FLL ROBOT GAME · BIOGLOW 2026-27

Learn Python. Drive the robot. Win the missions.

The Habitat Hackers' bootcamp for Pybricks and SPIKE Prime — built from the real code our team ran last season, bugs and all. Now with this year's robot, HHHub1.

```python
# your first mission starts here
await robot.straight(410)
await robot.turn(-84)
await larm.run_target(speed=500, target_angle=90)
print("Robot initialized successfully!")
```

HABITAT HACKERS · TEAM #71494

Python + Pybricks Bootcamp · 3rd Edition

Mission Map

Twelve parts, four appendices, one goal: by the end you can read, fix, and write every program on our robot.

PART 1

Python from Zero

1

Here's our deal with you: we teach Python using the actual programs our team ran at last year's tournament. Not toy examples. The real thing, including the bugs we shipped. By the end of this part you can read most of last season's code.

Python is a language for giving computers (and robots) instructions. A program is just a list of instructions the computer follows **top to bottom, one line at a time**. That's it. Everything else in this book is detail.

> **CORE CONCEPT · THE GOLDEN RULE OF CODING**
>
> A computer does **exactly** what you tell it — not what you *meant*. That sounds annoying, but it's actually great news: if something goes wrong, it's not magic and it's not broken. You just have to find the one instruction that didn't say what you thought. That hunt *is* coding.

1.1 Your first instruction: `print()`

```
print("Robot initialized successfully!")
```

`print()` makes the robot send a message to your laptop screen. Whatever is inside the quotes gets shown exactly as written. And here's a fun fact: that line above is the *last line of our real setup.py*. Our robot literally says hello every time it wakes up.

Three things to notice:

- `print` is a **function** — a named action the computer already knows how to do.
- The parentheses `()` hold the **input** you give the function.
- `"Robot initialized successfully!"` is a **string** — text wrapped in quotes.

1.2 Comments: notes for humans

Any line starting with `#` is invisible to the robot. It's a note for teammates.

```
# left and right drive motors     <-- robot skips this line
ldrive = Motor(port=Port.A)       # <-- robot runs this part, skips this note
```

Our code is full of comments like `# Hit the forge` and `# Speed up and go back home`. Good comments explain *why*, so a teammate can follow the plan. So can you, three weeks from now, at 9pm the night before a tournament, wondering what past-you was thinking.

1.3 Variables: giving things a name

A **variable** is a name that stores a value – think of it as a labeled box you can put something in and open later. You create one with `=` (read it as "gets", not "equals"):

```
timer = StopWatch()        # timer now means "the stopwatch"
attachment_color = sensor.color()   # store whatever color the sensor sees
current_voltage = hub.battery.voltage()
```

After that, anywhere you write `timer`, Python knows you mean that stopwatch.

> **CORE CONCEPT · NAMING RULES**
>
> Variable names can use letters, numbers, and underscores. They can't start with a number. And capitalization matters: `Timer` and `timer` are two different names, and Python will not warn you if you mix them up.

> **CORE CONCEPT · WHY VARIABLES MATTER**
>
> Imagine you typed the speed `500` in twenty places, then wanted to slow down. You'd have to change it twenty times – and you'd miss one. With a variable, you change it in **one** place and everything updates. Name things once, use them everywhere.

1.4 Numbers (and True/False)

Python understands numbers without quotes, and it does math for you:

```
robot.straight(120)     # 120 is a number: drive 120 millimeters
robot.straight(-165)    # negative number: drive BACKWARD 165 mm
await robot.straight(-67*3)   # Python computes -201 so you don't have to
```

`*` means multiply, `/` divide, `+` add, `-` subtract. That last line is real code from Run 6. Somebody needed three backwards nudges of 67 mm and let Python do the arithmetic. Good instinct – copy it.

(Spot that `await` out front? Ignore it for now. It's how we tell the robot "finish this before moving on," and Part 6 explains it properly. Nearly every robot command in this book wears one – just copy it along for the ride. One thing to know early: `await` only works *inside* the `async def run():` functions our run files use. If you're typing a quick two-line test directly into the editor, leave `await` off – the command still waits on its own. Same deal with names like `robot`, `timer`, and `larm`: they get built in Part 2. For now, just follow what each line does.)

