Young Engineers III: Engineers

Name _____ Date _____

Young Engineers III: Engineers · Printables pack

This pack has everything to print for the year: the safety pages, Engineer’s Notebook pages, the nine lab sheets with parts lists, rough costs, supervision levels and blank data tables, and every unit test, the midterm and the final, with answer keys at the back.

Supervision levels

- 🟢 Adult nearby: in the house, checks in at the start and end.
- 🔵 Adult present: in the room or at the field the whole time.
- 🔴 Adult hands-on: the adult does the marked steps.

Scripture for each unit (KJV)

1. **Luke 14:28**: “For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?”
2. **Psalm 19:1**: “The heavens declare the glory of God; and the firmament sheweth his handywork.”
3. **Proverbs 24:16**: “For a just man falleth seven times, and riseth up again:”
4. **Psalm 8:3**: “When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained;”
5. **Psalm 19:3**: “There is no speech nor language, where their voice is not heard.”
6. **Exodus 31:3**: “And I have filled him with the spirit of God, in wisdom, and in understanding, and in knowledge, and in all manner of workmanship,”
7. **Proverbs 22:29**: “Seest thou a man diligent in his business? he shall stand before kings; he shall not stand before mean men.”
8. **Job 28:10**: “He cutteth out rivers among the rocks; and his eye seeth every precious thing.”
9. **Genesis 2:15**: “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.”

Safety Pages

Name _____ Date _____

Young Engineers III: Engineers · Read together before the first lab; post in your work area

Read this page with your student before the first lab. Every lab in the course is marked with one of three supervision levels:

- 🟢 Adult nearby: in the house, checks in at the start and end.
- 🔵 Adult present: in the room or at the field the whole time.
- 🔴 Adult hands-on: the adult does the marked steps.

General shop rules

- Safety glasses on for every build and test, for everyone nearby too.
- Tie back long hair; no loose sleeves or dangling cords near tools or spinning parts.
- Ask before using any sharp or power tool; an adult does all cutting with craft knives for grades 3–5.
- Keep a first-aid kit and a fire extinguisher (or a bucket of sand) where you build.

Rockets

- Follow the NAR Model Rocket Safety Code for every motor-powered flight. Only certified, commercially made motors, never altered; never make propellant.
- An adult buys, stores and installs every motor and igniter, and holds the launch key. Grades 3–5 fly only air-powered (stomp) rockets.
- Ceiling for this track: up to F/G-class model rocket motors, flown by the adult as the flier of record and within the motor's labeling and state law. High-power rocketry is out of scope.
- Misfire: remove the safety key or disconnect the battery and wait 60 seconds. Stand back at least 15 ft for D and smaller motors and 30 ft for larger ones. Wind no more than 20 mph; no dry grass at the pad.
- Water rockets: only undamaged bottles, a pressure limit set by the adult, eye protection, nobody over the rocket.

Batteries

- Grades 3–5 use AA, AAA, C and D cells only. Keep button cells and magnets away from small children because swallowing them is a medical emergency.
- LiPo/Li-ion: balance charger on the right setting, fire-safe surface or LiPo bag, never unattended, never a swollen, dented or hot pack; store at storage voltage; recycle at a drop-off (EPA: Used Lithium-Ion Batteries).
- Fuse every battery near its positive terminal. Never short the terminals.

Electrical

- Students work only on low-voltage DC: 12 V solar, and at most 36 V nominal for the high-school EV.
- No student work on 120 V household wiring or on inverter AC output. Use inverter outlets only through plug-in devices. Never back-feed a house circuit.
- An adult makes all LiFePO4/Li-ion battery terminal connections in Grades 9–12 labs.

Vehicles

- The electric soapbox runs on a closed private course only, never streets or sidewalks. Helmet, gloves and closed shoes; mechanical brakes that work with power off; a kill switch and main fuse tested every session; top speed limited to about 15 mph.

Vacuum, magnets, digging and radio

- Vacuum: thick-wall plastic only, never glass; eye protection; no more than −80 kPa gauge.
- Neodymium magnets pinch and shatter; keep them away from pacemakers, phones and cards.
- Digging: tabletop or sandbox scale only. Never dig a pit or tunnel a person could enter.
- Radio: listening needs no license; transmitting on ham bands requires an FCC license. Keep all antennas far from power lines.

Labs, Supervision and Rough Costs

Name _____ Date _____

Young Engineers III: Engineers · Plan purchases for the year

Lesson	Lab	Supervision	Cost
Unit 1 · 1.4	Cantilever to Spec	🟢 Adult nearby	about $18
Unit 2 · 2.4	Predict and Fly	🔴 Adult hands-on	about $119
Unit 3 · 3.4	Tune the Balancer	🟢 Adult nearby	about $50
Unit 4 · 4.4	1U Payload Build	🔵 Adult present	about $37
Unit 5 · 5.4	Dipole Build and Tune	🔵 Adult present	about $76
Unit 6 · 6.4	Prony-Brake Dyno	🔵 Adult present	about $107
Unit 7 · 7.4	Electric Soapbox Build and Test	🔴 Adult hands-on	about $500
Unit 8 · 8.4	Low-Pressure Tube and Glider Runs	🔵 Adult present	about $92
Unit 9 · 9.4	Off-Grid Solar Capstone	🔴 Adult hands-on	about $360

Rough total for the year: about $1359 per family, less if you reuse parts or borrow tools (a multimeter, for example, serves Units 6–9). Optional kits are listed on each unit page. School Launch is independent and free.

Engineer’s Notebook Page

Name _____ Date _____

Young Engineers III: Engineers · Copy as many as you need

Test Log

Name _____ Date _____

Young Engineers III: Engineers · Any experiment

Trial	Variable changed	Setting	Result	Units	Notes

Lab Sheet 1.4: Cantilever to Spec

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🟢 Adult nearby: in the house, checks in at the start and end.

Lowest-mass cantilever that meets the load requirement. Score = failure load ÷ mass.

Parts list

Part	Rough cost	Have it?
Craft sticks (200)	$6	
Wood glue	$4	
Clamps (2)	$8	
Bucket and sand or water for loading	on hand	
Kitchen scale	on hand	
Estimated total	**about $18**	

Steps

1. Write the requirements and a two-option trade study.
2. Sketch the truss to scale; predict the weakest member.
3. Build and cure overnight. Weigh it.
4. Clamp to a table; add load in 100 g steps until failure. Record the deflection at the tip.
5. Compute the factor of safety and score; present a 5-minute design review with a “what failed and why” photo.

Data

Load (g)	Tip deflection (mm)	Notes

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ Requirement met (FoS ≥ 1.5) ☐ Trade study shown ☐ Failure analyzed

Lab Sheet 2.4: Predict and Fly

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔴 Adult hands-on: the adult does the marked steps.

Adult-led launch under the NAR Model Rocket Safety Code. The adult handles motors, igniters and the launch key.

Parts list

Part	Rough cost	Have it?
Estes kit and launch set	$55	
Motors (B and C, 3 each)	$30	
Small altimeter	$30	
Recovery wadding	$4	
Safety glasses	on hand	
Estimated total	**about $119**	

Steps

1. Build the kit carefully; weigh it; find CG with the motor installed.
2. Model it in OpenRocket; record predicted apogee and margin for each motor.
3. Choose a field at least as large as the NAR site table requires; check wind (≤ 20 mph) and field permission.
4. The adult installs the motor and igniter. Run the range: countdown, everyone back 15 ft (30 ft for motors larger than D).
5. Recover; read the altimeter; compute percent error; fly the second motor.

Data

Motor	Liftoff mass (g)	Predicted apogee (m)	Altimeter (m)	% error

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ Adult held the launch key ☐ Margin 1–2 calibers ☐ Predicted vs measured logged

Lab Sheet 3.4: Tune the Balancer

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🟢 Adult nearby: in the house, checks in at the start and end.

Find gains that keep the robot balanced and recover from a 2 cm nudge.

