Congratulations! You passed!

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1. What is the **order** of the following transfer function?

1 / 1 point

$$G(s) = \frac{s - 10}{s^2 + 2s + 1}$$

- ○ This is the first order transfer function
- ◉ This is the second order transfer function
- ○ This is the third order transfer function
- ○ This is the fifth order transfer function
- ○ None of the above

Correct

Correct! This transfer function contains a first order numerator and a second order denominator. The order of the function is the highest exponent in the transfer function, so that this is the second order transfer function.

2. What are the **poles and zeros** of the following transfer function?

1 / 1 point

$$G(s) = \frac{s^2 + 3s - 10}{s^2 - s - 12}$$

- ◉ The poles are -3 and 4; the zeros are 2 and -5
- ○ The poles are -4 and 3; the zeros are 5 and -2
- ○ The poles are 2 and -5; the zeros are -3 and 4
- ○ The poles are 5 and -2; the zeros are -4 and 3
- ○ None of the above

Correct

Correct! The zeros of a system are the roots of the numerator, and the poles of a system are the roots of its denominator.

3. What might be your action as a system control engineer if you need to **increase the overshoot** of a control loop system? (Select all that apply)

1 / 1 point

- [ ] Decrease K_I
- [x] Decrease K_D

Correct

Correct! Decreasing derivative gain leads to an increase of overshoot.

- [x] Increase K_I

Correct

Correct! Increasing integral gain leads to an increase of the overshoot.

- [ ] Decrease K_P
- [x] Increase K_P

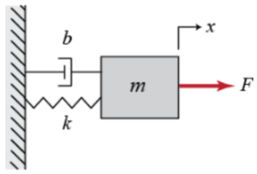
Correct

Correct! Increasing proportional gain leads to an increase of the overshoot.

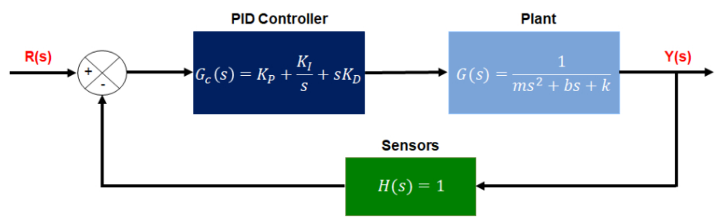
- [ ] Increase K_D

4. Recall the Mass-Spring-Damper System example form the video on PID Control. This system is shown in the figure below.

1 / 1 point



As a system control engineer, you constructed the following closed loop transfer function to represent the Mass-Spring-Damper System. What is the **correct transfer function** for this closed loop?



○ Transformation function 1

$$G(s) = \frac{K_D s^2 + sK_P + K_I}{K_P + \frac{K_I}{s} + K_D s}$$

○ Transformation function 2

$$G(s) = \frac{K_P + \frac{K_I}{s} + K_D s}{K_D s^2 + sK_P + K_I}$$

○ Transformation function 3

$$G(s) = \frac{ms^2 + bs + k + K_P + \frac{K_I}{s} + K_D s}{K_P + \frac{K_I}{s} + K_D s}$$

◉ Transformation function 4

$$G(s) = \frac{K_D s^2 + sK_P + K_I}{ms^3 + (b + K_D)s^2 + (k + K_P)s + K_I}$$

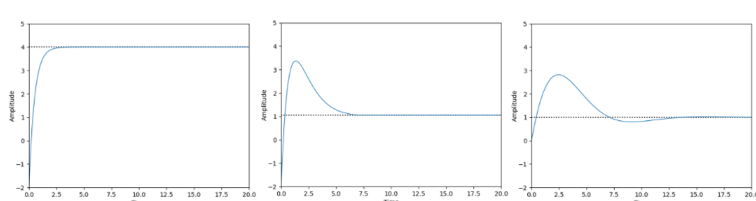
○ None of the above

✓ **Correct**

Correct!

5. You are given the step response of a few different PID controllers using the same gains for the same first order transfer function. **Determine a possible set of controllers** that generated these step responses:

1 / 1 point



○ 1st response by PI; 2nd response by PD; 3rd response by PID

○ 1st response by PD; 2nd response by PI; 3rd response by PID

○ 1st response by PI; 2nd response by PID; 3rd response by PD

◉ 1st response by PD; 2nd response by PID; 3rd response by PI

○ None of the above

Correct

Correct! Adding derivative control improves the step response in terms of overshoot and settling time, but slows down the rise time. Adding the integral term instead maintains a short rise time, and is able to reduce oscillation and overshoot, leading to a fast settling time as well. Adding both derivative and integral control terms brings the advantages of both these approaches.

6. What is the output of a typical output of a Longitudinal control module? (Select all that apply)

1 / 1 point

- [ ] Reference velocity
- [x] Throttle angle

Correct

Correct! A longitudinal control module takes a reference velocity as an input and outputs throttle angle and brake pedal position.

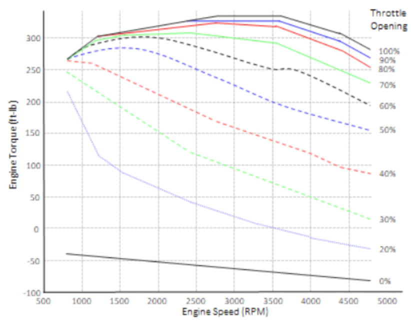
- [ ] Steering angle
- [x] Brake position

Correct

Correct! A longitudinal control module takes reverence velocity as an input and outputs throttle angle and brake pedal position.

