

Answer key for the sample papers

Internet of Things and Robotics

IoT and Robotics crash course

2026-10-11

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Numeric answers were computed by `site_src/assessment.py` using the course modules. Short answers are model answers; accept any answer that says the same thing.

Mid-semester paper (Units 1 to 5): answers

1. (1, Unit 1) A. It senses the world; the network carries its data, the edge and cloud process it.
2. (2, Unit 1) $(20 + 10) \times 86400 / 60 = 43,200$ bytes per day.
3. (3, Unit 1) 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.
4. (4, Unit 1) 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.
5. (1, Unit 2) $R = (3.3 - 2.0) / 0.010 = 130$ ohm.
6. (2, Unit 2) Unloaded: $5 \times 20/30 = 3.333$ V. Loaded: the bottom becomes 10 kohm, so $5 \times 10/20 = 2.500$ V.
7. (3, Unit 2) Charge per 60 s cycle = $10 + 130 + 42 + 10 + 0.58 = 192.58$ mA s; average 3.210 mA; life = $1600 / 3.210 / 24 = 20.8$ days. The 2 s awake dominate.
8. (4, Unit 2) 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.
9. (1, Unit 3) B. The readings agree with each other (precise) but are far from the truth (biased).
10. (2, Unit 3) slope = $100/(3000 - 1200)$; percent = $(2100 - 1200) \times \text{slope} = 50\%$.
11. (3, Unit 3) $\alpha = 1 - e^{-(1/5)} = 0.1813$; noise variance gain = $\alpha/(2 - \alpha) = 0.316$.
12. (4, Unit 3) Distance per count = $2 \pi \times 0.033 / 1320 = 0.1571$ mm; speed step = $0.1571 \text{ mm} / 0.1 \text{ s} = 1.57 \text{ mm/s}$.

13. (1, Unit 4) B.
14. (2, Unit 4) 10 bits (start + 8 data + stop); $10/115200 = 86.8$ microseconds.
15. (3, Unit 4) $7643 \times 5e-6 = 3.82\%$ of the CPU.
16. (4, Unit 4) $1 - 0.3^3 = 0.973$ (97.3%). Each extra attempt costs energy at the waiting current.
17. (1, Unit 5) B. QoS 0 is at most once; QoS 1 at least once (duplicates possible); QoS 2 exactly once.
18. (2, Unit 5) 23 bytes (computed with the course's MQTT packet encoder).
19. (3, Unit 5) $20 \log_{10}(4 \pi d f / c) = 80.1$ dB.
20. (4, Unit 5) 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.

End-semester paper (Units 1 to 12, weighted to Units 6 to 12): answers

1. (2, Unit 1) $2000 \times 0.8 / 100 = 16$ h = 0.67 days.
2. (4, Unit 1) 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.
3. (2, Unit 2) $\text{LSB} = 3.3 / 4096 = 0.806$ mV; RMS error = $\text{LSB} / \sqrt{12} = 0.233$ mV.
4. (4, Unit 2) 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.
5. (2, Unit 3) Aliased to $|70 - 100| = 30$ Hz.
6. (4, Unit 3) Distance per count = $2 \pi \times 0.033 / 1320 = 0.1571$ mm; speed step = 0.1571 mm / 0.1 s = 1.57 mm/s.
7. (2, Unit 4) 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).
8. (4, Unit 4) $1 - 0.3^3 = 0.973$ (97.3%). Each extra attempt costs energy at the waiting current.
9. (2, Unit 5) $1/(1-p)^2 + 1/(1-p) = 2.346$ packets.
10. (4, Unit 5) 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.
11. (1, Unit 6) C.
12. (2, Unit 6) JSON 54 bytes, CBOR 51 bytes, packed 7 bytes.
13. (3, Unit 6) $P(|z| > 3) = 0.00270$; times 1440 samples = 3.89 false alarms per day.
14. (4, Unit 6) 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.
15. (1, Unit 7) D. It tried a short list of default username and password pairs on telnet.
16. (2, Unit 7) $8 \times \log_2(26) = 37.6$ bits.
17. (3, Unit 7) 8 bytes: $2^{-64} = 5.42e-20$; 4 bytes: $2^{-32} = 2.33e-10$.

- 18.** (4, Unit 7) 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.
- 19.** (1, Unit 8) A.
- 20.** (2, Unit 8) $x = 0.3 \cos 30 + 0.2 \cos 75 = 0.3116$ m; $y = 0.3 \sin 30 + 0.2 \sin 75 = 0.3432$ m.
- 21.** (3, Unit 8) $q_1 = 1.22$ degrees, $q_2 = 74.29$ degrees.
- 22.** (4, Unit 8) True end pose (arc): (18.77, 6.06) m; the odometry says (20, 0): the error is 6.19 m (31% of the distance).
- 23.** (1, Unit 9) A. The command is K_p times the error, so a nonzero command needs a nonzero error.
- 24.** (2, Unit 9) $1/(1 + K K_p) = 0.2227$ (22.3%).
- 25.** (3, Unit 9) $K_u = 3.368$; $T_u = 57.3$ ms.
- 26.** (4, Unit 9) $v t + v^2/(2 \mu g) = 0.5 \times 0.15 + 0.25/(2 \times 0.6 \times 9.81) = 9.62$ cm.
- 27.** (1, Unit 10) D. 68%, 95% and 99.7% for one, two and three standard deviations.
- 28.** (2, Unit 10) $0.9 \times 0.05 / (0.9 \times 0.05 + 0.08 \times 0.95) = 0.3719$.
- 29.** (3, Unit 10) $P^- = (q + \sqrt{q^2 + 4 q r})/2$; $K = P^-/(P^- + r) = 0.0488$; an EMA with $\alpha = 0.049$.
- 30.** (4, Unit 10) 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.
- 31.** (1, Unit 11) B.
- 32.** (2, Unit 11) $(7 + 2) + (\sqrt{2} - 2) \times 2 = 7.828$ cells.
- 33.** (3, Unit 11) $T \leq (0.05 - v^2/(2 \mu g))/v - 0.015 = 42.5$ ms (23.5 Hz).
- 34.** (4, Unit 11) $v (0.2 + 0.015) + v^2/(2 \mu g) = 12.9$ cm.
- 35.** (1, Unit 12) A.
- 36.** (2, Unit 12) $0.3^5 = 0.00243 = 0.243\%$.
- 37.** (3, Unit 12) $s = 0.8 \times \sqrt{40}/1.96 = 2.6$ percentage points.
- 38.** (4, Unit 12) 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 0.15τ); 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.