One more kind of value you'll meet: **True / False** (called a *boolean*) – the answer to a yes/no question. `robot.use_gyro(True)` and `while True:` both use one.

1.5 f-strings: mixing text and values

Put an `f` before the quotes and wrap variables in `{curly braces}` to build messages with live values inside:

```
print(f"RUN 3: ", timer.time())            # works, but clunky
print(f"Run 2 Complete! Time: {timer.time()/1000} seconds")   # nicer!
```

The second line, straight from Run 2, grabs the stopwatch time, divides by 1000 to convert milliseconds to seconds, and drops the result right into the sentence.

1.6 Functions: making your own named actions

You already used functions other people wrote, like `print`. You can **define** your own with `def`:

```
def main():
    timer = StopWatch()
    print("Menu is starting")
```

- `def main():` means "I'm defining a function named main."
- Everything **indented** underneath belongs to the function.
- Defining a function doesn't run it! You run it later by writing `main()`.

> **WATCH OUT · INDENTATION IS THE GRAMMAR**
>
> In Python, indentation is not decoration. Four spaces at the start of a line tells Python "this line is inside the thing above it." Get the indentation wrong and the program breaks, or worse, runs but does the wrong thing. When your code acts weird, check the indentation first.

> **CORE CONCEPT · FUNCTIONS = YOUR MISSION TOOLBOX**
>
> Later you'll write functions like `run()` for each mission. Each one packs a whole routine into a single name. That's how a big, scary program becomes a short, tidy list of friendly names.

1.7 Arguments: giving functions information

Functions can take inputs, called **arguments**:

```
robot.straight(410)                          # one argument: distance
robot.arc(radius=-40, distance=33)           # named (keyword) arguments
larm.run_angle(speed=-200, rotation_angle=200, then=Stop.HOLD)
```

Named arguments like `radius=-40` earn their keystrokes because you can *read* what each number means. `robot.arc(-40, 33)` would work, but quick — which number is which? Our team's style is to name arguments on anything with more than one number. Keep doing that.

1.8 Making decisions: if / elif / else

```
if attachment_color == Color.WHITE:
    print("White Attachment")
    menu = (1,2,3,4,5,6,7,8,9)
elif attachment_color == Color.YELLOW:
    print("Yellow Attachment")
    menu = (3,4,5,6,7,8,9,1,2)
else:
    print("Unable to detect colored attachment")
    menu = (1,2,3,4,5,6,7,8,9)
```

This is straight from our master program. Read it out loud: "**If** the attachment color equals white, do this. **Or else if** it's yellow, do that. **Otherwise**, do the fallback." Python checks each condition from the top and runs the first block that matches.

> **WATCH OUT · THE #1 BEGINNER BUG**
>
> `==` (two equals signs) asks a question: "are these equal?" A single `=` stores a value. Write `if color = Color.WHITE:` and Python refuses to run. Every programmer on Earth has made this typo. You will too. Now you'll know why the robot is sulking.

1.9 Repeating things: loops

A **for loop** repeats a known number of times. This is from Run 3, the Silo mission, where the arm has to pump three times:

```
for i in range(3):
    await rarm.run_angle(speed=1000, rotation_angle=205, then=Stop.HOLD)
    await rarm.run_angle(speed=-1000, rotation_angle=205, then=Stop.HOLD)
```

`range(3)` produces 0, 1, 2 — so the indented lines run three times. Arm down, arm up, three times. Without the loop we'd copy-paste those two lines three times, and then when you re-tune the angle at practice, you'd have to fix it in three places and you'd forget one. (Foreshadowing: Part 9 is full of bugs born exactly this way.)

A **while loop** repeats as long as something is true. From our main menu:

```
while True:
    selected = hub_menu(*menu)
    ...
```

`while True:` means "repeat forever" — until something inside stops it, like `break`, which jumps out of the loop immediately.

