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EE361 Fall 2016 HW#4

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Q1)

Motor-1

a.

It is constant. As the rotor rotates, the reluctance does not change.

b.

It is varying. The linkage of the flux by one coil to the other changes as the rotor rotates.

c.

It is constant. As the rotor rotates, the reluctance does not change.

d.

Both coils should have currents so that this motor can produce torque. The answer is NO.

e.

Both coils should have currents so that this motor can produce torque. The answer is NO.

f.

Both coils should have currents so that this motor can produce torque. The answer is NO.

Motor-2

a.

It is varying. As the rotor rotates, the reluctance which the flux of stator coil changes.

b.

It is varying. The linkage of the flux by one coil to the other changes as the rotor rotates.

c.

It is constant. As the rotor rotates, the reluctance does not change.

d.

Stator coil current is enough for this motor to produce torque due to L11 term. The answer is YES.

e.

L22 term cannot produce torque. The answer is NO.

f.

Stator coil should have current so that this motor can produce torque. The answer is NO.

Motor-3

a.

It is varying. As the rotor rotates, the reluctance which the flux of stator coil changes.

b.

It is varying. The linkage of the flux by one coil to the other changes as the rotor rotates.

c.

It is varying. As the rotor rotates, the reluctance which the flux of rotor coil changes.

d.

Having current on only one coil is enough as all the terms can produce torque. The answer is YES.

e.

The answer is YES.

f.

If neither of the coils have current, the motor cannot produce any torque. The answer is NO.

Motor-4

a.

It is constant. As the rotor rotates, the reluctance does not change.

b.

It is varying. The linkage of the flux by one coil to the other changes as the rotor rotates.

c.

It is varying. As the rotor rotates, the reluctance which the flux of rotor coil changes.

d.

Rotor coil should have current so that this motor can produce torque. The answer is NO.

e.

Having current on rotor coil will produce torque. The answer is YES.

f.

If neither of the coils have current, the motor cannot produce any torque. The answer is NO.

Q2)

PARAMETERS

```
% drag force
p = 1.225; % kg/m^3
A = 0.5; % m^2
Cd = 0.8;

% friction
K = 0.8; % kg/s

% gravity
g = 9.8; % m/s^2

% motor
Ka = 1; % V/(rad/sec)
Ra = 0.285; % ohm
Prated = 350; % watt
Vrated = 28; % volts

% bicycle
vrated = 30/3.6; % m/s
weight = 100; % kg
inertia = 12.25; % kgm^2
wheel_diameter = 0.7; % m
```

Part I

```
wheel_radius = wheel_diameter/2; % m
```

```
wrated = vrated/wheel_radius; % rad/sec
Trated = Prated/wrated; % Nm
Irated = Trated/Ka; % A

fprintf('Rated speed of the motor is %g rad/sec.\n',wrated);
fprintf('Rated torque of the motor is %g Nm.\n',Trated);
fprintf('Rated current of the motor is %g A.\n',Irated);
```

```
Rated speed of the motor is 23.8095 rad/sec.
Rated torque of the motor is 14.7 Nm.
Rated current of the motor is 14.7 A.
```

Part II

```
Fdrag = 0.5*p*A*Cd*vrated^2; % N
Ffriction = K*vrated; % N
Fnet = 0; % N
Fmotor = Fnet + Fdrag + Ffriction; % N

Tmotor = Fmotor*wheel_radius; % Nm

Ia = Tmotor/Ka; % A

wm = vrated/wheel_radius; % rad/sec
Ea = Ka*wm; % V
Vt = Ra*Ia+Ea; % V

Pin = Vt*Ia; % W
Pout = Ea*Ia; % W
efficiency = 100*Pout/Pin;

fprintf('The drag force at rated speed is %g N.\n',Fdrag);
fprintf('The frictional force at rated speed is %g N.\n',Ffriction);
fprintf('The net force at rated speed is %g N.\n',Fnet);
fprintf('The motor torque (T2) is %g N.\n',Tmotor);
fprintf('The armature current is %g A.\n',Ia);
fprintf('The back emf is %g V.\n',Ea);
fprintf('The terminal voltage is %g V.\n',Vt);
fprintf('The efficiency is %g %%.\n',efficiency);
```

```
The drag force at rated speed is 17.0139 N.
The frictional force at rated speed is 6.66667 N.
The net force at rated speed is 0 N.
The motor torque (T2) is 8.28819 N.
The armature current is 8.28819 A.
The back emf is 23.8095 V.
The terminal voltage is 26.1717 V.
The efficiency is 90.9745 %.
```

