ENTRANCE ONLINE TEST FOR ENERGY SYSTEMS MSC PROGRAM

(sample)

Problem

If you have one mole of Argon (monoatomic gas, Ar, with molar mass 40 g/mol), one mole of Nitrogen (bi-atomic gas, N_2, molar mass 28 g/mol) and one mole of Carbon dioxide (triatomic gas, CO_2, molar mass 44 g/mol), assuming ideal gas, which one will occupy the larger volume at 0 ^{0}C and atmospheric pressure?

a. Monoatomic gas occupies a volume 2 times larger than bi-atomic gas and 3 times larger than the three-atomic one
b. All different not possible to quantify with given information
c. All the same

Answer: C.

Problem

Is it possible that a Linear Programming problem has infinite solutions?

a. No, because linear programming problems always have a single solution
b. Yes, but it is needed to have an unbounded domain
c. Yes, although it is not necessary to have unbounded domain
d. Only when the problem has repeated constraints

Answer: C.

Problem

The Wheatstone bridge is a useful circuit for resistance – based measurements. Figure 1 shows the basic circuit. The bridge is balanced when the voltage between A and B is zero. Which is the value of Rx that balances the bridge, if the other resistance values are R1=5 Ohm, R2=20 Ohm, R3=10 Ohm?

a. Rx=40 Ohm
b. Rx=20 Ohm
c. Rx=50 Ohm

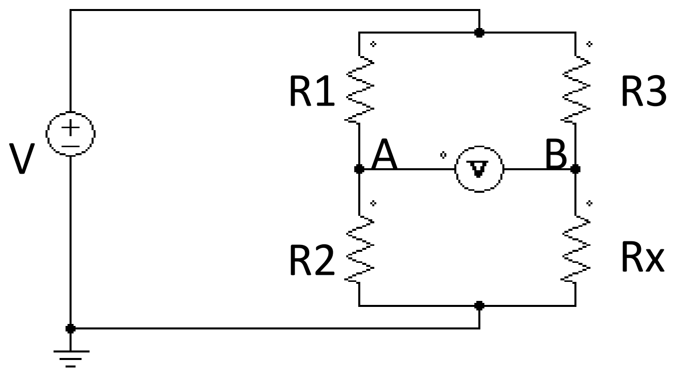

Figure 1. Basic circuit.

Answer: A.

Problem

In order to get maximum power transfer from a capacitive source, the load must

a. have a capacitive reactance equal to circuit resistance
b. have an impedance that is the complex conjugate of the source impedance
c. be as capacitive as it is inductive
d. none of the above

Answer: B.

Problem

$2^a + 2^a + 8 \cdot 2^{a-1} + 2^a + 2^a = ?$

a. 8^{3a}
b. 8^a
c. $2^{a+2} + 2^{a+2}$
d. 16^{2a}

Answer: C.

Problem

Calculate the integral $\int_{-\infty}^{+\infty} \frac{dx}{1+x^2}$

a. 0
b. 1
c. π
d. 2π

Answer: C.

Problem

Consider the following ordinary differential equation:

$$y' + \frac{y}{x} - 2\exp(x^2) = 0,$$

and $y(1) = 0$. What is the value of $y(2)$?

a. $e^4/2 - e/2$
b. $e - 1$
c. $e^2 - 1/2$
d. 0

Answer: A.

Problem

Which sentence is correct?

a. Heat engine is a device which can transform heat into mechanical work
b. Heat engine is a device which has an efficiency larger than one
c. Heat engine is not an external combustion engine, e.g. Steam engine.

Answer: A.

Problem

A board (Fig. 1) is leaned in its middle point against a linchpin (D). The masses A and B are placed in the point 4, the mass C in the point 11. All the masses are equal and the points 1 ÷ 12 are equidistant. In order to obtain the static equilibrium of the system, a single mass has to be moved:

a. From the point 4 to the point 5
b. From the point 11 to the point 12
c. From the point 11 to the point 7.

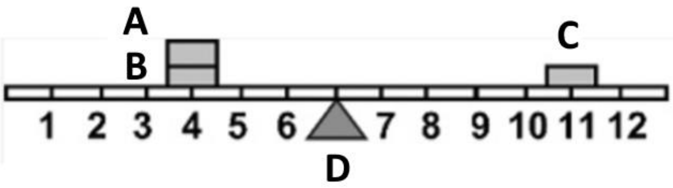

Fig. 1.

