1) A 24-bit digital signal has how many corresponding quantization levels?

$$2^{24} = 16777216 \quad \boxed{+2}$$

2) Express the binary number 1001110011 in decimal form. How many bits is this?

$$2^0 + 2^1 + 2^4 + 2^5 + 2^6 + 2^9 = 627 \quad \boxed{+2}$$

$$10 \text{ bits} \quad \boxed{+1}$$

3) An EKG signal is sampled at f_s = 5 kHz. What is the sampling period? What is the maximum signal bandwidth that may be sampled without aliasing errors?

$$T = \frac{1}{5k} = 0.2 \text{ ms} \quad or \quad 200 \text{ } \mu s \quad \boxed{+2}$$

$$BW = \frac{5k}{2} = 2.5 \text{ kHz} \quad \boxed{+2} \quad (Shannon\text{-}Nyquist)$$

4) What is the clock frequency in an Arduino Uno? What is the purpose of the clock?

$$f_c = 16 \text{ MHz} \quad \boxed{+1}$$

Synchronizes all operations $\boxed{+1}$

5) Explain the principle of pulse width modulation (PWM) as a means of dimming an LED.

instead of varying current, use **max** current and vary the duration of the ON part of waveform; eye/brain integrates into average intensity $\boxed{+2}$

+13

6) The Arduino Uno usually uses a PWM frequency of ≈ 490 Hz. What is the ON time for a 490-Hz PWM signal at 33% duty cycle?

$$T = \frac{1}{490} = 2.04 \text{ ms}$$

⟨+3⟩

$$2.04 \times 0.33 = 0.6732 \text{ ms or } 673.2 \text{ μs}$$

7) Examine the following lines of code taken from the LED-dimming lab:

```
void loop() {
// fade in from min to max in increments of 5 points:
for (int fadeValue = 0 ; fadeValue <= 255; fadeValue += 5) {
  // sets the value (range from 0 to 255):
  analogWrite(ledPin, fadeValue);
  // wait for 30 milliseconds to see the dimming effect
  delay(30);
}
```

change to 10 or 20   ⟨+2⟩

```
// fade out from max to min in increments of 5 points:
for (int fadeValue = 255 ; fadeValue >= 0; fadeValue -= 5) {
  // sets the value (range from 0 to 255):
  analogWrite(ledPin, fadeValue);
  // wait for 30 milliseconds to see the dimming effect
  delay(30);
}
}
```

change to 100 etc.   ⟨+2⟩

What would you change if you wanted a fast increase but slow decrease? Circle the values in the code and indicate alternative values.

8) A negative-temperature-coefficient (NTC) thermistor is to be used in a circuit that turns off a hot water boiler when the temperature gets too high. The thermistor has a resistance of ~~12kΩ~~ 30k when operating normally and 2 kΩ when 200 F is reached. Draw the circuit that would cause a LOW to HIGH state change when the high temperature condition occurs. Choose an E24 pullup/pulldown resistor that achieves the correct voltages for a 5V Arduino Uno.

5V

NTC thermistor   ⟨+2⟩

→ to I/o pin
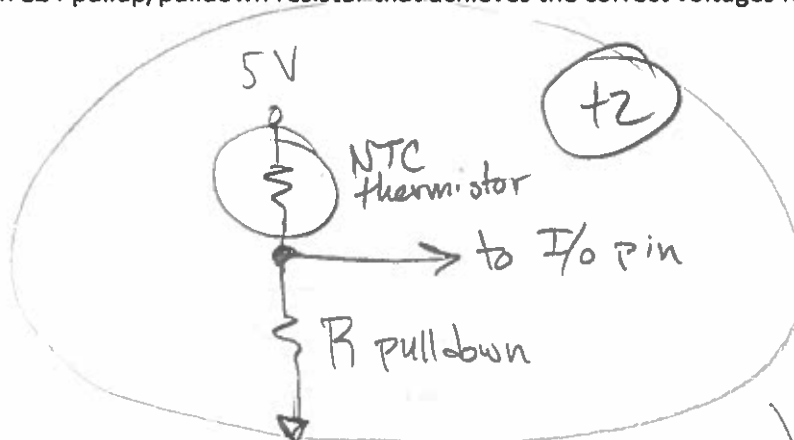
R pulldown

Try 10 kΩ pulldown

then low temp

$$V = 5 \left(\frac{10k}{10k + 30k} \right) = 1.25 \text{ V} < 1.5 \text{ V} ✓$$

high temp

$$V = 5 \left(\frac{10k}{10k + 2k} \right) = 4.16 \text{ V} > 3V ✓$$

⟨+2⟩

+1