Duration: 2h00.

Notes:
*** Write your name on every exam sheet you submit**
*** Closed book exam**
*** The use of any calculator with graphic support is prohibited**

1. [2] Compare the operating principles and construction of Brushless DC (BLDC) motors and Servomotors - permanent magnet synchronous (PMSync) motors. Provide one common application for each type of motor in a Battery Electric Vehicle (BEV).

2. [2] Fuses are well-known protective devices used in electrical circuits.
   a) What type of curve is used to characterize the behavior of a fuse, and what does it represent?
   b) Consider two fuses with identical nominal values but distinct behaviors. Illustrate their respective curves on the same graph and identify each one.
   c) Why is it important to have fuses with the same nominal value but different behaviors?

3. [3] Refer to the motor plate shown in Figure 1.
   a) Identify the type of motor and calculate its efficiency, considering that the motor has a power factor (cos φ) of 0.7. Provide the necessary calculations.
   b) How many terminals do you expect this motor has? Justify.
   c) If this motor is to be controlled using Direct-On-Line (DOL) starting, specify the electrical supply network and motor configuration that would be required.

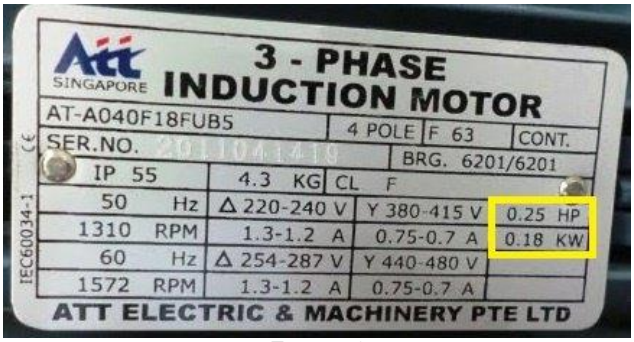

Figure 1

   d) Can a star/delta starter be used as an alternative to a DOL starter for this motor? Justify your answer.
   e) What electromechanical components are required to set up a star-delta starter'?

4. [2] Among high-performance three-phase industrial motors, axial-flux motors and Synchronous Reluctance Motors (SyncRM) stand out. What do they have in common and what distinguishes them?

5. [2] Refer to the circuit in Figure 2, to control a three-phase induction motor with a soft-starter.
   a) Identify the components labeled A, B, C, and D
   b) What is the function of component B?
   c) What parameters do you expect to configure in the soft-starter?
   d) Is it possible to adjust the maximum continuous speed?

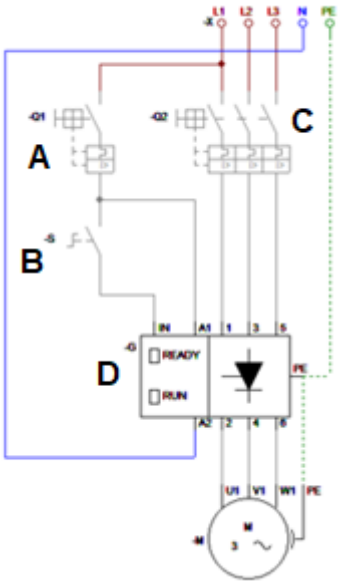

Figure 2

6. [1] Consider the block diagram of figure 3. For each block, list two examples of switchgear components that can be used.

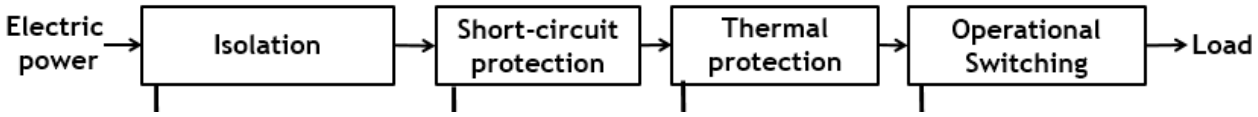

Figure 3

7. [5.5] Consider the operation of a overhead crane, Figure 4 below, with the capability of moving horizontally in two directions (longitudinal and transversal) in addition to the vertical (lifting) direction, with the following load and operation parameters:

- maximum carrying load, *m = 8000 kg*
- horizontal transversal speed, *v = 25 m/min*
- diameter of the power wheel, *d = 250 mm*
- rolling coefficient of supporting wheels, *μ = 0,03*
- acceleration time, t_{acc} *=1,5 s*

Also, consider an overall efficiency of the gear box connecting the shaft to the power wheel, of 82%.

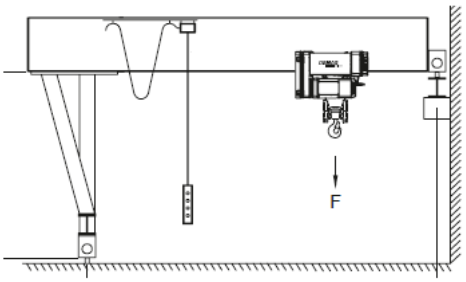

Figure 4

a) Assuming 3-phase induction motors with 4 poles, from the table below, present the steps followed and respective calculations to select a motor for the horizontal transversal movement of this application. Justify the selection made.
b) Represent the characteristic torque/speed curve, indicating the values corresponding to the chosen motor and the operating point for maximum load.
d) Estimate the electric power consumed by the motor in the conditions of previous question (b).

Table 1: The values correspond to a 50 Hz specification; ZBE corresponds to a motor with an incorporated electromechanical brake.