Parts list

Part	Rough cost	Have it?
microcontroller balancing-robot kit with IMU	$50	
USB cable and free microcontroller IDE	on hand	
Rechargeable pack supplied with the kit	on hand	
Ruler	on hand	
Estimated total	**about $50**	

Steps

1. Assemble and upload the starter code; calibrate the IMU on a level surface.
2. Set Ki = Kd = 0. Raise Kp until it oscillates steadily; record that Kp.
3. Add Kd until the oscillation damps out.
4. Add a small Ki to remove a slow drift.
5. Nudge test: push 2 cm and record recovery time and overshoot for three gain sets.

Data

Kp	Ki	Kd	Recovers? (Y/N)	Recovery time (s)	Notes

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ Gains logged for every trial ☐ Recovery time measured ☐ Code commented

Lab Sheet 4.4: 1U Payload Build

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔵 Adult present: in the room or at the field the whole time.

Requirement: log pressure and acceleration at 10 Hz for 30 minutes from a pack inside a 10 × 10 × 10 cm frame.

Parts list

Part	Rough cost	Have it?
Raspberry Pi Pico or small microcontroller board	$6	
Barometer + IMU breakout	$12	
microSD module and card	$8	
Small LiPo (1S) with protection board, or 3×AAA	$8	
Frame (3D print or foam board)	$3	
Estimated total	**about $37**	

Steps

1. Write requirements and a power budget (mA × hours).
2. Wire and code it; log to CSV; check the data on a bench.
3. Drop test from 1 m onto grass; freezer test for 10 minutes.
4. Fly: kite or tethered balloon (an adult controls the line), or rocket payload bay.
5. Plot altitude from pressure; compare with known height.

Data

Test	Duration (min)	Samples logged	Max accel (g)	Max altitude (m)

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ Power budget closes with 30% margin ☐ Survived drop test ☐ Altitude plot made

Lab Sheet 5.4: Dipole Build and Tune

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔵 Adult present: in the room or at the field the whole time.

Goal: SWR below 1.5 at 146.52 MHz.

Parts list

Part	Rough cost	Have it?
Copper wire (2 m) and a PVC T mount	$6	
SO-239 connector and short coax	$10	
NanoVNA or antenna analyzer (optional, can borrow from a club)	$60	
Technician study guide (free question pool)	on hand	
Estimated total	**about $76**	

Steps

1. Compute the starting length; cut 3% long.
2. Mount the halves on the PVC T; solder to the connector (adult present for soldering).
3. Measure SWR from 140 to 150 MHz; note the resonance.
4. Trim both halves equally and re-measure until resonant near 146.52 MHz.
5. Take a full practice Technician exam; log your score.

Data

Trim	Length (cm)	Resonance (MHz)	Min SWR	Notes

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ SWR plot recorded ☐ Trim log kept ☐ Practice exam score logged

Lab Sheet 6.4: Prony-Brake Dyno

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔵 Adult present: in the room or at the field the whole time.

Plot torque, power and efficiency across five load settings.

Parts list

Part	Rough cost	Have it?
12 V DC gear motor or brushless motor + ESC	$25	
Bench power supply or 12 V LiFePO4 pack with fuse	$30	
Two multimeters (V and I)	$25	
Pulley, cord and two spring scales	$12	
Optical tachometer	$15	
Estimated total	**about $107**	

Steps

1. Clamp the motor; wrap the cord around the pulley between the two spring scales.
2. Measure input V and I, the two scale readings, and rpm at five friction settings.
3. Torque = $(F_1 - F_2) \times$ pulley radius. $P_{out} = \tau\omega$. $P_{in} = VI$.
4. Plot efficiency vs torque; find the peak.
5. Write which load point an EV should cruise at, and why.

Data

Point	V (V)	I (A)	$F_1 - F_2$ (N)	rpm	η (%)

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ Five load points ☐ Efficiency curve plotted ☐ Motor temperature checked

Lab Sheet 7.4: Electric Soapbox Build and Test

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔴 Adult hands-on: the adult does the marked steps.

Ceiling: 36 V nominal, top speed limited to about 15 mph, closed private course only.

Parts list

Part	Rough cost	Have it?
Frame (kit, plywood or salvaged go-kart)	$80	
24–36 V motor and controller kit	$150	
LiFePO4 pack with BMS (24–36 V, 10–20 Ah)	$180	
Main fuse, kill switch, thumb throttle	$30	
Mechanical brakes	$40	
Helmet, gloves, closed shoes	on hand	
Watt meter	$20	
Estimated total	**about $500**	

Steps

1. Design: sketch the layout; compute expected range from pack Wh and an estimated 20–30 Wh/mi.
2. Build the frame, steering and brakes first. Test brakes by pushing before any electrics.
3. The adult connects the pack, fuse and kill switch; the student wires the throttle and controller with the pack disconnected.
4. Tech inspection: brakes, steering, kill switch, fuse, wire routing, helmet.
5. Run laps on a closed course; log Wh used and miles; compute Wh/mi and compare with your estimate.

Data

Run	Laps	Distance (mi)	Wh used	Wh/mi	Max speed (mph)

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ Passed tech inspection ☐ Kill switch tested every session ☐ Wh/mi computed

Lab Sheet 8.4: Low-Pressure Tube and Glider Runs

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔵 Adult present: in the room or at the field the whole time.

Quantify the end-cap load and the leak rate; compare glider times with and without levitation.

Parts list

Part	Rough cost	Have it?
Clear thick-wall PVC or acrylic tube (5–7.5 cm) with Schedule 40 end caps	$25	
Hand vacuum pump with gauge	$25	
Marshmallows, small balloon	$2	
Neodymium magnet strip track or shop-vac air track	$40	
Photogate or phone slow-motion video	on hand	
Estimated total	**about $92**	

Steps

1. Seal the tube; pump to −50 kPa gauge; compute the end-cap force ($F = \Delta P \times A$).
2. Record pressure every 30 s for 5 minutes to find the leak rate.
3. Observe the marshmallow and balloon; explain with the gas laws.
4. Build the glider and time 1 m runs at three loads, levitated and in contact.
5. Compare friction losses and report.

Data

Time (s)	Gauge P (kPa)	Glider load (g)	Run time (s)	Mode

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ End-cap force computed ☐ Leak-down graph ☐ Levitated vs contact compared

Lab Sheet 9.4: Off-Grid Solar Capstone

Name _____ Date _____

Young Engineers III: Engineers · Build-and-test lab

Supervision: 🔴 Adult hands-on: the adult does the marked steps.

All DC wiring by the student with an adult checking; all battery terminals and the inverter connected by the adult.

Parts list

Part	Rough cost	Have it?
100 W 12 V panel	$80	
MPPT charge controller (10–20 A)	$45	
12 V LiFePO4 battery 50 Ah with BMS	$150	
300 W pure-sine inverter	$50	
Fuses/breakers, MC4 leads, 10 AWG wire, lugs	$35	
Multimeter	on hand	
Estimated total	**about $360**	

Steps

1. Write requirements and the daily load table; size panel and battery.
2. Draw the one-line diagram with wire gauges and fuse ratings; the adult reviews it.
3. Mount the panel at your computed tilt; wire panel → controller → fuse → battery (the adult makes the battery connections).
4. Log controller data for a week: Wh harvested, battery state of charge and load Wh.
5. Design review: compare measured harvest with predicted (percent error), payback and improvements.

Data

Day	Sun (est. hours)	Wh harvested	Wh used	Battery SOC (%)

Design cycle. Ask · Imagine · Plan · Build · Test · Improve · Share

Problem and constraints:

My prediction:

What I will change next time and why:

Check

☐ One-line diagram approved ☐ Every positive lead fused near the battery ☐ Week of data logged ☐ Design review given

Unit 1 Test: Thinking Like an Engineer

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A motor takes in 50 W of electrical power and delivers 33.4 W of mechanical power. What is its efficiency? Round to 0.1%.

2. A motor takes in 50 W of electrical power and delivers 42.7 W of mechanical power. What is its efficiency? Round to 0.1%.