TRY THIS · BE THE COMPUTER

No robot needed — just paper. Write down exactly what this prints, line by line, then check with a teammate:

```
for i in range(3):
    print(f"lap {i}")
```

Got *lap 0, lap 1, lap 2*? You just did what the hub does — followed the instructions top to bottom, no imagination allowed. Predicting code before running it is the single most useful habit in this book.

1.10 Imports: borrowing code from other files

Nobody writes everything from scratch. `import` pulls in code someone else already wrote — including past-you:

```
from pybricks.hubs import PrimeHub     # get PrimeHub from the pybricks library
from setup import hub, robot, larm, rarm, timer   # get OUR robot from OUR setup.py
import setup                           # run the whole setup file
```

CORE CONCEPT · BUILD ONCE, IMPORT EVERYWHERE

That middle line is the secret of how our team's code is organized: **setup.py builds the robot once**, and every run file imports the finished robot. No copy-pasting motor setup into nine files. When the new robot's wheels change, we edit one file and all nine runs are fixed.

1.11 Tuples: a bundle of values

```
menu = (3,4,5,6,7,8,9,1,2)
```

Parentheses with commas make a **tuple** — an ordered bundle of values. We use one to hold the menu order. The `*` in `hub_menu(*menu)` "unpacks" the bundle, handing each number to `hub_menu` as a separate argument. You'll meet `*`-unpacking again in Part 10, where it gets even more useful.

PART 2

Meet Pybricks and Our Robot

2

Time to meet the machine. In this part you'll learn what Pybricks is, write your very first hub program, and then we'll walk through our real setup.py line by line — because every single run imports it. Understand this one file and you understand the foundation of everything.

Pybricks is the software we install on the SPIKE Prime hub so we can program it in Python. (Technically it's MicroPython, a small Python that fits on the hub — for everything in this book, it's just Python.) You write code at **code.pybricks.com**, it travels to the hub over Bluetooth, and `print()` messages come back to your screen while the robot moves.

BOOKMARK THESE

docs.pybricks.com is the official API reference — when this book and your memory disagree, the docs win. **pybricks.com/learn** has interactive lessons that make great homework between practices.

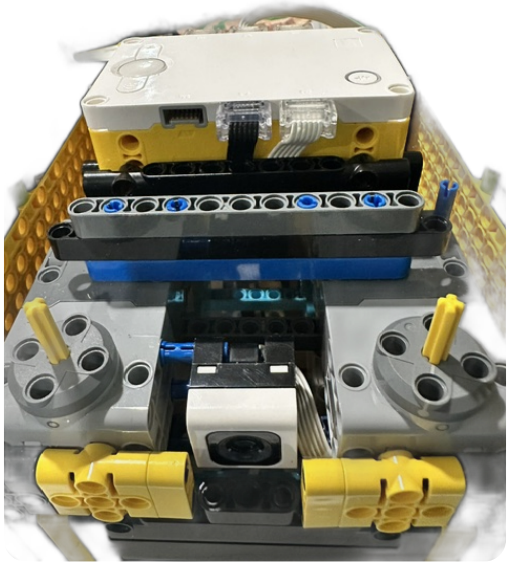
Our robot — the machine every program in this book drives

The SPIKE Prime hub — brain, display, buttons, gyro, and lettered ports

2.1 The hub and the ports

The hub is the robot's brain: a small computer with a 5×5 light display, buttons, a gyro sensor inside, and lettered ports around the edges. Everything plugs into those ports, and the letters matter — code says "the motor on Port A," so if someone rebuilds the robot and swaps two cables, the robot turns left when it should go right. On our robot:

Port	What's plugged in	Name in code
A	Left drive wheel motor	`ldrive`
B	Right drive wheel motor	`rdrive`
C	Left attachment arm motor	`larm`
D	Right attachment arm motor	`rarm`
(sensor port)	Color sensor (reads attachment color)	`sensor`



The hub and ports up close — follow each cable to its letter

2.2 Hello, hub: your first program

Before the big setup file, make the hub glow, smile, and beep — three lines of pure joy:

