

Question bank

Internet of Things and Robotics: 60 questions with answers

IoT and Robotics crash course

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Marks follow difficulty: easy 1, medium 2, medium-hard 3, hard 4. Questions with numbers have answers computed by the course code.

Unit 1: Foundations

1.1. In the four-layer architecture of an IoT system, a soil-moisture node belongs to the: *(1 mark; easy)*

- (A) Device layer
- (B) Cloud layer
- (C) Network layer
- (D) Edge layer

Answer. A. It senses the world; the network carries its data, the edge and cloud process it.

1.2. A node sends a 20-byte payload with 10 bytes of overhead every 60 s. How many bytes does it send in a day? *(2 marks; medium)*

Answer. $(20 + 10) \times 86400 / 60 = 43,200$ bytes per day.

1.3. A battery of 2000 mAh (80% usable) feeds a load of 100 mA average. How long does it last? *(2 marks; medium)*

Answer. $2000 \times 0.8 / 100 = 16$ h = 0.67 days.

1.4. A bang-bang thermostat with a hysteresis band swings wider than the band when its sensor reading is delayed. Why? *(3 marks; medium-hard)*

Answer. After the temperature crosses the switching level the heater stays in its old state until the delayed reading arrives, so the room keeps moving during the delay. The extra swing is about the rate of change times the delay.

1.5. A room obeys $dT/dt = -(T - T_{\text{out}})/\tau + k u$ with $\tau = 60$ min, $k = 0.5$ degC/min, $T_{\text{out}} = 5$ degC. With the heater on, how long does it take to warm from 15 to 21 degC? *(4 marks; hard)*

Answer. The heater-on equilibrium is $T_{\text{out}} + k \tau = 35$ degC. $T(t) = 35 - (35 - 15)e^{-t/60} = 21$ gives $t = 60 \ln(20/14) = 21.4$ min.

Unit 2: Electronics

2.1. A 3.3 V supply drives an LED (forward drop 2.0 V) at 10 mA. What series resistor? *(1 mark; easy)*

Answer. $R = (3.3 - 2.0) / 0.010 = 130$ ohm.

2.2. A divider of 10 kohm (top) and 20 kohm (bottom) is fed from 5 V. What is the output unloaded, and with a 20 kohm load across the bottom resistor? *(2 marks; medium)*

Answer. Unloaded: $5 \times 20/30 = 3.333$ V. Loaded: the bottom becomes 10 kohm, so $5 \times 10/20 = 2.500$ V.

2.3. A 12-bit ADC has a 3.3 V reference. Give the size of one step (LSB) and the RMS quantisation error of an ideal converter. *(2 marks; medium)*

Answer. $\text{LSB} = 3.3 / 4096 = 0.806 \text{ mV}$; $\text{RMS error} = \text{LSB} / \sqrt{12} = 0.233 \text{ mV}$.

2.4. A node wakes for 0.2 s at 50 mA, connects for 1.3 s at 100 mA, publishes for 0.3 s at 140 mA, shuts down for 0.2 s at 50 mA and sleeps 58 s at 0.01 mA. Average current and life of a 2000 mAh battery (80% usable)? (3 marks; medium-hard)

Answer. Charge per 60 s cycle = $10 + 130 + 42 + 10 + 0.58 = 192.58 \text{ mA s}$; average 3.210 mA; life = $1600 / 3.210 / 24 = 20.8 \text{ days}$. The 2 s awake dominate.

2.5. A motor needs an average of 6 V. The pack is 7.4 V. What PWM duty is needed if the bridge drops 0.4 V, and what if the bridge drops 2 V? (4 marks; hard)

Answer. Duty = $6 / (7.4 - 0.4) = 0.857$. With a 2 V drop: $6 / (7.4 - 2.0) = 1.11 > 1$, so even full duty cannot give 6 V: that bridge is unsuitable.

Unit 3: Sensors

3.1. A sensor reads 25.3, 25.2, 25.3, 25.2 when the true value is 20.0. It is: (1 mark; easy)

- (A) Accurate but not precise
- (B) Precise but not accurate
- (C) Neither precise nor accurate
- (D) Both accurate and precise

Answer. B. The readings agree with each other (precise) but are far from the truth (biased).

3.2. A soil sensor reads raw 1200 in air (0%) and 3000 in water (100%). Using a two-point linear calibration, what is the reading for raw 2100? (2 marks; medium)

Answer. slope = $100 / (3000 - 1200)$; percent = $(2100 - 1200) \times \text{slope} = 50\%$.

3.3. A 70 Hz signal is sampled at 100 Hz. At what frequency does it appear? (2 marks; medium)

Answer. Aliased to $|70 - 100| = 30 \text{ Hz}$.