4-pole Z.E. motors 100% CDF (IE2)

Type	P_N [kW]	n_N [rpm]	M_N [Nm]	I_N 400 V [A]	$\cos\varphi_N$	IE - 2 $\eta_{1/2}$ %	IE - 2 $\eta_{3/4}$ %	IE - 2 4) $\eta_{4/4}$ %	I_A/I_N	M_A/M_N	M_K/M_N	J_{Mot} [kgm² x 10⁻³] ZNE	J_{Mot} [kgm² x 10⁻³] ZBE	Z_0 [1/h] 1)	Z_0 [1/h] 2)	Brake Type	Brake [Nm] M_{BStd}	Weight [kg] 3) ZNE	Weight [kg] 3) ZBE
Z.E 63 B4	0,18	1385	1,2	0,6	0,64	66,5	71,2	72,1	4,0	2,8	2,8	0,55	0,61	13000	13000	B003	2,5	7,8	10,5
Z.E 71 A4	0,25	1390	1,7	0,8	0,63	69,5	74,0	74,9	4,0	3,0	3,0	0,65	0,71	10000	12000	B007	3,4	8,5	11,2
Z.E 80 A4	0,55	1420	3,7	1,5	0,68	78,0	78,3	78,1	5,0	3,0	3,0	1,43	1,49	7800	11200	B007	7,6	12,2	15,6
Z.E 80 B4	0,75	1425	5	2	0,66	79,3	82,2	79,6	4,9	2,8	3,0	2,06	2,19	9400	13500	B020	10	15,1	19,5
Z.E 90 A4	1,1	1445	7,3	2,7	0,69	79,8	82,3	81,4	5,7	2,3	2,8	2,47	2,60	9400	13500	B020	16	16,0	20,4
Z.E 90 B4	1,5	1435	10	3,3	0,77	82,1	83,4	82,8	6,2	2,7	3,2	4,60	4,73	5000	7200	B020	20	20,7	26,3
Z.E 100 A4	2,2	1430	14,6	4,7	0,79	83,8	84,9	84,3	6,1	2,3	3,0	5,75	6,21	5400	7800	B050	33	24,5	33,6
Z.E 100 B4	3	1445	19,8	6,6	0,77	83,6	86,4	85,5	5,6	2,0	2,8	7,06	7,52	5300	7600	B050	39	23,2	32,3

Only for operation with an inverter

1) Operation with brake rectifier without high-speed excitation
2) Operation with brake rectifier with high-speed excitation
3) Weight for B14 model
4) The nominal efficiencies as per efficiency class IE2 in accordance with IEC 60034-30 are specified

Duration: 2h00.

8. [2.5] The figure 5, below, illustrates the Torque/Speed curves of a specific type of motor, as you certainly remember from the lab classes.

   a) What type of motor do these curves represent? Explain how the curves represented can be used in the selection of this type of motor, for a specific application.
   b) Before getting to these curves, what other information from a specific motor must be considered to verify whether one should proceed in the sizing steps?
   c) Once a motor is selected what else is necessary to fully characterize this type of motor solution for a specific application?

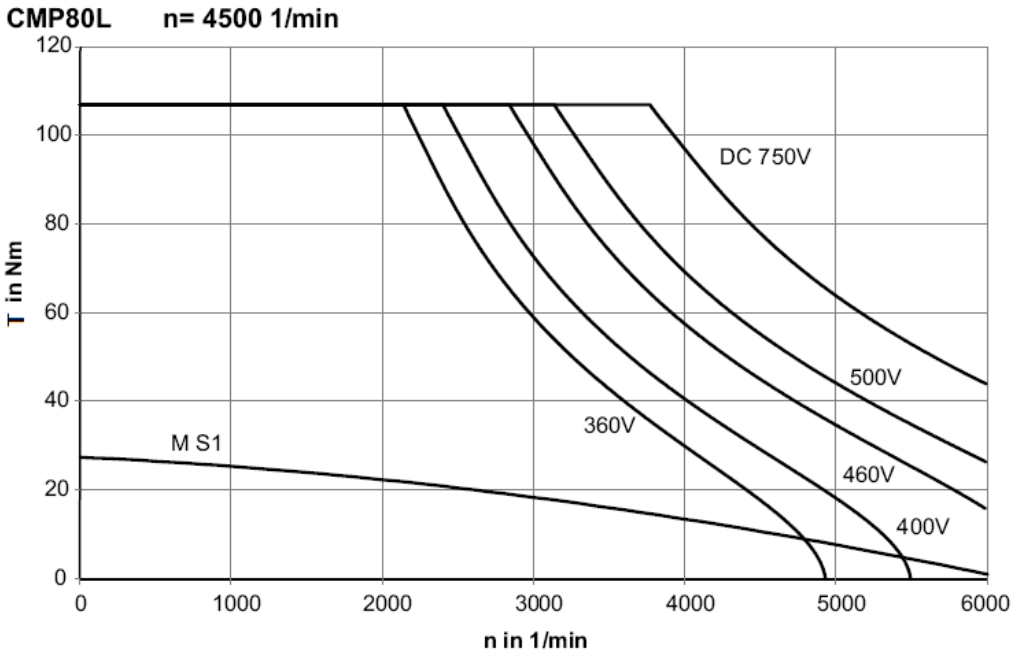

Figure 5

Notes: $J^{motor}_{linear\ load} = \frac{m}{\eta} \cdot \left(\frac{v}{w}\right)^2$; $T^{f2>fbase}_{max} = T^{fbase}_{max} \cdot \left(\frac{fbase}{f2}\right)^2$; $\sum T_{ext} = J_{total} \cdot a$;

$T^{fmax}_{max\ load} < 130\% \frac{P^{vfd}_N}{\omega_{max}}$