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Color, Icon

hub = PrimeHub()

hub.light.on(Color.GREEN)      # glow green
hub.display.icon(Icon.HAPPY)   # show a smiley
hub.speaker.beep()             # beep!
```

See the dots? `hub.light.on()` reads like ownership: the hub's light, turned on. Each dot zooms into a smaller part — like "my backpack's front pocket's zipper."

TRY THIS

Swap `Color.GREEN` for `Color.RED`, and `Icon.HAPPY` for `Icon.HEART`. Then try `hub.display.number(71)`. What changes?

WATCH OUT · THE CENTER BUTTON IS THE STOP BUTTON

In Pybricks, pressing the hub's center button **stops your running program**. So never write code that waits for a center-button press — your program will die before it ever sees it. Wait for the left or right button instead (`Button.LEFT in hub.buttons.pressed()`). This exact mistake was a real bug in one of our early test programs.

2.3 setup.py — building the robot, line by line

This is last year's real setup file with a tour-guide commentary. **Every run imports this file**, so understand it once and you understand the foundation of everything.

```
from pybricks.hubs import PrimeHub
from pybricks.pupdevices import Motor
from pybricks.parameters import Direction, Port, Stop
from pybricks.robotics import DriveBase
from pybricks.tools import StopWatch
```

Borrow the building blocks from the Pybricks library: the hub type, the motor type, some named constants (`Port.A` , `Stop.HOLD` ...), the DriveBase (two motors working as one vehicle), and a stopwatch.

```
hub = PrimeHub()
timer = StopWatch()
```

Create the hub object and a stopwatch, and give them names.

```
ldrive = Motor(port=Port.A, positive_direction=Direction.COUNTERCLOCKWISE)
rdrive = Motor(port=Port.B, positive_direction=Direction.CLOCKWISE)
```

Create the two drive motors. Why is one counterclockwise? The motors are mounted mirror-image on either side of the robot. Telling Python which spin direction counts as "positive" means "positive = robot goes forward" for both wheels.

The SPIKE Prime angular motor — the muscle on every port

```
robot = DriveBase(left_motor=ldrive, right_motor=rdrive,
                  wheel_diameter=56, axle_track=120)
```

The DriveBase is the smartest object in Pybricks. Give it both motors plus two measurements — wheel diameter (56 mm) and the distance between the wheels (120 mm) — and it can do the math to "drive exactly 300 mm" or "turn exactly 90 degrees." If those two numbers are wrong, every distance and every turn will be wrong. Part 3 shows you how to measure them properly on the new robot.

```
robot.use_gyro(True)
robot.reset()
robot.settings(900, 600, 600, 400)
```

- `use_gyro(True)` — use the hub's built-in gyroscope for straighter driving and more accurate turns (instead of only trusting wheel rotation, which slips on the mat).
- `reset()` — set the distance/angle counters to zero.
- `settings(...)` — four numbers, in this exact order: **straight speed (mm/s), straight acceleration, turn rate (deg/s), turn acceleration**. You'll see `robot.settings(...)` sprinkled all through the runs to go fast on open mat and slow down for precision moves.

```
larm = Motor(port=Port.C, gears=[12, 20, 12, 20])
rarm = Motor(port=Port.D, gears=[12, 20, 12, 20])

larm.control.limits(speed=1000, acceleration=1000, torque=1000)
rarm.control.limits(speed=1000, acceleration=1000, torque=1000)
```

The two attachment arm motors. `gears=[12, 20, 12, 20]` tells Pybricks the gear train between motor and arm (a 12-tooth driving a 20-tooth, twice), so when we say "rotate the arm 100 degrees" Pybricks converts that to the right amount of *motor* rotation automatically. `control.limits` caps how fast/hard the arm motor is allowed to work.