7. Based on the engine map in the figure below, **determine the throttle angle** needed to produce 250 ft-lb of torque given that the current engine speed is 3500 RPM.

1 / 1 point



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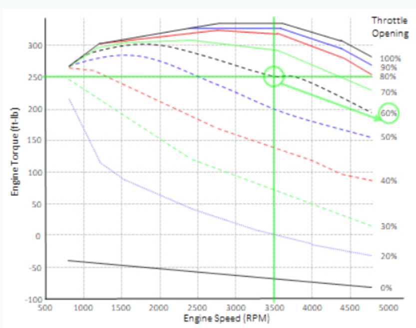
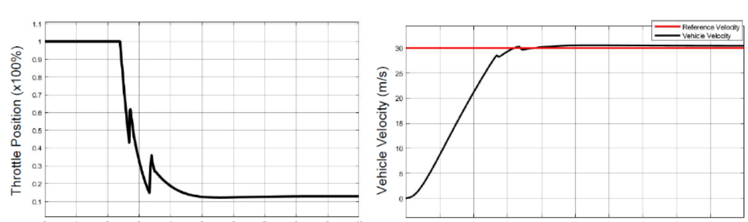
Correct

Correct!



8. The results of a simulation of the control response to a step change in desired speed of a dynamic vehicle model with a PID controller are shown in the figures below. There are two spikes on these figures: one spike is between 2 and 3 seconds, another spike is between 3 and 4 seconds. **What is the reason of these spikes?**

1 / 1 point

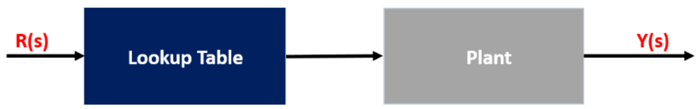


- ◯ Engine-transmission torque loss
- ◯ Tire slip
- ◉ Nonlinear engine map
- ◯ High level controller simplification: changing the integral to a summation over fixed length time steps in the Integral term
- ◯ None of the above

Correct
Correct! These artefacts are caused by the engine map nonlinearities.

9. What type of **control system** is shown in the figure below?

1 / 1 point



- ◯ Feedback control
- ◉ Feedforward control
- ◯ Feedback-feedforward control
- ◯ None of the above

Correct
reference signal is directly fed into the feedforward controller, which generates the inputs to the plant.

10. What types of inaccuracies are corrected by a feedback controller?

1 / 1 point

- [x] Disturbances

Correct
Correct! The feedback controller corrects for errors that result from disturbances.

- [ ] Nonlinear engine map
- [x] Errors in the plant model

Correct
Correct! The feedback controller corrects for errors that result from inaccuracies in the plant model.

- [ ] High level controller simplification: changing the integral to a summation over fixed length time steps in the Integral term

11. What assumptions are essential for creation of a **longitudinal feedforward input**? (Select all that apply)

1 / 1 point

- [x] The vehicle is at steady state

Correct
Correct! Modelling feedforward block requires converting the entire longitudinal dynamics model into a fixed lookup table or reference map, that maps the reference velocity to the corresponding actuator signals assuming the vehicle is at steady state.

- [ ] The plant system is linear
- [ ] Torque from the engine passes directly to the transmission without loss
- [ ] The tire slip angle and ratio are negligible

12. What are the sources of the load torque considered for a **longitudinal feedforward look-up table computation**? (Select all that apply)

1 / 1 point

- [x] Gravitational resistance

Correct! Gravitational resistance is a force acting opposite to the relative motion, so that it is a part of the load torque acting on the vehicle.

- [ ] Cornering force

- [ ] Sliding resistance
- [ ] Static friction
- [x] Rolling resistance

Correct
Correct! Rolling resistance is a force acting opposite to the relative motion, so that it is a part of the load torque acting on the vehicle.

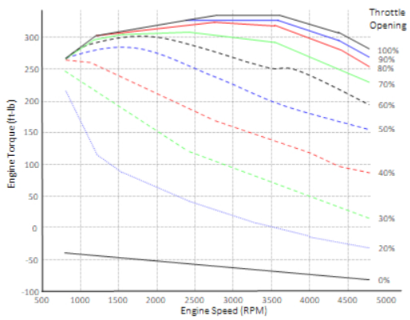
- [x] Aerodynamic resistance

Correct
Correct! Aerodynamic resistance is a force acting opposite to the relative motion, so that it is a part of the load torque acting on the vehicle.

13. A vehicle is being operated on a highway with the reference velocity of 126 km/h (35 m/s) in gear 4 and it overcomes the total load torque of 300 ft-lb. This vehicle specification includes effective wheel radius of 0.35 m and 4th gear ratio of 2. **What throttle angle** is required for maintaining the the current speed of the vehicle?

1 / 1 point

Please use the below engine map for your computation.



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Correct
Correct!

$$\omega_w = \frac{V_ref}{r_eff} = \frac{35[m/s]}{0.35[m]} = 100[1/s] = 100[hertz]$$

$$\omega_e = \frac{\omega_w}{GR} = \frac{100[hertz]}{2} = 50[hertz]$$

$$\omega_e = 50[1/s] \cdot 60[s/min] = 3000RPM$$

An intersection of $\omega_e = 3000[RPM]$ and $T_{engine} = 300$[ft-lb] falls on the green line on the chart, where the green line defines the throttle angle of 70%.