3. An amplifier raises a signal from 10 W to 100 W. What is the gain in decibels? Round to 0.1 dB.

4. A motor takes in 240 W of electrical power and delivers 170.9 W of mechanical power. What is its efficiency? Round to 0.1%.

5. A motor takes in 240 W of electrical power and delivers 172.3 W of mechanical power. What is its efficiency? Round to 0.1%.

6. A motor takes in 1000 W of electrical power and delivers 948.3 W of mechanical power. What is its efficiency? Round to 0.1%.

7. An amplifier raises a signal from 2 W to 20 W. What is the gain in decibels? Round to 0.1 dB.

8. A motor takes in 500 W of electrical power and delivers 301.6 W of mechanical power. What is its efficiency? Round to 0.1%.

Unit 2 Test: How Rockets Fly

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A 0.128 kg rocket has an average thrust of 12.0 N for 1.6 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.

2. A stage has I_{sp} = 350 s, starting mass 260 t and burnout mass 113 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.

3. At burnout a rocket is moving straight up at 101 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

4. At burnout a rocket is moving straight up at 102 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

5. A 0.076 kg rocket has an average thrust of 8.0 N for 1.0 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.

6. A stage has I_{sp} = 80 s, starting mass 448 t and burnout mass 191 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.

7. At burnout a rocket is moving straight up at 26 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

8. At burnout a rocket is moving straight up at 24 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

Unit 3 Test: Reusable Rockets and Landing

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A $900 off-grid kit replaces 120 kWh per year of grid power at $0.12 per kWh. What is the simple payback time? Round to 0.1 years.

2. A vehicle rounds a curve of radius 10 m at 10 m/s. What is its sideways acceleration in g? Round to 0.01 g.

3. At burnout a rocket is moving straight up at 21 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

4. A vehicle rounds a curve of radius 23,500 m at 340 m/s. What is its sideways acceleration in g? Round to 0.01 g.

5. A $250 off-grid kit replaces 180 kWh per year of grid power at $0.15 per kWh. What is the simple payback time? Round to 0.1 years.

6. A vehicle rounds a curve of radius 23,500 m at 340 m/s. What is its sideways acceleration in g? Round to 0.01 g.

7. At burnout a rocket is moving straight up at 30 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

8. A vehicle rounds a curve of radius 2,000 m at 20 m/s. What is its sideways acceleration in g? Round to 0.01 g.

Unit 4 Test: Satellites and Orbits

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. Find the circular orbital speed at an altitude of 20,200 km. Use GM = 3.986×10^{14} m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

2. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 1.524 AU. Round to 0.01 years.

3. Find the circular orbital speed at an altitude of 20,200 km. Use GM = 3.986×10^{14} m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

4. Find the period of a circular orbit 550 km above Earth, in minutes. Use GM = 3.986×10^{14} m³/s², R_E = 6,371 km. Round to 0.1 min.

5. Find the circular orbital speed at an altitude of 300 km. Use GM = 3.986×10^{14} m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

6. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 2.77 AU. Round to 0.01 years.

7. Find the circular orbital speed at an altitude of 35,786 km. Use GM = 3.986×10^{14} m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

8. Find the period of a circular orbit 550 km above Earth, in minutes. Use GM = 3.986×10^{14} m³/s², R_E = 6,371 km. Round to 0.1 min.

Unit 5 Test: Radio and Communication

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. An amplifier raises a signal from 5 W to 20 W. What is the gain in decibels? Round to 0.1 dB.

2. Find the free-space path loss for a 145.8 MHz signal over 35,786 km: FSPL(dB) = $20 \log_{10}(d_{km}) + 20 \log_{10}(f_{MHz}) + 32.44$. Round to 0.1 dB.

3. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 445.0 MHz. Round to 0.01 m.

4. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 445.0 MHz. Round to 0.01 m.

5. An amplifier raises a signal from 2 W to 20 W. What is the gain in decibels? Round to 0.1 dB.

6. Find the free-space path loss for a 437.8 MHz signal over 1,000 km: FSPL(dB) = $20 \log_{10}(d_{km}) + 20 \log_{10}(f_{MHz}) + 32.44$. Round to 0.1 dB.

7. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 445.0 MHz. Round to 0.01 m.

8. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 14.2 MHz. Round to 0.01 m.

Unit 6 Test: Electric Motors and Batteries

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A motor delivers 13.2 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.

2. A motor takes in 500 W of electrical power and delivers 355.4 W of mechanical power. What is its efficiency? Round to 0.1%.

3. You need about 48 V nominal and at least 10 Ah from 3.6 V cells of 3.0 Ah each. How many cells in total (series × parallel)?

4. A motor delivers 25.1 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.

5. A motor delivers 36.4 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.

6. A motor takes in 50 W of electrical power and delivers 30.8 W of mechanical power. What is its efficiency? Round to 0.1%.

7. You need about 48 V nominal and at least 10 Ah from 3.6 V cells of 3.0 Ah each. How many cells in total (series × parallel)?

8. A motor delivers 35.4 N·m of torque at 1,500 rpm. What mechanical power is that? Round to the nearest W.

Unit 7 Test: Building an Electric Vehicle

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A vehicle has 100,000 Wh of usable battery and uses 280 Wh per mile. Estimate its range. Round to 0.1 mi.

2. A 60 kg vehicle (with rider) moves at 5 m/s. What is its kinetic energy? Round to the nearest J.

3. A vehicle rounds a curve of radius 10 m at 20 m/s. What is its sideways acceleration in g? Round to 0.01 g.

4. A vehicle has 1,000 Wh of usable battery and uses 25 Wh per mile. Estimate its range. Round to 0.1 mi.

5. A vehicle has 1,000 Wh of usable battery and uses 20 Wh per mile. Estimate its range. Round to 0.1 mi.

6. A 40 kg vehicle (with rider) moves at 15 m/s. What is its kinetic energy? Round to the nearest J.

7. A vehicle rounds a curve of radius 2,000 m at 10 m/s. What is its sideways acceleration in g? Round to 0.01 g.

8. A vehicle has 500 Wh of usable battery and uses 30 Wh per mile. Estimate its range. Round to 0.1 mi.

Unit 8 Test: Tunnels and Tube Travel

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A sealed end cap closes a tube 0.1 m in inside diameter. The pressure difference across it is 101,225 Pa. What force acts on the cap? Round to the nearest N.

2. A sealed end cap closes a tube 2.23 m in inside diameter. The pressure difference across it is 80,000 Pa. What force acts on the cap? Round to the nearest N.

3. Find the drag force: air density 0.02 kg/m³, speed 300 m/s, C_d = 0.75, frontal area 0.0025 m². Round to 0.001 N.

4. A sealed end cap closes a tube 2.23 m in inside diameter. The pressure difference across it is 80,000 Pa. What force acts on the cap? Round to the nearest N.

5. A sealed end cap closes a tube 0.05 m in inside diameter. The pressure difference across it is 101,225 Pa. What force acts on the cap? Round to the nearest N.

6. A sealed end cap closes a tube 0.15 m in inside diameter. The pressure difference across it is 80,000 Pa. What force acts on the cap? Round to the nearest N.

7. Find the drag force: air density 1.2 kg/m³, speed 20 m/s, C_d = 0.5, frontal area 0.001 m². Round to 0.001 N.

8. A sealed end cap closes a tube 0.1 m in inside diameter. The pressure difference across it is 50,000 Pa. What force acts on the cap? Round to the nearest N.

Unit 9 Test: Solar Power and the Capstone

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. At latitude 25° N, what is the Sun’s elevation angle at solar noon on the June solstice (declination +23.44°)? Round to 0.01°.

2. A motor takes in 1000 W of electrical power and delivers 621.5 W of mechanical power. What is its efficiency? Round to 0.1%.

3. A shed needs 600 Wh per day. Your site gets 5.5 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.

4. A shed needs 200 Wh per day. Your site gets 5.0 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.

5. At latitude 30° N, what is the Sun’s elevation angle at solar noon on an equinox (declination 0°)? Round to 0.01°.

6. A motor takes in 240 W of electrical power and delivers 162.7 W of mechanical power. What is its efficiency? Round to 0.1%.