```
current_voltage = hub.battery.voltage()
print("Robot initialized successfully!")
```

Read the battery voltage and announce we're alive. (Spoiler for Part 10: we read the voltage into a variable... and then never use it. Battery level strongly affects robot consistency — we should print it!)

2.4 Working with files in the Pybricks editor

Our code lives in **many files** – `setup.py`, `run1.py` through `run9.py`, `main.py` – and they import each other. Here's how that works at **code.pybricks.com**:

1. 1. **Create a file:** click the **+** (new file) button in the file list on the left and type the name, like `setup.py`. The `.py` ending matters.
2. 2. **Run a file:** open it so it's the active tab, then press the **Run** button (or F5). Pybricks sends *that* file to the hub – plus any files it imports.
3. 3. **Import between files:** `from setup import robot` works as long as `setup.py` sits in the same file list. No folders, no paths – just the name without `.py`.
4. 4. **Name files exactly.** `import run1` looks for `run1.py` – capitalization and spelling must match, or you get `ImportError: no module named 'run1'`. (Ask us how we know.)

> **PRO TIP · TEST ONE RUN, THEN THE MENU**
>
> During practice, open `run5.py` itself and press Run – the `if __name__ == '__main__':` trick (Part 6.5) launches just that run. On competition day, open `main.py` and press Run once – the menu takes over from there.

PART 3

This Year's Robot — Build HHHub1's setup.py

Last year's code drives last year's robot. This year's robot — hub name **HHHub1** — needs its own setup.py, and this part is where *you* build it. The skeleton is the same; the measurements and strategy are new.

3.1 This year's port map

Port	What's plugged in	Use it like
A	Left drive wheel	`Motor(Port.A, ...)`
B	Right drive wheel	`Motor(Port.B, ...)`
C	Left liftarm / attachment	`Motor(Port.C)`
D	Right liftarm / attachment	`Motor(Port.D)`
E	Color sensor (attachment ID)	`ColorSensor(Port.E)`
F	(empty)	–

CORE CONCEPT · TWO ATTACHMENTS IN ONE

HHHub1 carries two liftarms, each driven by its own motor (C and D). One mounted "attachment" is really **two attachments in one** — each liftarm does its own job, so a single mount can finish two missions before you ever return to base. Fewer swaps, more points. This is our team's signature strategy.

3.2 Measure wheel_diameter (the easy one)

It's the height of your wheel in millimeters. LEGO prints it right on the tire! Look on the rubber for tiny writing like `56 x 14` — the first number is the diameter: 56 mm. No writing? Measure across the middle of the wheel with a ruler.

3.3 Measure axle_track (the sneaky one)

It's the distance between the **middles** of the two wheels — not the insides, not the outsides, the *centers*. Measure from the center of the left tire straight across to the center of the right tire. A LEGO trick: count studs between wheel centers and multiply by 8, because one stud = 8 mm.

3.4 Now test it – the drive-and-measure check

Numbers from a ruler get you close. Real robots have squishy tires and tiny wobbles, so we let the **robot itself** tell us the truth:

```
# Calibration test 1: does 500 mm really mean 500 mm?
from setup import robot
robot.straight(500)
# Now measure with a tape measure how far it ACTUALLY went.
```

> **WATCH OUT · NO `AWAIT` IN QUICK TESTS**
>
> Notice there's no `await` here. `await` only works inside an `async def` function (Part 6) – in a quick top-level test like this, writing `await` gives a `SyntaxError`. Just leave it off: the command still finishes before the next line runs.

- Drove **too far** (say 510 mm)? Your real wheels are bigger than you told it. Nudge `wheel_diameter` up a tiny bit.
- Drove **too short**? Nudge `wheel_diameter` down.

```
# Calibration test 2: does a 360 spin end facing the same way?
robot.turn(360)
# Put a piece of tape on the front so you can see exactly where it points.
```

- Turned **too little**? Make `axle_track` bigger.
- Turned **too much**? Make `axle_track` smaller.

> **PRO TIP · CHANGE A LITTLE, TEST AGAIN**
>
> Adjust by 1–2 mm at a time and re-run the test. Two or three rounds usually nails it. Fix `wheel_diameter` first (with the straight test), *then* tune `axle_track` (with the turn test) – the turn math uses both.

3.5 Named speed profiles

Last year, mystery tuples like `robot.settings(970, 8000, 900, 2000)` appear dozens of times. Which one is "precision mode"? Nobody remembers. This year we name them (you'll see them again in Part 10):

