Closed book, closed notes. Short answer questions - use the space provided for written answers.

1. True/False Questions (1 pt each)
   
   ____ a) Placing a smaller resistance across the leads of a dynamometer’s generator increases the load (torque) on the motor.
   
   ____ b) Absolute encoders are usually more expensive than incremental encoders since they require more wires and optical sensors to operate.
   
   ____ c) Total uncertainty is found by adding the precision and bias uncertainties.
   
   ____ d) The length of an LVDT is normally about 3 times the linear measurement range.
   
   ____ e) Timer based methods always give an instantaneous value for measured velocity.
   
   ____ f) Piezoresistive accelerometers can measure a constant (or DC) acceleration.
   
   ____ g) The gage factor for foil strain gages is typically in the range of 2.0 to 2.2.
   
   ____ h) Accelerometers are frequently used to measure high frequency vibrations (> 1000 Hz).
   
   ____ i) A readout device should have a low input impedance to measure a potentiometer-type sensor.
   
   ____ j) When used as a tachometer, a DC motor will produce a voltage that is proportional to the angular velocity.
   
   ____ k) PWM stands for Partial Weighting Method - a way to vary the speed of an electric motor.
   
   ____ l) The slip of an AC motor depends on input frequency and number of poles.
   
   ____ m) A half-Wheatstone bridge has half as many strain gages as fixed resistors.
   
   ____ n) Torque is proportional to speed in a brush-type DC motor.

Short answer questions - use the space provided for written answers.

2. [6] Photographs of three motors are shown below. Identify each type of motor.
3. [4] a. How can a potentiometer be used to measure velocity?

b. How can an accelerometer be used to measure velocity?

4. [6] Select and briefly justify the single best type of small electric motor that we have studied in ME 360 for each of the following applications.

- $10 electric can opener

- $25 cordless electric screwdriver

- $75 ink-jet printer
6. [20pt] The formula for computing the undamped natural frequency, \( f \) of a cantilever beam with a round cross-section is given below. Nominal values for all parameters are given along with their uncertainties. The nominal natural frequency is 6.0 Hz for these values.

Calculate the uncertainty in the undamped natural frequency, \( U_f \).

\[
f = 6.0Hz = \frac{3}{16\pi} \sqrt{\frac{E\pi d^4}{ML^3}}
\]

\( E = 11 \times 10^6 \text{ psi} \pm 0.1 \times 10^6 \text{ psi} \quad d = 0.500 \text{ inch} \pm 0.002 \text{ inch} \)

\( M = 0.00612 \text{ lbf-sec}^2/\text{in} \pm 1\% \quad L = 25\frac{3}{4} \text{ inch} \pm \frac{1}{4} \text{ in} \)

7. [25pt] Two strain gages are mounted to a hollow square tube as shown in the figure below. The tube is loaded in axial tension. A cross-section of the square tube is also shown in the figure.

Use the numerical values given below to find the stress, the strain, and the voltage output, \( V_{out} \), from the Wheatstone bridge for this case

\( E = 30 \times 10^6 \text{ lbf/in}^2 \quad X = 20\frac{1}{4} \text{ inch} \quad w_o = 0.750 \text{ inch} \quad V_{in} = 10.6 \text{ volts} \quad F = 2.12 \)

\( \nu = 0.33 \quad L = 25\frac{3}{4} \text{ inch} \quad w_i = 0.460 \text{ inch} \quad P = 5260 \text{ lbf} \quad R = 350 \text{ ohms} \)
8. [25pt] Experimental data from a DC permanent magnet motor operated at 50 volts armature voltage is given in the table on the right.

- Determine the torque constant, back-EMF constant, armature resistance, stall torque, and no-load speed for this motor.

- What is the armature current, input power, output power, and efficiency of this motor at 50 volts armature voltage and speed of 1800 RPM?

<table>
<thead>
<tr>
<th>RPM</th>
<th>Torque, in-lb</th>
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<tbody>
<tr>
<td>1100</td>
<td>6.79</td>
</tr>
<tr>
<td>1800</td>
<td>5.04</td>
</tr>
<tr>
<td>2500</td>
<td>3.29</td>
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