Answer: B.

Problem

We would like to model the technical constraints of a thermal generation unit. We found the formulation shown below. We know that p_t is the power produced by the generator at time t. Highlight the true assertions (none, one or more) about the interpretation of this formulation. P_{min}, P_{max}, R, and L are positive known values.

$$P_{min}x_t \leq p_t \leq P_{max}x_t \qquad \forall t = \{1, \dots, 24\} \qquad (1)$$
$$p_t - p_{t-1} \leq R \qquad \forall t = \{2, \dots, 24\} \qquad (2)$$
$$p_{t-1} - p_t \leq L \qquad \forall t = \{2, \dots, 24\} \qquad (3)$$
$$p_t \geq 0, x_t \in \{0,1\} \qquad \forall t = \{1, \dots, 24\} \qquad (4)$$

a. The equation (1) represents that the total energy produced during 24 hours of a day by the thermal generator has to be within the limits P_{min} and P_{max}
b. The symbol x_t is associated with the decision of starting-up (switching on) the thermal generator in period t
c. Equation 2 limits the rate of increasing the power generated from period t-1 to t
d. Equation 3 limits the rate of increasing the power generated from period t-1 to t.

Answer: C.

Problem

In a -connected source feeding a Y-connected load,

a. each phase voltage equals the difference of the corresponding load voltages
b. each phase voltage equals the corresponding load voltage
c. each phase voltage is one-third the corresponding load voltage
d. each phase voltage is 60° out of phase with the corresponding load voltage.

Answer: A.

Problem

Find the derivative with respect to x of the following function $f(x) = (x-1)^{(x-1)}$

a. $(x-1)^{(x-1)}(\log(x-1)+1)$
b. $(x-1)^{(x-1)}$
c. $x(x-1)^{(x-1)} + \log(x-2)$.

Answer: A.

Problem

Calculate $(\cos(\pi/8) + i\sin(\pi/8))^{2080}$.

Answer: 1.

Problem

Customers visit a supermarket randomly at an average rate of 5 customers per hour. What is the probability of observing exactly 4 new visitors in a given hour at the supermarket? Estimate the result (approximately) numerically. Format of the answer is 000.000.

Answer: 0.176.

Problem

Consider the electrical circuit depicted on the figure below (Fig. 1). Notations for voltages, currents and resistances are standard.

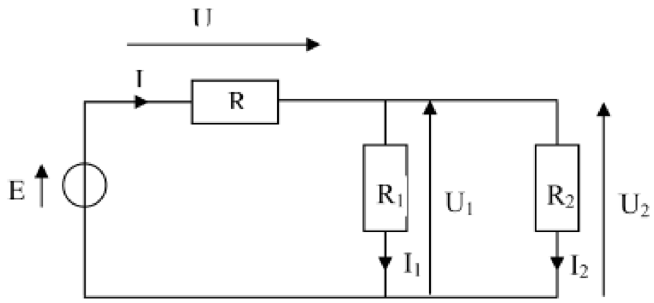

Fig. 1.

1. The relationship between I, I_1 and I_2 is:

   a. $I + I_1 + I_2 = 0$
   b. $I - I_1 - I_2 = 0$
   c. None of the above.

2. The relationship between U, R and I is:

   a. $U = RI$
   b. $U = -RI.$

3. What relationship(s) between E, U, U_1 and U_2 exist(s):

   a. $E + U = U_1 + U_2$
   b. $E = U + U_1$
   c. $E + U = U_2$
   d. $U_1 = U_2.$

4. Knowing that$R_1 = R_2 = 10\ \Omega$, the value of the equivalent resistance R_{eq} is:

   a. $R_{eq} = 10\ \Omega$
   b. $R_{eq} = 5\ \Omega$
   c. $R_{eq} = 20\ \Omega.$

Answers: 1 – B, 2 – B, 3 – B and D, 4 – B.