3.4. An exponential filter is designed for a time constant of 5 s at a 1 s sample period. Give its coefficient and the factor by which it reduces white-noise variance. (3 marks; medium-hard)

Answer. $\alpha = 1 - e^{(-1/5)} = 0.1813$; noise variance gain = $\alpha / (2 - \alpha) = 0.316$.

3.5. A 1320 counts-per-revolution encoder is on a wheel of radius 33 mm. What distance does one count represent, and what is the speed resolution if speed is the count change over 100 ms? (4 marks; hard)

Answer. Distance per count = $2 \pi \times 0.033 / 1320 = 0.1571 \text{ mm}$; speed step = $0.1571 \text{ mm} / 0.1 \text{ s} = 1.57 \text{ mm/s}$.

Unit 4: Microcontrollers

4.1. A mechanical button is debounced to: *(1 mark; easy)*

- (A) Make it press harder
- (B) Ignore the rapid on-off bounces so one press counts once
- (C) Save battery in deep sleep
- (D) Raise the logic voltage

Answer. B.

4.2. How many bits does one UART byte occupy on the wire in the 8N1 format, and how long does it take at 115200 baud? *(2 marks; medium)*

Answer. 10 bits (start + 8 data + stop); $10/115200 = 86.8$ microseconds.

4.3. Using the course's I2C model, how long does a 2-byte read take at a 100 kHz clock? *(2 marks; medium)*

Answer. 480 microseconds (a register read: 3 start/restart/stop clocks, 27 clocks for address+W, register and address+R, and 9 clocks per data byte: 48 clocks at 10 microseconds).

4.4. An encoder produces 7643 transitions per second and the interrupt handler takes 5 microseconds. What fraction of the CPU does it use? *(3 marks; medium-hard)*

Answer. $7643 \times 5 \times 10^{-6} = 3.82\%$ of the CPU.

4.5. A node retries a failed publish up to 3 times and each attempt fails with probability 0.3, independently. What fraction of cycles delivers? *(4 marks; hard)*

Answer. $1 - 0.3^3 = 0.973$ (97.3%). Each extra attempt costs energy at the waiting current.

Unit 5: Networking

5.1. Which MQTT quality-of-service level guarantees delivery at least once? *(1 mark; easy)*

- (A) None of them
- (B) QoS 1
- (C) QoS 0
- (D) Only QoS 2

Answer. B. QoS 0 is at most once; QoS 1 at least once (duplicates possible); QoS 2 exactly once.

5.2. How many bytes is an MQTT PUBLISH at QoS 1 with the 10-byte topic 'gh/p1/soil' and a 7-byte payload (fixed header, length fields and packet id included)? (2 marks; medium)

Answer. 23 bytes (computed with the course's MQTT packet encoder).

5.3. With independent loss $p = 0.1$ per packet, how many packets (both directions) does one QoS 1 message cost on average, with unlimited retries? (2 marks; medium)

Answer. $1/(1-p)^2 + 1/(1-p) = 2.346$ packets.

5.4. Free-space path loss at 100 m and 2.4 GHz? (3 marks; medium-hard)

Answer. $20 \log_{10}(4 \pi d f / c) = 80.1$ dB.

5.5. Does the subscription 'greenhouse/+ /soil' receive a message published on 'greenhouse/zone1/soil/raw'? What would match both? (4 marks; hard)

Answer. No: '+' matches exactly one level, so the topic has an extra level 'raw'. 'greenhouse/#' (or 'greenhouse/+ /soil/#') matches both; '#' must be the last character and also matches the parent level.

Unit 6: Data, cloud and edge

6.1. Compared with JSON, CBOR is mainly: (1 mark; easy)

- (A) A database
- (B) A different network protocol
- (C) A more compact binary encoding of the same kinds of data
- (D) An encryption standard

Answer. C.

6.2. For the reading {zone: 1, soil_raw: 1832, temp_c: 21.5, batt_v: 3.71}, how many bytes does it take as compact JSON, as CBOR and as the packed binary of the course? (2 marks; medium)

Answer. JSON 54 bytes, CBOR 51 bytes, packed 7 bytes.

6.3. 100 nodes each send 20 bytes every 60 s. How many bytes per day reach the cloud, and how many if each node sends one 20-byte aggregate every 600 s? (2 marks; medium)

Answer. Every 60 s: 2,880,000 bytes per day; every 600 s: 288,000 bytes per day (10 times less).

6.4. A z-score alarm at $k = 3$ on Gaussian noise is checked once a minute for one zone. How many false alarms per day should you expect? (3 marks; medium-hard)

Answer. $P(|z| > 3) = 0.00270$; times 1440 samples = 3.89 false alarms per day.

6.5. Which detector finds a small persistent shift in the mean sooner, an EWMA or a CUSUM, for the same false-alarm rate, and why? (*4 marks; hard*)

Answer. Both accumulate evidence; the CUSUM, designed for a shift of a chosen size, adds up every small deviation beyond a reference value and is the optimal sequential test for that shift, so it usually reacts sooner to a small, steady change. A threshold on single samples is much slower.