7. A shed needs 200 Wh per day. Your site gets 5.5 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.

8. A shed needs 480 Wh per day. Your site gets 5.0 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.

Midterm Exam

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A motor takes in 120 W of electrical power and delivers 108.5 W of mechanical power. What is its efficiency? Round to 0.1%.

2. A motor takes in 500 W of electrical power and delivers 354.6 W of mechanical power. What is its efficiency? Round to 0.1%.

3. An amplifier raises a signal from 1 W to 50 W. What is the gain in decibels? Round to 0.1 dB.

4. A motor takes in 1000 W of electrical power and delivers 829.8 W of mechanical power. What is its efficiency? Round to 0.1%.

5. A 0.137 kg rocket has an average thrust of 8.0 N for 1.8 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.

6. A stage has I_{sp} = 380 s, starting mass 436 t and burnout mass 114 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.

7. At burnout a rocket is moving straight up at 75 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

8. At burnout a rocket is moving straight up at 33 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

9. A $300 off-grid kit replaces 240 kWh per year of grid power at $0.18 per kWh. What is the simple payback time? Round to 0.1 years.

10. A vehicle rounds a curve of radius 23,500 m at 100 m/s. What is its sideways acceleration in g? Round to 0.01 g.

11. At burnout a rocket is moving straight up at 29 m/s. Ignoring drag, how much higher will it coast? Use $g = 9.8$ m/s². Round to the nearest m.

12. A vehicle rounds a curve of radius 23,500 m at 10 m/s. What is its sideways acceleration in g? Round to 0.01 g.

13. Find the circular orbital speed at an altitude of 420 km. Use $GM = 3.986 \times 10^{14}$ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

14. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 9.58 AU. Round to 0.01 years.

15. Find the circular orbital speed at an altitude of 35,786 km. Use $GM = 3.986 \times 10^{14}$ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

16. Find the period of a circular orbit 400 km above Earth, in minutes. Use $GM = 3.986 \times 10^{14}$ m³/s², $R_E = 6{,}371$ km. Round to 0.1 min.

Final Exam

Name _____ Date _____

Young Engineers III: Engineers · Show your work and units

1. A motor takes in 500 W of electrical power and delivers 321.2 W of mechanical power. What is its efficiency? Round to 0.1%.

2. A motor takes in 1000 W of electrical power and delivers 635.5 W of mechanical power. What is its efficiency? Round to 0.1%.

3. An amplifier raises a signal from 1 W to 2 W. What is the gain in decibels? Round to 0.1 dB.

4. A motor takes in 240 W of electrical power and delivers 224.5 W of mechanical power. What is its efficiency? Round to 0.1%.

5. A 0.447 kg rocket has an average thrust of 13.1 N for 0.8 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.

6. A stage has I_{sp} = 311 s, starting mass 89 t and burnout mass 24 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.

7. At burnout a rocket is moving straight up at 34 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

8. At burnout a rocket is moving straight up at 75 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.

9. A $600 off-grid kit replaces 120 kWh per year of grid power at $0.15 per kWh. What is the simple payback time? Round to 0.1 years.

10. A vehicle rounds a curve of radius 4,800 m at 100 m/s. What is its sideways acceleration in g? Round to 0.01 g.

11. At burnout a rocket is moving straight up at 119 m/s. Ignoring drag, how much higher will it coast? Use $g = 9.8$ m/s². Round to the nearest m.

12. A vehicle rounds a curve of radius 10 m at 340 m/s. What is its sideways acceleration in g? Round to 0.01 g.

13. Find the circular orbital speed at an altitude of 1,200 km. Use $GM = 3.986 \times 10^{14}$ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

14. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 2.77 AU. Round to 0.01 years.

15. Find the circular orbital speed at an altitude of 800 km. Use $GM = 3.986 \times 10^{14}$ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.

16. Find the period of a circular orbit 20,200 km above Earth, in minutes. Use $GM = 3.986 \times 10^{14}$ m³/s², $R_E = 6{,}371$ km. Round to 0.1 min.

17. An amplifier raises a signal from 2 W to 40 W. What is the gain in decibels? Round to 0.1 dB.

18. Find the free-space path loss for a 11700 MHz signal over 2,000 km: $\text{FSPL(dB)} = 20 \log_{10}(d_{\text{km}}) + 20 \log_{10}(f_{\text{MHz}}) + 32.44$. Round to 0.1 dB.

19. A common starting length for a half-wave wire dipole is $L(\text{m}) \approx 143 \div f(\text{MHz})$ (the 0.95 factor for wire is built in). Find the length for 14.2 MHz. Round to 0.01 m.

20. A common starting length for a half-wave wire dipole is $L(\text{m}) \approx 143 \div f(\text{MHz})$ (the 0.95 factor for wire is built in). Find the length for 28.4 MHz. Round to 0.01 m.

21. A motor delivers 36.2 N·m of torque at 6,000 rpm. What mechanical power is that? Round to the nearest W.

22. A motor takes in 1000 W of electrical power and delivers 902.2 W of mechanical power. What is its efficiency? Round to 0.1%.

23. You need about 48 V nominal and at least 15 Ah from 3.6 V cells of 5.0 Ah each. How many cells in total (series × parallel)?

24. A motor delivers 29.3 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.

Unit 1 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A motor takes in 50 W of electrical power and delivers 33.4 W of mechanical power. What is its efficiency? Round to 0.1%.
   66.8 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 33.4 / 50 × 100 ≈ 66.8%

2. A motor takes in 50 W of electrical power and delivers 42.7 W of mechanical power. What is its efficiency? Round to 0.1%.
   85.4 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 42.7 / 50 × 100 ≈ 85.4%

3. An amplifier raises a signal from 10 W to 100 W. What is the gain in decibels? Round to 0.1 dB.
   10.0 dB
   1. Gain(dB) = 10 $\log_{10}(P_2 / P_1)$
   2. P_2/P_1 = 100/10 = 10
   3. 10 $\log_{10}(10)$ ≈ 10.0 dB

4. A motor takes in 240 W of electrical power and delivers 170.9 W of mechanical power. What is its efficiency? Round to 0.1%.
   71.2 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 170.9 / 240 × 100 ≈ 71.2%

5. A motor takes in 240 W of electrical power and delivers 172.3 W of mechanical power. What is its efficiency? Round to 0.1%.
   71.8 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 172.3 / 240 × 100 ≈ 71.8%

6. A motor takes in 1000 W of electrical power and delivers 948.3 W of mechanical power. What is its efficiency? Round to 0.1%.
   94.8 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 948.3 / 1000 × 100 ≈ 94.8%

7. An amplifier raises a signal from 2 W to 20 W. What is the gain in decibels? Round to 0.1 dB.
   10.0 dB
   1. Gain(dB) = 10 $\log_{10}(P_2 / P_1)$
   2. P_2/P_1 = 20/2 = 10
   3. 10 $\log_{10}(10)$ ≈ 10.0 dB

8. A motor takes in 500 W of electrical power and delivers 301.6 W of mechanical power. What is its efficiency? Round to 0.1%.
   60.3 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 301.6 / 500 × 100 ≈ 60.3%

Unit 2 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A 0.128 kg rocket has an average thrust of 12.0 N for 1.6 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.
   134.3 m/s
   1. Net force = thrust − weight
   2. $F_{net} = 12.0 - 0.128 \times 9.8 = 10.746$ N
   3. $a = F_{net}/m = 83.950$ m/s²
   4. $v = a\,t = 83.950 \times 1.6 \approx 134.3$ m/s

2. A stage has I_{sp} = 350 s, starting mass 260 t and burnout mass 113 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.
   2,858 m/s
   1. $\Delta v = I_{sp} \cdot g_0 \cdot \ln(m_0 / m_f)$
   2. $m_0/m_f = 260/113 = 2.3009$
   3. $\ln(2.3009) = 0.8333$
   4. $\Delta v = 350 \times 9.8 \times 0.8333 \approx 2{,}858$ m/s

