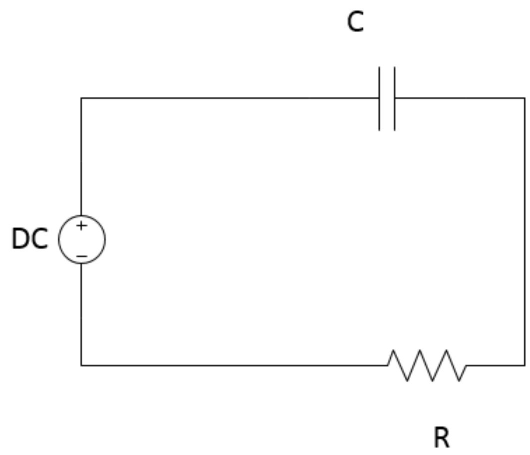
Current I through voltage source and R1: $I = V_i/(R1 + R23)$.

$V_o = R23 * I; V_o = (R23/(R1 + R23))V_i$.

The correct answer is: 0.99

Electrics 6

The voltage source is adjusted to $V = 12.9\ V$. $R = 1.3\ k\Omega$ and $C = 160\ pF$. Calculate the current I through the circuit after the equilibrium is reached.



Answer:

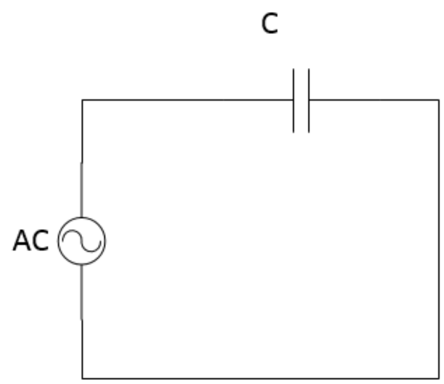
Check

With direct current, a capacitor seems like an insulator after equilibrium is reached. $I = 0$.

The correct answer is: 0.00

Electrics 7

The voltage source produces an alternating current with frequency $f = 52.8\ Hz$ and (rms) voltage $V = 11.1\ V$. $C = 14.5\ \mu F$. What is the (rms) current through the capacitor? Give your answer in unit A.



Answer:

Check

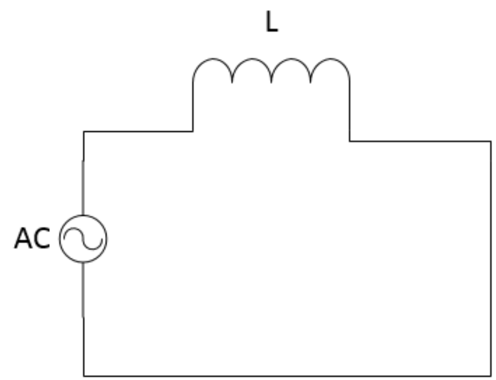
Capacitive reactance: $X_c = 1/(2\pi f C)$

$I = V/X_c$.

The correct answer is: 0.05

Electrics 8

The voltage source produces an alternating current with frequency $f = 259.5\ Hz$ and (rms) voltage $V = 11.6\ V$. $L = 2066.1\ \mu H$. What is the (rms) current through the inductor? Assume that the inductor is ideal.



Answer:

Check

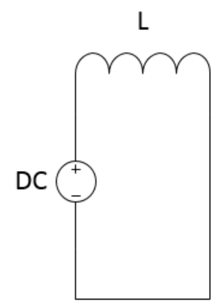
Capacitive reactance: $X_L = 2\pi f L$.

Current: $I = V / X_L$

The correct answer is: 3.44

Electrics 9

What will happen, when the dc source is enabled? Assume that the inductor is ideal.



Select one:

- a. Current will start to alternate.
- b. Current will raise very high (theoretically infinite).
- c. Current will raise logarithmically towards a steady-state value.
- d. Current will be zero.

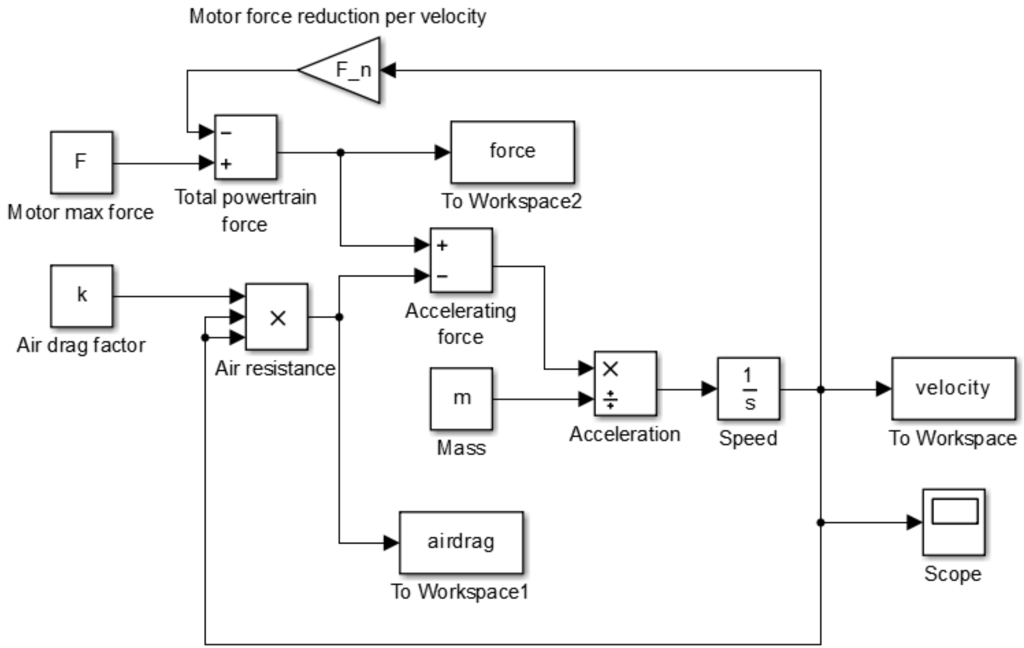
Check

Your answer is incorrect.