Part III

```
Fdrag = 0.5*p*A*Cd*vrated^2; % N
Ffriction = K*vrated; % N
```

```
Fgravitation = weight*g*sin(2*pi/180); % N
Fnet = 0; % N
Fmotor = Fnet + Fdrag + Ffriction + Fgravitation; % N

Tmotor = Fmotor*wheel_radius; % Nm

Ia = Tmotor/Ka; % A

wm = vrated/wheel_radius; % rad/sec
Ea = Ka*wm; % V
Vt = Ra*Ia+Ea; % V

Pin = Vt*Ia; % W
Pout = Ea*Ia; % W
efficiency = 100*Pout/Pin;

fprintf('The gravitational force is %g N.\n',Fgravitation);
fprintf('The drag force at rated speed is %g N.\n',Fdrag);
fprintf('The frictional force at rated speed is %g N.\n',Ffriction);
fprintf('The net force at rated speed is %g N.\n',Fnet);
fprintf('The motor torque (T2) is %g N.\n',Tmotor);
fprintf('The armature current is %g A.\n',Ia);
fprintf('The back emf is %g V.\n',Ea);
fprintf('The terminal voltage is %g V.\n',Vt);
fprintf('The efficiency is %g %%.\n',efficiency);
```

```
The gravitational force is 34.2015 N.
The drag force at rated speed is 17.0139 N.
The frictional force at rated speed is 6.66667 N.
The net force at rated speed is 0 N.
The motor torque (T2) is 20.2587 N.
The armature current is 20.2587 A.
The back emf is 23.8095 V.
The terminal voltage is 29.5833 V.
The efficiency is 80.4831 %.
```

Part IV

```
Fdrag = 0.5*p*A*Cd*vrated^2; % N
Ffriction = K*vrated; % N
Fgravitation = weight*g*sin(2*pi/180); % N
Fnet = 0; % N
Fmotor = Fgravitation + Fnet - Fdrag - Ffriction; % N

Tmotor = Fmotor*wheel_radius; % Nm

Ia = Tmotor/Ka; % A

wm = vrated/wheel_radius; % rad/sec
Ea = Ka*wm; % V
Vt = -Ra*Ia+Ea; % V

Pout = Vt*Ia; % W
```

```
Pin = Ea*Ia; % W
efficiency = 100*Pout/Pin;

fprintf('The gravitational force is %g N.\n',Fgravitation);
fprintf('The drag force at rated speed is %g N.\n',Fdrag);
fprintf('The frictional force at rated speed is %g N.\n',Ffriction);
fprintf('The net force at rated speed is %g N.\n',Fnet);
fprintf('The motor torque (T2) is %g N.\n',Tmotor);
fprintf('The armature current is %g A.\n',Ia);
fprintf('The back emf is %g V.\n',Ea);
fprintf('The terminal voltage is %g V.\n',Vt);
fprintf('The efficiency is %g %%.\n',efficiency);
```

```
The gravitational force is 34.2015 N.
The drag force at rated speed is 17.0139 N.
The frictional force at rated speed is 6.66667 N.
The net force at rated speed is 0 N.
The motor torque (T2) is 3.68233 N.
The armature current is 3.68233 A.
The back emf is 23.8095 V.
The terminal voltage is 22.7601 V.
The efficiency is 95.5922 %.
```

Part V

a.

From standstill to rated speed, it is a common practice to accelerate the motor at rated torque. It is done by keeping the current constant. As the speed increases from zero to its rated value, back emf also increases as such. Therefore, the terminal voltage is controlled such that, it should start from a small value and increase up to rated voltage. This is done by the adjustable DC supply. If rated terminal voltage was applied from the beginnig, as the back emf is very small, huge amount of currents would flow which would damage the motor and the DC/DC converter.

b.

Between B and C, the motor operates at constant speed and constant torque. The torque only has drag and friction components. The mode is motoring mode of operation.

c.

During this interval, the power drawn from the input was calculated (Pin). The speed and torque do not change so this power is constant. If the operation takes 4 minutes, the energy delivered can be calculated from the power (Ein). From the capacitor energy change, final voltage can be calculated.

```
Pin = 216.92; % W
duration = 4*60; % sec
Ein = Pin*duration; % Joules
Vinitial = 36; % V
Cap = 1000; % F
Vfinal = sqrt(Vinitial^2-2*Ein/Cap); % V
```

```
fprintf('The final voltages is %g V.\n',Vfinal);
```

```
        The final voltages is 34.5236 V.
```

d.

During this interval, to travel at constant speed, motor torque is increased since gravitational force is also present in addition to drag and frictional force. It is not wise to use such kind of operation since high torque means high motor current. Motor currents above rated will cause higher loss and hence worse efficiency. They may also damage the motor windings as well as the converter. One can decrease the speed (let the bicycle decelerate a while) so that the friction and drag force will decrease. That way, it is possible to climb the slope at rated torque.

e.

Between E and F, the gravitational force is in the direction of the speed. To operate at constant speed, the motor torque is in the reverse direction so that the net force is zero. Therefore, the mode is generating mode of operation. The armature current is in the reverse direction and back emf is higher than the terminal voltage. The super capacitor is charged during this interval.

f.

This part is similar to part (c) whereas the capacitor will charge this time. During this interval, the power supplied to the terminals was calculated (Pin). The speed and torque do not change so this power is constant. If the operation takes 8 minutes, the energy delivered can be calculated from the power (Ein). From the capacitor energy change, final voltage can be calculated.

```
Pin = 83.81; % W
duration = 8*60; % sec
Ein = Pin*duration; % Joules
Vinitial = 30; % V
Cap = 1000; % F
Vfinal = sqrt(Vinitial^2+2*Ein/Cap); % V

fprintf('The final voltages is %g V.\n',Vfinal);
```

```
        The final voltages is 31.3123 V.
```

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