Problem

Given a gas which goes through a process which takes place at constant volume, the work you can extract is equal to:

a. Zero, because there is no volume variation
b. Not possible to determine without knowing which is the gas

c. The ratio between pressure and the volume variation.

Answer: A.

Problem

Suppose a fair coin is tossed repeatedly and heads appeared in the first 1000 tosses. What is the probability that tail will turn up in the 1001th toss?

Answer: 0.5.

Problem

The gate of POWER MOSFET or IGBT can be modelled as a capacitor with a capacitance, *C*. Figure 1 shows a typical input circuit of a POWER MOSFET. The driver can be considered as a voltage source, *Vi(t)*, with an internal resistance, *R*. It delivers an amount of charge during the turn-on and turn-off processes. In a normal cycle, the POWER MOSFET is on during a time interval and then is turned off waiting for the next cycle. Figure 1 shows the waveforms of the voltage source that produces this behavior.
If the *Vi(t)* has the voltage pattern of the figure, which the average power losses in the internal resistance? Consider that the capacitor achieves full charge and discharge, *R*C<<T*.
C=capacitance (F)
R=resistance (Ohm)
T=period (s)
V=maximum voltage (Volts).

a. $CV^2/(2T)$
b. CV^2/T
c. TV^2/R
d. Not enough information to be determined.

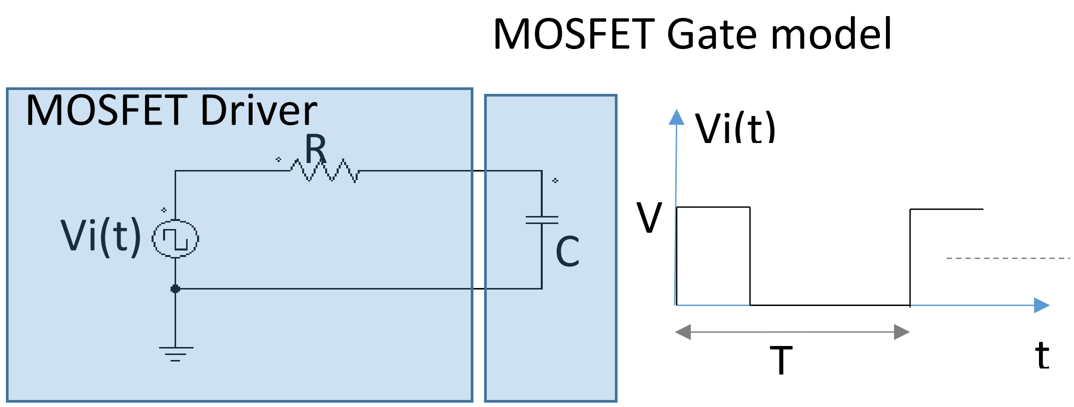

Fig. 1.

Answer: B.

Problem

In a series *RLC* circuit that is operating above the resonant frequency, the current

a. lags the applied voltage
b. leads the applied voltage
c. is in phase with the applied voltage
d. is zero.

Answer: A.

Problem

Find eigenvalues and eigenvectors of the matrix $A = \begin{pmatrix} 2 & -1 & -1 \\ 0 & -1 & 0 \\ 0 & 2 & 1 \end{pmatrix}$.

a. Eigen values $\{0,\ 1, -1\}$, Eigen vectors: $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$

b. Eigen values $\{2,\ 1,\ -1\}$, Eigen vectors: $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}, \begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$

c. Eigen values $\{4,\ 1, -1\}$, Eigen vectors: $\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} -1 \\ 0 \\ 2 \end{bmatrix}, \begin{bmatrix} 0 \\ 2 \\ -1 \end{bmatrix}$.

Answer: B.

Problem

Calculate $1 + 2 - 3 + 4 + 5 - 6 + 7 + 8 - 9 + \cdots + 2018$

Answer: 680403.

Problem

Which of the following statements are true?

I. There exists a constant C such that $|\arctan x - x| \leq Cx^3$, $|x| \leq 1$
II. There exists a constant C such that $|1 - \cos x| \leq Cx^2$, for any real x
III. There exists a constant C such that $\sum_{k=1}^{n} k^3 \leq Cn^3$.

a. none
b. II
c. I and II
d. III.

Answer: B.