3. At burnout a rocket is moving straight up at 101 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   520 m
   1. At the top, v = 0, so $v^2 = 2\,g\,h$ and $h = v^2 / (2g)$
   2. $h = 101^2 / (2 \times 9.8) = 10201 / 19.6 \approx 520$ m

4. At burnout a rocket is moving straight up at 102 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   531 m
   1. At the top, v = 0, so $v^2 = 2\,g\,h$ and $h = v^2 / (2g)$
   2. $h = 102^2 / (2 \times 9.8) = 10404 / 19.6 \approx 531$ m

5. A 0.076 kg rocket has an average thrust of 8.0 N for 1.0 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.
   95.5 m/s
   1. Net force = thrust − weight
   2. $F_{net} = 8.0 - 0.076 \times 9.8 = 7.255$ N
   3. $a = F_{net}/m = 95.463$ m/s²
   4. $v = a\,t = 95.463 \times 1.0 \approx 95.5$ m/s

6. A stage has I_{sp} = 80 s, starting mass 448 t and burnout mass 191 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.
   668 m/s
   1. $\Delta v = I_{sp} \cdot g_0 \cdot \ln(m_0 / m_f)$
   2. $m_0/m_f = 448/191 = 2.3455$
   3. $\ln(2.3455) = 0.8525$
   4. $\Delta v = 80 \times 9.8 \times 0.8525 \approx 668$ m/s

7. At burnout a rocket is moving straight up at 26 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   34 m
   1. At the top, v = 0, so $v^2 = 2\,g\,h$ and $h = v^2 / (2g)$
   2. $h = 26^2 / (2 \times 9.8) = 676 / 19.6 \approx 34$ m

8. At burnout a rocket is moving straight up at 24 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   29 m
   1. At the top, v = 0, so $v^2 = 2\,g\,h$ and $h = v^2 / (2g)$
   2. $h = 24^2 / (2 \times 9.8) = 576 / 19.6 \approx 29$ m

Unit 3 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A $900 off-grid kit replaces 120 kWh per year of grid power at $0.12 per kWh. What is the simple payback time? Round to 0.1 years.
   62.5 years
   1. Yearly savings = 120 × 0.12 = $14.40
   2. Payback = 900 ÷ 14.40 ≈ 62.5 years

2. A vehicle rounds a curve of radius 10 m at 10 m/s. What is its sideways acceleration in g? Round to 0.01 g.
   1.02 g
   1. a = v² / r, then divide by 9.8 to get g
   2. a = 10² / 10 = 10.000 m/s²
   3. 10.000 ÷ 9.8 ≈ 1.02 g

3. At burnout a rocket is moving straight up at 21 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   22 m
   1. At the top, v = 0, so v² = 2 g h and h = v² / (2g)
   2. h = 21² / (2 × 9.8) = 441 / 19.6 ≈ 22 m

4. A vehicle rounds a curve of radius 23,500 m at 340 m/s. What is its sideways acceleration in g? Round to 0.01 g.
   0.50 g
   1. a = v² / r, then divide by 9.8 to get g
   2. a = 340² / 23500 = 4.919 m/s²
   3. 4.919 ÷ 9.8 ≈ 0.50 g

5. A $250 off-grid kit replaces 180 kWh per year of grid power at $0.15 per kWh. What is the simple payback time? Round to 0.1 years.
   9.3 years
   1. Yearly savings = 180 × 0.15 = $27.00
   2. Payback = 250 ÷ 27.00 ≈ 9.3 years

6. A vehicle rounds a curve of radius 23,500 m at 340 m/s. What is its sideways acceleration in g? Round to 0.01 g.
   0.50 g
   1. a = v² / r, then divide by 9.8 to get g
   2. a = 340² / 23500 = 4.919 m/s²
   3. 4.919 ÷ 9.8 ≈ 0.50 g

7. At burnout a rocket is moving straight up at 30 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   46 m
   1. At the top, v = 0, so v² = 2 g h and h = v² / (2g)
   2. h = 30² / (2 × 9.8) = 900 / 19.6 ≈ 46 m

8. A vehicle rounds a curve of radius 2,000 m at 20 m/s. What is its sideways acceleration in g? Round to 0.01 g.
   0.02 g
   1. a = v² / r, then divide by 9.8 to get g
   2. a = 20² / 2000 = 0.200 m/s²
   3. 0.200 ÷ 9.8 ≈ 0.02 g

Unit 4 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. Find the circular orbital speed at an altitude of 20,200 km. Use GM = 3.986 × 10^{14} m^3/s^2 and Earth's radius 6,371 km. Round to the nearest m/s.
   3,873 m/s
   1. r = 6,371 + 20,200 = 26,571 km = 2.6571e+07 m
   2. v = √(GM / r)
   3. v = √(3.986×10^{14} / 2.6571e+07) ≈ 3,873 m/s

2. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 1.524 AU. Round to 0.01 years.
   1.88 years
   1. T = a^(3/2)
   2. T = 1.524^1.5 ≈ 1.88 years

3. Find the circular orbital speed at an altitude of 20,200 km. Use GM = 3.986 × 10^{14} m^3/s^2 and Earth's radius 6,371 km. Round to the nearest m/s.
   3,873 m/s
   1. r = 6,371 + 20,200 = 26,571 km = 2.6571e+07 m
   2. v = √(GM / r)
   3. v = √(3.986×10^{14} / 2.6571e+07) ≈ 3,873 m/s

4. Find the period of a circular orbit 550 km above Earth, in minutes. Use GM = 3.986 × 10^{14} m^3/s^2, R_E = 6,371 km. Round to 0.1 min.
   95.5 min
   1. r = 6,921 km = 6.9210e+06 m
   2. T = 2π √(r^3 / GM)
   3. T = 5,730 s ÷ 60 ≈ 95.5 min

5. Find the circular orbital speed at an altitude of 300 km. Use GM = 3.986 × 10^{14} m^3/s^2 and Earth's radius 6,371 km. Round to the nearest m/s.
   7,730 m/s
   1. r = 6,371 + 300 = 6,671 km = 6.6710e+06 m
   2. v = √(GM / r)
   3. v = √(3.986×10^{14} / 6.6710e+06) ≈ 7,730 m/s

6. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 2.77 AU. Round to 0.01 years.
   4.61 years
   1. T = a^(3/2)
   2. T = 2.77^1.5 ≈ 4.61 years

7. Find the circular orbital speed at an altitude of 35,786 km. Use GM = 3.986 × 10^{14} m^3/s^2 and Earth's radius 6,371 km. Round to the nearest m/s.
   3,075 m/s
   1. r = 6,371 + 35,786 = 42,157 km = 4.2157e+07 m
   2. v = √(GM / r)
   3. v = √(3.986×10^{14} / 4.2157e+07) ≈ 3,075 m/s

8. Find the period of a circular orbit 550 km above Earth, in minutes. Use GM = 3.986 × 10^{14} m^3/s^2, R_E = 6,371 km. Round to 0.1 min.
   95.5 min
   1. r = 6,921 km = 6.9210e+06 m
   2. T = 2π √(r^3 / GM)
   3. T = 5,730 s ÷ 60 ≈ 95.5 min

Unit 5 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. An amplifier raises a signal from 5 W to 20 W. What is the gain in decibels? Round to 0.1 dB.
   6.0 dB
   1. Gain(dB) = 10 $\log_{10}(P_2 / P_1)$
   2. P_2/P_1 = 20/5 = 4
   3. 10 $\log_{10}(4)$ ≈ 6.0 dB

2. Find the free-space path loss for a 145.8 MHz signal over 35,786 km: FSPL(dB) = 20 $\log_{10}(d_{km})$ + 20 $\log_{10}(f_{MHz})$ + 32.44. Round to 0.1 dB.
   166.8 dB
   1. 20 $\log_{10}(35786)$ = 91.07
   2. 20 $\log_{10}(145.8)$ = 43.28
   3. FSPL = 91.07 + 43.28 + 32.44 ≈ 166.8 dB

3. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 445.0 MHz. Round to 0.01 m.
   0.32 m
   1. L ≈ 143 ÷ f
   2. L ≈ 143 ÷ 445.0 = 0.3213 ≈ 0.32 m

4. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 445.0 MHz. Round to 0.01 m.
   0.32 m
   1. L ≈ 143 ÷ f
   2. L ≈ 143 ÷ 445.0 = 0.3213 ≈ 0.32 m

5. An amplifier raises a signal from 2 W to 20 W. What is the gain in decibels? Round to 0.1 dB.
   10.0 dB
   1. Gain(dB) = 10 $\log_{10}(P_2 / P_1)$
   2. P_2/P_1 = 20/2 = 10
   3. 10 $\log_{10}(10)$ ≈ 10.0 dB

6. Find the free-space path loss for a 437.8 MHz signal over 1,000 km: FSPL(dB) = 20 $\log_{10}(d_{km})$ + 20 $\log_{10}(f_{MHz})$ + 32.44. Round to 0.1 dB.
   145.3 dB
   1. 20 $\log_{10}(1000)$ = 60.00
   2. 20 $\log_{10}(437.8)$ = 52.83
   3. FSPL = 60.00 + 52.83 + 32.44 ≈ 145.3 dB

7. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 445.0 MHz. Round to 0.01 m.
   0.32 m
   1. L ≈ 143 ÷ f
   2. L ≈ 143 ÷ 445.0 = 0.3213 ≈ 0.32 m

8. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 14.2 MHz. Round to 0.01 m.
   10.07 m
   1. L ≈ 143 ÷ f
   2. L ≈ 143 ÷ 14.2 = 10.0704 ≈ 10.07 m

Unit 6 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A motor delivers 13.2 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.
   4,147 W
   1. ω = 2π n / 60 = 2π × 3000 / 60 = 314.159 rad/s
   2. P = τ ω = 13.2 × 314.159 ≈ 4,147 W

2. A motor takes in 500 W of electrical power and delivers 355.4 W of mechanical power. What is its efficiency? Round to 0.1%.
   71.1 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 355.4 / 500 × 100 ≈ 71.1%

3. You need about 48 V nominal and at least 10 Ah from 3.6 V cells of 3.0 Ah each. How many cells in total (series × parallel)?
   56 cells
   1. Series count: 48 ÷ 3.6 = 13.33 → round up to 14S
   2. Parallel count: 10 ÷ 3.0 = 3.33 → round up to 4P
   3. Total = 14 × 4 = 56 cells (14S4P, 50.4 V nominal)

4. A motor delivers 25.1 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.
   7,885 W
   1. ω = 2π n / 60 = 2π × 3000 / 60 = 314.159 rad/s
   2. P = τ ω = 25.1 × 314.159 ≈ 7,885 W

5. A motor delivers 36.4 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.
   11,435 W
   1. ω = 2π n / 60 = 2π × 3000 / 60 = 314.159 rad/s
   2. P = τ ω = 36.4 × 314.159 ≈ 11,435 W

6. A motor takes in 50 W of electrical power and delivers 30.8 W of mechanical power. What is its efficiency? Round to 0.1%.
   61.6 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 30.8 / 50 × 100 ≈ 61.6%

7. You need about 48 V nominal and at least 10 Ah from 3.6 V cells of 3.0 Ah each. How many cells in total (series × parallel)?
   56 cells
   1. Series count: 48 ÷ 3.6 = 13.33 → round up to 14S
   2. Parallel count: 10 ÷ 3.0 = 3.33 → round up to 4P
   3. Total = 14 × 4 = 56 cells (14S4P, 50.4 V nominal)

8. A motor delivers 35.4 N·m of torque at 1,500 rpm. What mechanical power is that? Round to the nearest W.
   5,561 W
   1. ω = 2π n / 60 = 2π × 1500 / 60 = 157.080 rad/s
   2. P = τ ω = 35.4 × 157.080 ≈ 5,561 W

Unit 7 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A vehicle has 100,000 Wh of usable battery and uses 280 Wh per mile. Estimate its range. Round to 0.1 mi.
   357.1 miles
   1. Range = usable energy ÷ energy per mile
   2. 100,000 ÷ 280 ≈ 357.1 mi

2. A 60 kg vehicle (with rider) moves at 5 m/s. What is its kinetic energy? Round to the nearest J.
   750 J
   1. KE = ½ m v²
   2. KE = 0.5 × 60 × 5² = 750 J

3. A vehicle rounds a curve of radius 10 m at 20 m/s. What is its sideways acceleration in g? Round to 0.01 g.
   4.08 g
   1. a = v² / r, then divide by 9.8 to get g
   2. a = 20² / 10 = 40.000 m/s²
   3. 40.000 ÷ 9.8 ≈ 4.08 g

4. A vehicle has 1,000 Wh of usable battery and uses 25 Wh per mile. Estimate its range. Round to 0.1 mi.
   40.0 miles
   1. Range = usable energy ÷ energy per mile
   2. 1,000 ÷ 25 ≈ 40.0 mi

5. A vehicle has 1,000 Wh of usable battery and uses 20 Wh per mile. Estimate its range. Round to 0.1 mi.
   50.0 miles
   1. Range = usable energy ÷ energy per mile
   2. 1,000 ÷ 20 ≈ 50.0 mi

6. A 40 kg vehicle (with rider) moves at 15 m/s. What is its kinetic energy? Round to the nearest J.
   4,500 J
   1. KE = ½ m v²
   2. KE = 0.5 × 40 × 15² = 4,500 J

7. A vehicle rounds a curve of radius 2,000 m at 10 m/s. What is its sideways acceleration in g? Round to 0.01 g.
   0.01 g
   1. a = v² / r, then divide by 9.8 to get g
   2. a = 10² / 2000 = 0.050 m/s²
   3. 0.050 ÷ 9.8 ≈ 0.01 g

8. A vehicle has 500 Wh of usable battery and uses 30 Wh per mile. Estimate its range. Round to 0.1 mi.
   16.7 miles
   1. Range = usable energy ÷ energy per mile
   2. 500 ÷ 30 ≈ 16.7 mi

Unit 8 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A sealed end cap closes a tube 0.1 m in inside diameter. The pressure difference across it is 101,225 Pa. What force acts on the cap? Round to the nearest N.
   795 N
   1. $A = \pi (d/2)^2 = \pi \times 0.05^2 = 0.007854$ m²
   2. $F = \Delta P \times A = 101{,}225 \times 0.007854 \approx 795$ N

2. A sealed end cap closes a tube 2.23 m in inside diameter. The pressure difference across it is 80,000 Pa. What force acts on the cap? Round to the nearest N.
   312,457 N
   1. $A = \pi (d/2)^2 = \pi \times 1.115^2 = 3.905707$ m²
   2. $F = \Delta P \times A = 80{,}000 \times 3.905707 \approx 312{,}457$ N

3. Find the drag force: air density 0.02 kg/m³, speed 300 m/s, $C_d = 0.75$, frontal area 0.0025 m². Round to 0.001 N.
   1.688 N
   1. $F_d = \tfrac{1}{2} \rho v^2 C_d A$
   2. $F_d = 0.5 \times 0.02 \times 300^2 \times 0.75 \times 0.0025 \approx 1.688$ N

4. A sealed end cap closes a tube 2.23 m in inside diameter. The pressure difference across it is 80,000 Pa. What force acts on the cap? Round to the nearest N.
   312,457 N
   1. $A = \pi (d/2)^2 = \pi \times 1.115^2 = 3.905707$ m²
   2. $F = \Delta P \times A = 80{,}000 \times 3.905707 \approx 312{,}457$ N

5. A sealed end cap closes a tube 0.05 m in inside diameter. The pressure difference across it is 101,225 Pa. What force acts on the cap? Round to the nearest N.
   199 N
   1. $A = \pi (d/2)^2 = \pi \times 0.025^2 = 0.001963$ m²
   2. $F = \Delta P \times A = 101{,}225 \times 0.001963 \approx 199$ N