Unit 7: Security

7.1. The Mirai botnet spread mainly by: (*1 mark; easy*)

- (A) Phishing e-mails
- (B) A zero-day in the TCP stack
- (C) Physical access
- (D) Logging in to devices with default credentials

Answer. D. It tried a short list of default username and password pairs on telnet.

7.2. How many bits of entropy has a random password of 8 lowercase letters? (*2 marks; medium*)

Answer. $8 \times \log_2(26) = 37.6$ bits.

7.3. At 10^9 guesses per second, how long on average to guess it? (*2 marks; medium*)

Answer. Expected guesses = $2^{(bits-1)}$; time = 104 s (1.7 minutes).

7.4. A command is authenticated by an HMAC truncated to 8 bytes, or to 4 bytes. What is the probability that one random guess of the tag is accepted? (*3 marks; medium-hard*)

Answer. 8 bytes: $2^{-64} = 5.42e-20$; 4 bytes: $2^{-32} = 2.33e-10$.

7.5. Why does the course put TLS on the gateway rather than on the battery node, and how does the node still authenticate commands? (*4 marks; hard*)

Answer. A TLS handshake costs the node about 1.5 kB and an extra round trip on every connection, which dominates its energy. The node instead verifies a short HMAC envelope (counter, command, 8-byte tag) with a pre-shared per-device key: 12 bytes and no extra round trips; the gateway terminates TLS toward the cloud.

Unit 8: Kinematics

8.1. How many degrees of freedom has a planar 2-link arm (two revolute joints)? *(1 mark; easy)*

- (A) 2
- (B) 4
- (C) 3
- (D) 1

Answer. A.

8.2. A 2-link arm with links 0.30 m and 0.20 m has joint angles 30 and 45 degrees. Where is the tip? *(2 marks; medium)*

Answer. $x = 0.3 \cos 30 + 0.2 \cos 75 = 0.3116$ m; $y = 0.3 \sin 30 + 0.2 \sin 75 = 0.3432$ m.

8.3. A differential drive with track 0.16 m has left wheel speed 0.4 m/s and right 0.6 m/s. Give the body speed and turn rate. *(2 marks; medium)*

Answer. $v = (0.4 + 0.6)/2 = 0.50$ m/s; $\omega = (0.6 - 0.4)/0.16 = 1.25$ rad/s.

8.4. Inverse kinematics (elbow up) for the target (0.35, 0.20) m with links 0.30 and 0.20 m: give both joint angles in degrees. *(3 marks; medium-hard)*

Answer. $q_1 = 1.22$ degrees, $q_2 = 74.29$ degrees.

8.5. The right wheel of a rover is 0.5% larger than assumed (left exact), track 0.16 m, and the odometry believes it drove 20 m straight. How far is the true end point from where the odometry says it is? *(4 marks; hard)*

Answer. True end pose (arc): (18.77, 6.06) m; the odometry says (20, 0): the error is 6.19 m (31% of the distance).

Unit 9: Control

9.1. A proportional-only controller on a motor speed loop leaves: *(1 mark; easy)*

- (A) A steady-state error
- (B) Only overshoot
- (C) No error ever
- (D) An unstable loop at every gain

Answer. A. The command is K_p times the error, so a nonzero command needs a nonzero error.

9.2. A plant has DC gain $K = 3.491$ rad/s per volt. With P control $K_p = 1$, what fraction of the setpoint is the steady-state error? (2 marks; medium)

Answer. $1/(1 + K K_p) = 0.2227$ (22.3%).

9.3. Design a PI by pole-zero cancellation for $\tau = 112.5$ ms, $K = 3.491$ and a closed-loop time constant of 30 ms. Give K_p and T_i . (2 marks; medium)

Answer. $T_i = \tau = 112.5$ ms; $K_p = \tau/(K \tau_c) = 1.074$ V per rad/s.

9.4. For the wheel loop (10 ms sample, one sample of delay) the course finds the ultimate gain from the loop's characteristic polynomial. Give K_u (V per rad/s) and the oscillation period. (3 marks; medium-hard)

Answer. $K_u = 3.368$; $T_u = 57.3$ ms.

9.5. The rover brakes at the traction limit with $\mu = 0.6$ from 0.5 m/s. If the reaction takes 150 ms, how far does it travel from detection to rest? (4 marks; hard)

Answer. $v t + v^2/(2 \mu g) = 0.5 \times 0.15 + 0.25/(2 \times 0.6 \times 9.81) = 9.62$ cm.