Problem

Consider a series RLC circuit. The impedance modulus Z as a function of frequency ω reads

a. $Z = \sqrt{R^2 + L^2\omega^2 + C^2\omega^2}$

b. $Z = R + jL\omega - \frac{j}{C\omega}$ with $j^2 = -1$

c. $Z = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$

d. $Z = \sqrt{R^2 + L^2 + C^2}$

e. none of the above.

Answer: C.

Problem

Given Energy conservation (1st principle thermodynamics) and a gas that goes through a process, which takes place at constant temperature (isothermal) which sentence is not correct:

a. The exchanged heat with external environment is equal to the exchanged mechanical work
b. The exchanged heat with external environment is equal to zero
c. The internal energy variation is equal to zero.

Answer: B.

Problem

Three different masses M1, M2 and M3 (Fig. 1) are leaned on an horizontal smooth plane (namely without friction) and are connected by an ideal wire (namely not extendible and with negligible mass). The masses (where M3 > M1 > M2) are pulled by the force F applied on the wire. The acceleration (a) of the system is:

a. Not possible to determine without knowing the application point of F
b. a = F / M3
c. a = F / (M1 + M2 + M3).

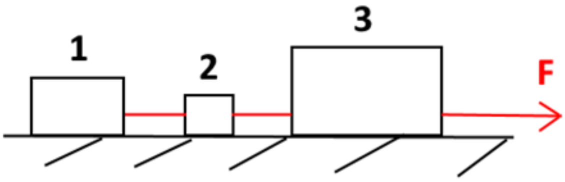

Fig. 1.

Answer: C.

Problem

An agent faces a positive opportunity cost if:

a. He paid more than he had in cash for a product (e.g., credit)
b. He chose an investment option that rents him an annual 10%, but there was an alternative option (with the same level of risk) that would rent him 12% per year
c. He chose an investment option that rents him 12% per year, but there was an alternative option (with the same level of risk) that would rent him 10% per year
d. There are other agents that benefit freely as a result of their actions (i.e., free-riders).

Answer: B.

Problem

Let $y = f(x)$ be a solution of the differential equation $x^2y' + xy + 1 = 0$ such that $y = 2$ when $x = 1$. What is the value of $f(2)$?

a. $1 - \log 2$
b. $2\log 2 + 4$
c. $1 + (\log 2)^2$
d. $4.$

Answer: A.

Problem

Given a point $a = [8,\ 4]$. Find the nearest point from the ball $x_1^2 + x_2^2 \leq 1$ to a.

a. $\left[\frac{2}{\sqrt{5}}\right], \left[\frac{1}{\sqrt{5}}\right]$
b. $[2, 1]$
c. $\left[\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{8}}\right].$

Answer: A.

Problem

Calculate $\sum_{n=1}^{\infty} 1/3^n$

Answer: 1/2.

Problem

Find the minimal f_* and maximal f^* values of $f(x)$

$$f(x) = \exp(x_1 - x_2) - x_1 - x_2,$$

on a set $X = \{x : \ x_1 + 2x_2 \leq 2, \ x_1 \geq 0, \ x_2 \geq 0\}$.

a. $f^* = e^2 - 2$ and $f_* = e^{-1} - 1$
b. $f^* = e^2 - 2$ and $f_* = e^{-2} - 1$
c. $f^* = e^2 - 1$ and $f_* = e^{-2} - 1$
d. $f^* = e^2 - 1$ and $f_* = e^{-1} - 1$.

Answer: A.

Essay question

Consider a car moving along a road at varying speed between two particular points *A* and *B*: the car accelerates and then decelerates. The *mean* speed measured between points *A* and *B* is 60 km/h. Is there *at least* one moment between the points *A* and *B* when the car reached exactly the speed of 60 km/h? Prove your answer mathematically.

a. no
b. yes
c. the question cannot be answered.

Essay question

A vehicle has a motor with an efficiency of 35%. The vehicle starts at point A and stops at point B (points A & B are at the same height). When it arrives at its destination

a. 65% of the energy used by the motor has been converted to heat
b. 100% of the energy used by the motor has been converted to heat
c. It depends whether the motor is electrical or internal combustion.

Please select the right answer and explain your answer (200 words).