```
# Speed profiles: (straight_speed, straight_accel, turn_rate, turn_accel)
PRECISE = (300, 300, 200, 200)    # slow + gentle: aligning on mission models
NORMAL  = (700, 600, 500, 400)    # everyday driving
FAST    = (970, 6000, 800, 4000)  # open mat / rushing home
```

WINNING MOVE · SLOW IS SMOOTH, SMOOTH IS FAST

A robot that zooms and skids loses more time redoing missions than it saves driving. Champions pick a speed that lands **every** time, then only speed up the parts that stay accurate.

3.6 Put it together: this year's setup.py

Here's the starting point — same shape as last year's, with this year's facts and the profiles built in. The `???` marks are yours to measure:

```python
# setup.py - HHHub1 (BIOGLOW 2026-27)
from pybricks.hubs import PrimeHub
from pybricks.pupdevices import Motor, ColorSensor
from pybricks.parameters import Direction, Port, Stop
from pybricks.robotics import DriveBase
from pybricks.tools import StopWatch

hub = PrimeHub()
timer = StopWatch()

ldrive = Motor(port=Port.A, positive_direction=Direction.COUNTERCLOCKWISE)
rdrive = Motor(port=Port.B, positive_direction=Direction.CLOCKWISE)

# MEASURE these (3.2-3.4), then calibrate. Wrong numbers = every move wrong.
robot = DriveBase(left_motor=ldrive, right_motor=rdrive,
                  wheel_diameter=56, axle_track=112)   # <-- ??? verify!

robot.use_gyro(True)
robot.reset()

# Speed profiles (3.5)
PRECISE = (300, 300, 200, 200)
NORMAL  = (700, 600, 500, 400)
FAST    = (970, 6000, 800, 4000)
robot.settings(*NORMAL)

larm = Motor(port=Port.C)    # add gears=[...] once the liftarm gearing is final
rarm = Motor(port=Port.D)

sensor = ColorSensor(Port.E)

voltage = hub.battery.voltage()   # millivolts
print(f"HHHub1 initialized. Battery: {voltage} mV")
if voltage < 7600:
    print("*** LOW BATTERY - runs may be inconsistent! Charge or swap. ***")
```

Notice it already includes two Part 10 upgrades (named profiles, the battery warning) – this year we start clean.

PART 4

Driving the Robot

4

All distances are **millimeters**, all angles are **degrees**. The sign conventions (from the official docs) are:

- **Positive distance = forward. Negative = backward.**
- **Positive angle = turn right (clockwise from above). Negative = left.**

4.1 The three core moves

```
await robot.straight(410)     # forward 410 mm
await robot.straight(-135)    # backward 135 mm
await robot.turn(90)          # spin in place 90° right
await robot.turn(-84)         # spin in place 84° left
await robot.arc(radius=-40, distance=33)   # curved drive
```

(That `await` word — "do this and wait until it finishes" — gets fully explained in Part 6. For now just include it.)

4.2 Arcs: driving in curves

`robot.arc(...)` drives along part of a circle. You pick:

- `radius` — the size of the circle. **Positive radius = circle is to the robot's right** (curving right); **negative = circle to the left** (curving left). Small radius = tight curve, big radius = gentle curve.
- Then how far along the circle: either `distance=...` (mm along the curved path; negative drives the arc in reverse) or `angle=...` (how many degrees of the circle to sweep).

Real examples from our runs:

```
robot.arc(radius=-900, distance=670)    # Run 1: gentle left sweep out of base, 670 mm
await robot.arc(radius=-20, distance=16)  # Run 1: tiny nudge to "Hit who lived here"
await robot.arc(radius=-2000, distance=-425)  # Run 2: nearly-straight arc BACKWARD to base
await robot.arc(radius=65, angle=86)    # Run 7: tight right arc sweeping 86°
```

Why arcs instead of turn-then-straight? **One smooth arc is faster and often more repeatable than stopping to turn.** Watch our Run 9: it's basically two arcs and a turn — that's the whole run.

WATCH OUT · TWO ARC() RULES

Give **either** `angle` **or** `distance` (not both, not neither), and the radius can't be zero — otherwise Python complains with a `ValueError`.

4.3 Changing speed mid-run with settings()

