Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

$E = 440 - 30 \times 0.4 = \mathbf{428\ V}$; $\omega = 104.7$ rad/s, $k\Phi = \dfrac{428}{104.7} = \mathbf{4.09\ V\ s}$; $T = 4.09 \times 30 = \mathbf{123\ N\ m}$

2.2

$T \propto I_a$ with $k\Phi$ fixed, so $I_a = \mathbf{60\ A}$; $E = 440 - 60 \times 0.4 = \mathbf{416\ V}$; $\omega = \dfrac{416}{4.09} = 101.8$ rad/s $= \mathbf{972\ rpm}$, a small drop

2.3

$V = 250 - 20 \times 0.5 = \mathbf{240\ V}$; $E \propto \omega$: $E = 250 \times \dfrac{1200}{1500} = 200$ V; $V = 200 - 10 = \mathbf{190\ V}$

2.4

$T \propto I_a^2$, so $I_a = \dfrac{40}{2} = \mathbf{20\ A}$; $E_1 = 230 - 40 \times 0.5 = 210$ V, $E_2 = 230 - 20 \times 0.5 = 220$ V; $n \propto \dfrac{E}{I_a}$: $n_2 = 600 \times \dfrac{220/20}{210/40} = \mathbf{1257\ rpm}$, so the speed doubles

3.1

no starter: $I = \dfrac{230}{0.25} = \mathbf{920\ A}$

$R_a + R_{start} = \dfrac{230}{100} = 2.3\ \Omega$, so $R_{start} = \mathbf{2.05}\ \Omega$

at 50 A: $E = 230 - 50 \times 2.3 = \mathbf{115\ V}$, about half of the rated $E = 217.5$ V, so about half speed

removing it all: $I = \dfrac{230 - 115}{0.25} = 460$ A, nine times rated; so the starter is cut out in several steps

3.2

$E = 240$ V, $k\Phi = \dfrac{240}{104.7} = \mathbf{2.29\ V\ s}$; $T = 2.29 \times 40 = \mathbf{91.7\ N\ m}$

$k\Phi = 0.85 \times 2.29 = 1.95$; $I_a = \dfrac{91.7}{1.95} = \mathbf{47.1\ A}$

$E = 250 - 47.1 \times 0.25 = 238.2$ V; $\omega = \dfrac{238.2}{1.95} = 122.3$ rad/s $= \mathbf{1168\ rpm}$

check: $T\omega = 91.7 \times 122.3 = 11.2$ kW $= EI_a = 238.2 \times 47.1$

3.3

(a) rated $E = 228$ V, so at half speed $E = \mathbf{114\ V}$; $R_a + R_{ext} = \dfrac{240 - 114}{30} = 4.2\ \Omega$, $R_{ext} = \mathbf{3.8}\ \Omega$

(b) $30^2 \times 3.8 = \mathbf{3.42\ kW}$ lost; output $EI_a = 3.42$ kW of 7.2 kW in: $\eta = \mathbf{47.5}\%$

(c) $V = 114 + 30 \times 0.4 = \mathbf{126\ V}$; $\eta = \dfrac{3420}{3780} = \mathbf{90.5}\%$

(d) the chopper: the resistor burns as much power as the winch uses and heats the cabinet; weaker field gives higher speed, not lower, so it cannot give half speed

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