6. A sealed end cap closes a tube 0.15 m in inside diameter. The pressure difference across it is 80,000 Pa. What force acts on the cap? Round to the nearest N.
   1,414 N
   1. $A = \pi (d/2)^2 = \pi \times 0.075^2 = 0.017671$ m²
   2. $F = \Delta P \times A = 80{,}000 \times 0.017671 \approx 1{,}414$ N

7. Find the drag force: air density 1.2 kg/m³, speed 20 m/s, $C_d = 0.5$, frontal area 0.001 m². Round to 0.001 N.
   0.120 N
   1. $F_d = \tfrac{1}{2} \rho v^2 C_d A$
   2. $F_d = 0.5 \times 1.2 \times 20^2 \times 0.5 \times 0.001 \approx 0.120$ N

8. A sealed end cap closes a tube 0.1 m in inside diameter. The pressure difference across it is 50,000 Pa. What force acts on the cap? Round to the nearest N.
   393 N
   1. $A = \pi (d/2)^2 = \pi \times 0.05^2 = 0.007854$ m²
   2. $F = \Delta P \times A = 50{,}000 \times 0.007854 \approx 393$ N

Unit 9 Test Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. At latitude 25° N, what is the Sun’s elevation angle at solar noon on the June solstice (declination +23.44°)? Round to 0.01°.
   88.44 °
   1. Noon elevation = 90° − latitude + declination
   2. = 90 − 25 + (23.44) = 88.44°

2. A motor takes in 1000 W of electrical power and delivers 621.5 W of mechanical power. What is its efficiency? Round to 0.1%.
   62.2 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 621.5 / 1000 × 100 ≈ 62.2%

3. A shed needs 600 Wh per day. Your site gets 5.5 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.
   145 W
   1. Panel W = daily Wh ÷ (sun hours × derate)
   2. = 600 ÷ (5.5 × 0.75) = 600 ÷ 4.125 ≈ 145 W

4. A shed needs 200 Wh per day. Your site gets 5.0 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.
   53 W
   1. Panel W = daily Wh ÷ (sun hours × derate)
   2. = 200 ÷ (5.0 × 0.75) = 200 ÷ 3.750 ≈ 53 W

5. At latitude 30° N, what is the Sun’s elevation angle at solar noon on an equinox (declination 0°)? Round to 0.01°.
   60.00 °
   1. Noon elevation = 90° − latitude + declination
   2. = 90 − 30 + (0) = 60.00°

6. A motor takes in 240 W of electrical power and delivers 162.7 W of mechanical power. What is its efficiency? Round to 0.1%.
   67.8 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 162.7 / 240 × 100 ≈ 67.8%

7. A shed needs 200 Wh per day. Your site gets 5.5 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.
   48 W
   1. Panel W = daily Wh ÷ (sun hours × derate)
   2. = 200 ÷ (5.5 × 0.75) = 200 ÷ 4.125 ≈ 48 W

8. A shed needs 480 Wh per day. Your site gets 5.0 peak sun hours. With a 0.75 system derate, what panel wattage is needed? Round to the nearest W.
   128 W
   1. Panel W = daily Wh ÷ (sun hours × derate)
   2. = 480 ÷ (5.0 × 0.75) = 480 ÷ 3.750 ≈ 128 W

Midterm Exam Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A motor takes in 120 W of electrical power and delivers 108.5 W of mechanical power. What is its efficiency? Round to 0.1%.
   90.4 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 108.5 / 120 × 100 ≈ 90.4%

2. A motor takes in 500 W of electrical power and delivers 354.6 W of mechanical power. What is its efficiency? Round to 0.1%.
   70.9 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 354.6 / 500 × 100 ≈ 70.9%

3. An amplifier raises a signal from 1 W to 50 W. What is the gain in decibels? Round to 0.1 dB.
   17.0 dB
   1. Gain(dB) = 10 $\log_{10}(P_2 / P_1)$
   2. P_2/P_1 = 50/1 = 50
   3. 10 $\log_{10}(50)$ ≈ 17.0 dB

4. A motor takes in 1000 W of electrical power and delivers 829.8 W of mechanical power. What is its efficiency? Round to 0.1%.
   83.0 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 829.8 / 1000 × 100 ≈ 83.0%

5. A 0.137 kg rocket has an average thrust of 8.0 N for 1.8 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.
   87.5 m/s
   1. Net force = thrust − weight
   2. F_{net} = 8.0 − 0.137 × 9.8 = 6.657 N
   3. a = F_{net}/m = 48.594 m/s²
   4. v = a t = 48.594 × 1.8 ≈ 87.5 m/s

6. A stage has I_{sp} = 380 s, starting mass 436 t and burnout mass 114 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.
   4,996 m/s
   1. Δv = I_{sp} · g_0 · ln(m_0 / m_f)
   2. m_0/m_f = 436/114 = 3.8246
   3. ln(3.8246) = 1.3414
   4. Δv = 380 × 9.8 × 1.3414 ≈ 4,996 m/s

7. At burnout a rocket is moving straight up at 75 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   287 m
   1. At the top, v = 0, so v² = 2 g h and h = v² / (2g)
   2. h = 75² / (2 × 9.8) = 5625 / 19.6 ≈ 287 m

8. At burnout a rocket is moving straight up at 33 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   56 m
   1. At the top, v = 0, so v² = 2 g h and h = v² / (2g)
   2. h = 33² / (2 × 9.8) = 1089 / 19.6 ≈ 56 m

9. A $300 off-grid kit replaces 240 kWh per year of grid power at $0.18 per kWh. What is the simple payback time? Round to 0.1 years.
   6.9 years
   1. Yearly savings = 240 × 0.18 = $43.20
   2. Payback = 300 ÷ 43.20 ≈ 6.9 years

10. A vehicle rounds a curve of radius 23,500 m at 100 m/s. What is its sideways acceleration in g? Round to 0.01 g.
    0.04 g
    1. a = v² / r, then divide by 9.8 to get g
    2. a = 100² / 23500 = 0.426 m/s²
    3. 0.426 ÷ 9.8 ≈ 0.04 g

11. At burnout a rocket is moving straight up at 29 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
    43 m
    1. At the top, v = 0, so $v^2 = 2 g h$ and $h = v^2 / (2g)$
    2. $h = 29^2 / (2 \times 9.8) = 841 / 19.6 \approx 43$ m

12. A vehicle rounds a curve of radius 23,500 m at 10 m/s. What is its sideways acceleration in g? Round to 0.01 g.
    0.00 g
    1. $a = v^2 / r$, then divide by 9.8 to get g
    2. $a = 10^2 / 23500 = 0.004$ m/s²
    3. $0.004 \div 9.8 \approx 0.00$ g

13. Find the circular orbital speed at an altitude of 420 km. Use GM = 3.986 × 10¹⁴ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.
    7,661 m/s
    1. r = 6,371 + 420 = 6,791 km = 6.7910e+06 m
    2. $v = \sqrt{(GM / r)}$
    3. $v = \sqrt{(3.986 \times 10^{14} / 6.7910e+06)} \approx 7{,}661$ m/s

14. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 9.58 AU. Round to 0.01 years.
    29.65 years
    1. T = a^(3/2)
    2. T = 9.58^1.5 ≈ 29.65 years

15. Find the circular orbital speed at an altitude of 35,786 km. Use GM = 3.986 × 10¹⁴ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.
    3,075 m/s
    1. r = 6,371 + 35,786 = 42,157 km = 4.2157e+07 m
    2. $v = \sqrt{(GM / r)}$
    3. $v = \sqrt{(3.986 \times 10^{14} / 4.2157e+07)} \approx 3{,}075$ m/s

16. Find the period of a circular orbit 400 km above Earth, in minutes. Use GM = 3.986 × 10¹⁴ m³/s², R_E = 6,371 km. Round to 0.1 min.
    92.4 min
    1. r = 6,771 km = 6.7710e+06 m
    2. $T = 2\pi \sqrt{(r^3 / GM)}$
    3. T = 5,545 s ÷ 60 ≈ 92.4 min

Final Exam Key

Name _____ Date _____

Young Engineers III: Engineers · Answers with steps

1. A motor takes in 500 W of electrical power and delivers 321.2 W of mechanical power. What is its efficiency? Round to 0.1%.
   64.2 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 321.2 / 500 × 100 ≈ 64.2%