```
robot.settings(970, 400, 600, 400)     # careful launch
...
robot.settings(970, 8000, 900, 2000)   # cranked acceleration to rush home
```

Slow and gentle near mission models (precision), fast and violent on the way home (the clock is running!). You'll see this pattern in every run. (This year: `robot.settings(*PRECISE)` and `robot.settings(*FAST)` — same idea, readable names.)

4.4 Flowing moves with then=Stop.NONE

By default the robot fully stops after each command (jerky!). `then=Stop.NONE` keeps the speed rolling into the next move — use it on every move *except the last*:

```
from pybricks.parameters import Stop

await robot.straight(400, then=Stop.NONE)  # keep rolling...
await robot.arc(radius=150, angle=90)      # ...glide into the curve, then stop
```

Chained with arcs, this is how a run stops looking like a robot doing homework and starts looking like a racing line.

4.5 The gyro trick at the end of runs

Almost every run ends with:

```
robot.use_gyro(False)
```

Why? With the gyro on, the DriveBase actively fights to hold its heading **even after the run ends** — if a kid picks the robot up, the wheels spin trying to "correct." Turning the gyro off makes the robot relax so it can be carried back to base safely. Then the next run's start (or setup) turns it back on. Neat trick — keep it.

4.6 Stop behaviors: HOLD, BRAKE, COAST

Many commands take `then=Stop.SOMETHING` — what should the motor do *after* finishing?

- `Stop.HOLD` — actively hold position (fights back if pushed). Best when the arm must stay put under load.
- `Stop.BRAKE` — passively resist.
- `Stop.COAST` — go limp. Used in Run 5's grabber so the claw can settle around the artifact without fighting it.
- `Stop.NONE` — don't even slow down; flow into the next command (4.4).

TRY THIS · THE SQUARE TEST

Program the robot to drive a 300 mm square: four straights, four turns, using a `for` loop. When it's done, the robot should be exactly where it started, facing the way it started. If it isn't — your `axle_track` needs the Part 3 calibration. (Worked answer in Appendix C. Reminder: in a quick test like this, skip the `await`s — they only belong inside `async def` run files.)

4.7 Lines and walls: fixing position mid-run

Wheels slip a tiny bit on every move, and tiny errors add up over a long run. The cure is to **re-check position against something real on the field** — a black line on the mat, or the border wall. Champions do this constantly.

Driving to a line. Point a color sensor at the mat and read `sensor.reflection()` — a brightness number from 0 (black) to 100 (white). Drive slowly until the number drops, and you know *exactly* where you are:

```
robot.drive(150, 0)                    # roll forward slowly, no turning
while sensor.reflection() > 25:        # white mat reads high, black line reads low
    wait(10)                           # check about 100 times per second
robot.stop()                           # front of the sensor is ON the line — a known spot!
```

`robot.drive(speed, turn_rate)` starts the robot moving and *keeps* it moving until you say stop — that's what lets the `while` loop watch the sensor mid-drive. Measure your own numbers first: `print(sensor.reflection())` over mat and over line, then pick a threshold in between.

Squaring on a wall. Even simpler — no sensor at all. Back up into the border wall a little farther than the distance to it; the wall stops both wheels, and now the robot is perfectly straight with a known position. It feels like cheating. It's not — it's engineering:

```
robot.settings(*PRECISE)     # gently!
robot.straight(-150)         # the wall stops you square
robot.reset()                # zero the counters at this trusted spot
```

CORE CONCEPT · LANDMARKS BEAT DEAD RECKONING

Driving by distances alone is called *dead reckoning* — every move adds a little error. A line-stop or wall-square **erases** the accumulated error and starts fresh. One landmark check in the middle of a long run is often the difference between 7/10 and 10/10 consistency (Part 11).

Hardware note for HHHub1: our color sensor on Port E currently faces the attachment (for the Part 7 menu), and Port F is free. If a mission run needs line stops, add a second, mat-facing color sensor on F — `line_sensor = ColorSensor(Port.F)` in setup.py — or build the season's attachments so the E sensor can see the mat.

PART 5

Attachment Arms

5

Drive motors move the robot; `larm`/`rarm` move whatever attachment is bolted on.

5.1 run_angle – move an exact amount