Unit 10: Perception

10.1. For Gaussian noise, the fraction of readings within two standard deviations of the mean is about: (1 mark; easy)

- (A) 99.7%
- (B) 50%
- (C) 68%
- (D) 95%

Answer. D. 68%, 95% and 99.7% for one, two and three standard deviations.

10.2. Dry soil has a 5% prior. A sensor flags 'dry' in 90% of dry cases and 8% of wet ones. What is $P(\text{dry})$ after one flag? (2 marks; medium)

Answer. $0.9 \times 0.05 / (0.9 \times 0.05 + 0.08 \times 0.95) = 0.3719$.

10.3. Fuse an ultrasonic range of 2.00 m (std 1 cm) with an infrared range of 2.04 m (std 3 cm). Give the fused value and its standard deviation. (2 marks; medium)

Answer. Variance = $1/(1/1e-4 + 1/9e-4) = 9.00e-05$; std = 0.95 cm; mean = 2.004 m.

10.4. A scalar Kalman filter has process variance $q = 1e-4$ per step and measurement variance $r = 0.04$. What is its steady-state gain, and the equivalent EMA coefficient? (3 marks; medium-hard)

Answer. $P^- = (q + \sqrt{q^2 + 4 q r})/2$; $K = P^-/(P^- + r) = 0.0488$; an EMA with $\alpha = 0.049$.

10.5. Why was the course's EKF overconfident about its position along the wall, though accurate across it? (*4 marks; hard*)

Answer. Wall ranges constrain only the distance perpendicular to the wall and the heading, so the along-wall position is corrected by nothing but odometry. The filter's model contained only random slip, not the systematic wheel-radius error, so its reported along-wall uncertainty (1.3 cm) was far below the actual error (5.3 cm): the model was incomplete.

Unit 11: Planning and ROS

11.1. Which search is guaranteed to find the path with the fewest steps on an unweighted grid? (*1 mark; easy*)

- (A) Depth-first search
- (B) Breadth-first search
- (C) Greedy best-first search
- (D) Random walk

Answer. B.

11.2. On an 8-connected grid the goal is 7 cells right and 2 up. Give the octile heuristic. (*2 marks; medium*)

Answer. $(7 + 2) + (\sqrt{2} - 2) \times 2 = 7.828$ cells.

11.3. In the rover frame the pure-pursuit target is at (0.4, -0.2) m. What curvature does the rover steer at? (*2 marks; medium*)

Answer. $\kappa = 2 y / L^2 = 2(-0.2)/(0.4^2 + 0.2^2) = -2.00$ per metre (turn right);
 $\omega = v \kappa$.

11.4. The rover brakes at $\mu = 0.6$ from 0.5 m/s with a 15 ms edge loop. What is the longest ultrasonic ping period that still stops it within 5 cm in the worst case? (*3 marks; medium-hard*)

Answer. $T \leq (0.05 - v^2/(2 \mu g))/v - 0.015 = 42.5$ ms (23.5 Hz).

11.5. A watchdog stops the rover when no command arrives for 0.2 s. At 0.5 m/s (15 ms edge loop, $\mu = 0.6$), how far does it travel after the last good command? (*4 marks; hard*)

Answer. $v (0.2 + 0.015) + v^2/(2 \mu g) = 12.9$ cm.

Unit 12: Capstone

12.1. In the capstone, ‘coverage’ means the fraction of: *(1 mark; easy)*

- (A) Plant-hours with moisture at or above the dry threshold
- (B) Battery charge left
- (C) Messages that arrive
- (D) Floor area the rover visits

Answer. A.

12.2. MQTT QoS 1 tries a PUBLISH up to 5 times; each attempt is lost with probability 0.3. What fraction of messages is lost for good? *(2 marks; medium)*

Answer. $0.3^5 = 0.00243 = 0.243\%$.

12.3. Using the course’s node power budget, how long does the 2000 mAh battery (80% usable) last if the node reads once every 300 s instead of 60 s? *(2 marks; medium)*

Answer. Average current = $(192 + 0.01 \times 298)/300 = 0.650$ mA; life = 102.6 days.

12.4. Over 40 days the success rate has a mean of 99.6% and a 95% interval of ± 0.8 percentage points (1.96 s/sqrt(n)). What is the standard deviation of the daily success rate? *(3 marks; medium-hard)*

Answer. $s = 0.8 \times \sqrt{40}/1.96 = 2.6$ percentage points.

12.5. The first end-to-end design served only 78% of dry events within 30 minutes although every component passed its tests. What was wrong and how was it fixed? *(4 marks; hard)*

Answer. The detector fired only when the filtered moisture crossed the dry level itself, so the delays of the 10-minute sampling, the EMA filter and the trip together used up the 30-minute deadline. Raising the detector threshold to 0.33 gives an earlier warning (a lead of about 0.15 tau); it raised the served fraction to 99.6% at the price of more water and trips. The flaw is in the composition, which no unit test sees.