2. A motor takes in 1000 W of electrical power and delivers 635.5 W of mechanical power. What is its efficiency? Round to 0.1%.
   63.5 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 635.5 / 1000 × 100 ≈ 63.5%

3. An amplifier raises a signal from 1 W to 2 W. What is the gain in decibels? Round to 0.1 dB.
   3.0 dB
   1. Gain(dB) = 10 $\log_{10}(P_2 / P_1)$
   2. P_2/P_1 = 2/1 = 2
   3. 10 $\log_{10}(2)$ ≈ 3.0 dB

4. A motor takes in 240 W of electrical power and delivers 224.5 W of mechanical power. What is its efficiency? Round to 0.1%.
   93.5 %
   1. Efficiency = P_{out} / P_{in} × 100
   2. 224.5 / 240 × 100 ≈ 93.5%

5. A 0.447 kg rocket has an average thrust of 13.1 N for 0.8 s. Ignoring drag and mass loss, find its speed at burnout. Round to 0.1 m/s.
   15.6 m/s
   1. Net force = thrust − weight
   2. F_{net} = 13.1 − 0.447 × 9.8 = 8.719 N
   3. a = F_{net}/m = 19.506 m/s²
   4. v = a t = 19.506 × 0.8 ≈ 15.6 m/s

6. A stage has I_{sp} = 311 s, starting mass 89 t and burnout mass 24 t. Find Δv with the rocket equation (g_0 = 9.8 m/s²). Round to the nearest m/s.
   3,994 m/s
   1. Δv = I_{sp} · g_0 · ln(m_0 / m_f)
   2. m_0/m_f = 89/24 = 3.7083
   3. ln(3.7083) = 1.3106
   4. Δv = 311 × 9.8 × 1.3106 ≈ 3,994 m/s

7. At burnout a rocket is moving straight up at 34 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   59 m
   1. At the top, v = 0, so v² = 2 g h and h = v² / (2g)
   2. h = 34² / (2 × 9.8) = 1156 / 19.6 ≈ 59 m

8. At burnout a rocket is moving straight up at 75 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
   287 m
   1. At the top, v = 0, so v² = 2 g h and h = v² / (2g)
   2. h = 75² / (2 × 9.8) = 5625 / 19.6 ≈ 287 m

9. A $600 off-grid kit replaces 120 kWh per year of grid power at $0.15 per kWh. What is the simple payback time? Round to 0.1 years.
   33.3 years
   1. Yearly savings = 120 × 0.15 = $18.00
   2. Payback = 600 ÷ 18.00 ≈ 33.3 years

10. A vehicle rounds a curve of radius 4,800 m at 100 m/s. What is its sideways acceleration in g? Round to 0.01 g.
    0.21 g
    1. a = v² / r, then divide by 9.8 to get g
    2. a = 100² / 4800 = 2.083 m/s²
    3. 2.083 ÷ 9.8 ≈ 0.21 g

11. At burnout a rocket is moving straight up at 119 m/s. Ignoring drag, how much higher will it coast? Use g = 9.8 m/s². Round to the nearest m.
    722 m
    1. At the top, v = 0, so $v^2 = 2\,g\,h$ and $h = v^2 / (2g)$
    2. $h = 119^2 / (2 \times 9.8) = 14161 / 19.6 \approx 722$ m

12. A vehicle rounds a curve of radius 10 m at 340 m/s. What is its sideways acceleration in g? Round to 0.01 g.
    1,179.59 g
    1. $a = v^2 / r$, then divide by 9.8 to get g
    2. $a = 340^2 / 10 = 11560.000$ m/s²
    3. 11560.000 ÷ 9.8 ≈ 1179.59 g

13. Find the circular orbital speed at an altitude of 1,200 km. Use GM = 3.986 × 10¹⁴ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.
    7,256 m/s
    1. r = 6,371 + 1,200 = 7,571 km = 7.5710e+06 m
    2. v = √(GM / r)
    3. v = √(3.986×10¹⁴ / 7.5710e+06) ≈ 7,256 m/s

14. Kepler's third law for the Sun's planets: $T^2 = a^3$ (T in years, a in AU). Find T for a = 2.77 AU. Round to 0.01 years.
    4.61 years
    1. T = a^(3/2)
    2. T = 2.77^1.5 ≈ 4.61 years

15. Find the circular orbital speed at an altitude of 800 km. Use GM = 3.986 × 10¹⁴ m³/s² and Earth's radius 6,371 km. Round to the nearest m/s.
    7,456 m/s
    1. r = 6,371 + 800 = 7,171 km = 7.1710e+06 m
    2. v = √(GM / r)
    3. v = √(3.986×10¹⁴ / 7.1710e+06) ≈ 7,456 m/s

16. Find the period of a circular orbit 20,200 km above Earth, in minutes. Use GM = 3.986 × 10¹⁴ m³/s², R_E = 6,371 km. Round to 0.1 min.
    718.4 min
    1. r = 26,571 km = 2.6571e+07 m
    2. $T = 2\pi \sqrt{(r^3 / GM)}$
    3. T = 43,105 s ÷ 60 ≈ 718.4 min

17. An amplifier raises a signal from 2 W to 40 W. What is the gain in decibels? Round to 0.1 dB.
    13.0 dB
    1. $\text{Gain(dB)} = 10 \log_{10}(P_2 / P_1)$
    2. $P_2/P_1 = 40/2 = 20$
    3. $10 \log_{10}(20) \approx 13.0$ dB

18. Find the free-space path loss for a 11700 MHz signal over 2,000 km: $\text{FSPL(dB)} = 20 \log_{10}(d_{km}) + 20 \log_{10}(f_{MHz}) + 32.44$. Round to 0.1 dB.
    179.8 dB
    1. $20 \log_{10}(2000) = 66.02$
    2. $20 \log_{10}(11700) = 81.36$
    3. FSPL = 66.02 + 81.36 + 32.44 ≈ 179.8 dB

19. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 14.2 MHz. Round to 0.01 m.
    10.07 m
    1. L ≈ 143 ÷ f
    2. L ≈ 143 ÷ 14.2 = 10.0704 ≈ 10.07 m

20. A common starting length for a half-wave wire dipole is L(m) ≈ 143 ÷ f(MHz) (the 0.95 factor for wire is built in). Find the length for 28.4 MHz. Round to 0.01 m.
    5.04 m
    1. L ≈ 143 ÷ f
    2. L ≈ 143 ÷ 28.4 = 5.0352 ≈ 5.04 m

21. A motor delivers 36.2 N·m of torque at 6,000 rpm. What mechanical power is that? Round to the nearest W.
    22,745 W
    1. $\omega = 2\pi\, n / 60 = 2\pi \times 6000 / 60 = 628.319$ rad/s
    2. $P = \tau\, \omega = 36.2 \times 628.319 \approx 22{,}745$ W

22. A motor takes in 1000 W of electrical power and delivers 902.2 W of mechanical power. What is its efficiency? Round to 0.1%.
    90.2 %
    1. Efficiency = $P_{out} / P_{in} \times 100$
    2. $902.2 / 1000 \times 100 \approx 90.2\%$

23. You need about 48 V nominal and at least 15 Ah from 3.6 V cells of 5.0 Ah each. How many cells in total (series × parallel)?
    42 cells
    1. Series count: $48 \div 3.6 = 13.33 \rightarrow$ round up to 14S
    2. Parallel count: $15 \div 5.0 = 3.00 \rightarrow$ round up to 3P
    3. Total = $14 \times 3 = 42$ cells (14S3P, 50.4 V nominal)

24. A motor delivers 29.3 N·m of torque at 3,000 rpm. What mechanical power is that? Round to the nearest W.
    9,205 W
    1. $\omega = 2\pi\, n / 60 = 2\pi \times 3000 / 60 = 314.159$ rad/s
    2. $P = \tau\, \omega = 29.3 \times 314.159 \approx 9{,}205$ W