An ideal inductor has no resistance, only inductance which causes the inductor to resist the change of current. A constant DC voltage over an inductor would theoretically cause the current to rise at a constant rate without a limit. In reality, an inductor always contains some resistance, so the current would be very high but not infinite.

The correct answer is: Current will raise very high (theoretically infinite).

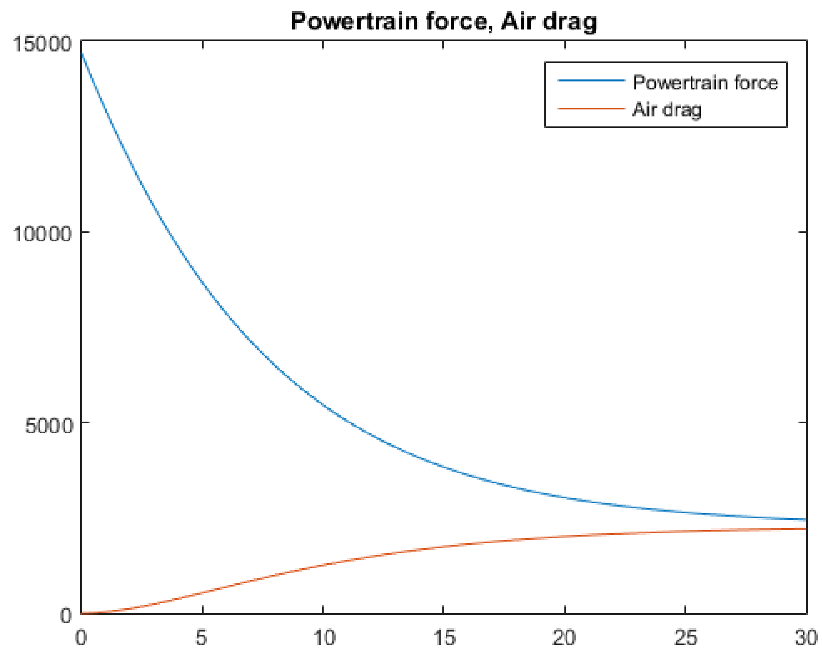
Simulink warmup



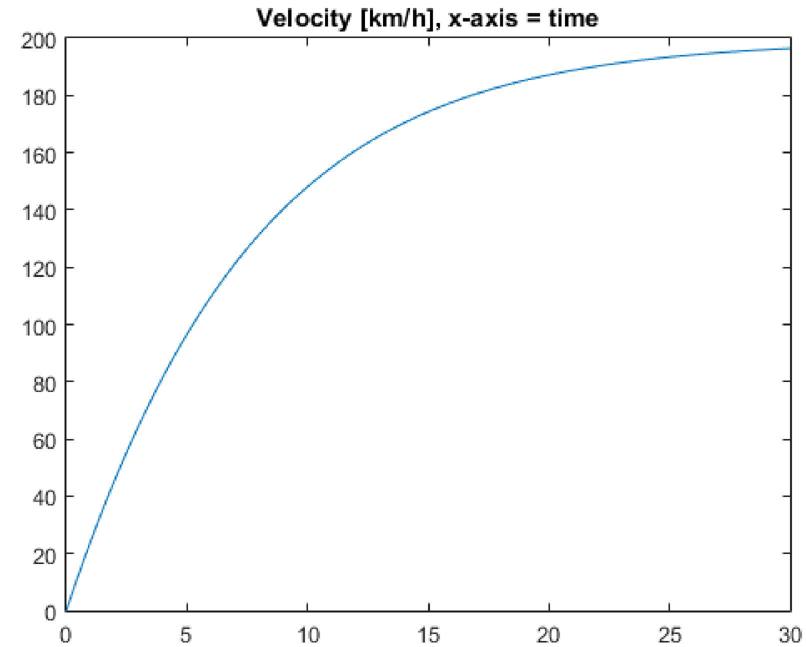
$$v = \int \frac{F - F_n v - k v^2}{m}$$

Air drag increases exponentially as the speed increases. The force produced by the powertrain decreases as the speed increases (due to back-EMF of the motor). At some speed the decelerating force from the air drag equals the force produced by the power train. The car is asymptotically approaching this speed.

Simulink warmup



Simulink warmup



2.1: Sensors for a forklift

Briefly describe (300-500 words) what kind of sensors you could use to determine the position of an autonomous forklift that works indoors in a warehouse environment. The forklift must locate itself as well as the pallets it is transporting, and the storage shelves inside the warehouse.

- **Automatic plagiarism check**

2.2: Position sensors

- **All the information for the tasks is not presented in the lecture slides**
  - Use of *internet* and other material is highly beneficial

- **Tasks are typical calculations, when selecting sensors for some application**

2.3 DC motor in Simulink

- **Individual help is available during the exercise sessions.**
- **Walkthrough instructions for model building in MyCourses**