```
await rarm.run_angle(speed=-970, rotation_angle=110, then=Stop.HOLD)
```

"Turn the right arm motor at speed 970 in the negative direction, through 110 degrees, then hold." Every run file has a comment block at the top reminding us which direction is which, like:

```
"""
- larm "+" down, "-" up
- rarm "+" down, "-" up
"""
```

(Triple quotes make a multi-line string – used here as a big comment. Also note Run 6's docstring says rarm is REVERSED compared to the others: `rarm "–" down, "+" up`. Attachment gearing can flip directions – always test with small angles first!)

5.2 run_until_stalled – push until it can't

```
larm.run_until_stalled(-970, then=Stop.HOLD, duty_limit=28)
```

Run the arm until it physically **stalls** (hits its mechanical limit), then hold. `duty_limit=28` caps the motor at 28% power so it presses *gently* instead of grinding gears or lifting the robot.

Why this is brilliant for FLL: it's self-calibrating. No matter where the arm started, `run_until_stalled` drives it to a known physical position (all the way up / all the way down). Our runs use it constantly to "zero" the arms at the start:

```
# Run 5: leave base while zeroing BOTH arms simultaneously
await multitask(
    robot.arc(radius=740, angle=65),
    rarm.run_until_stalled(speed=-970, duty_limit=20, then=Stop.HOLD),
    larm.run_until_stalled(speed=970, duty_limit=15, then=Stop.COAST)
)
larm.reset_angle(0)   # define this stalled position as "angle zero"
```

`reset_angle(0)` after stalling gives you a trustworthy reference point for every arm move that follows.

5.3 run_target – this year's accuracy upgrade

Last year's runs move arms with `run_angle` ("turn 110 more degrees from wherever you are"). That works – but small errors pile up, because each move starts from wherever the last one actually ended. Once you've zeroed an arm (5.2), there's a better tool:

```
larm.run_until_stalled(-200, then=Stop.HOLD, duty_limit=30)
larm.reset_angle(0)              # this spot is now "zero"

await larm.run_target(speed=500, target_angle=120)   # go TO position 120
await larm.run_target(speed=500, target_angle=0)     # return exactly home
```

CORE CONCEPT · RUN_ANGLE VS RUN_TARGET

`run_angle` means "turn 110 more from here" – like walking 20 steps from wherever you happen to stand. `run_target` means "go to the 120 *spot*" – like an exact street address. After a stall-zero, **prefer run_target** for anything that must land the same way every time. Zero once, then every position is absolute.

PART 6

6 Doing Two Things at Once (async, await, multitask)

This is the most advanced idea in our codebase — and our biggest competitive weapon. FLL runs are 2.5 minutes total. A robot that raises its arm *while driving* beats a robot that drives, stops, then raises its arm.

6.1 The problem

Normally Python does one thing at a time. `robot.straight(500)` would block everything until the drive finishes.

6.2 The Pybricks solution: three new words

Pybricks supports **cooperative multitasking** (see the official docs page "tools — multitask"). Three new words, each with a friendly translation:

- `async def run():` — "this function knows how to share time." Defining a function with `async` makes it a **coroutine**: a function that can be paused and resumed, so other tasks can run during its waits.
- `await something` — "finish this step before the next line" — but while waiting, *other* tasks are allowed to run.
- `multitask(a, b, c)` — "run these together" — several awaitable things **at the same time**, finishing when all are done.
- `run_task(run())` — the launcher: runs a coroutine from start to finish. This is how a normal (non-async) program kicks off the async world.

6.3 Reading a real multitask

From Run 1's launch:

```
await multitask(
    larm.run_until_stalled(-970, then=Stop.HOLD, duty_limit=28),
    rarm.run_until_stalled(670, then=Stop.HOLD, duty_limit=20),
    robot.arc(radius=-900, distance=670)
)
```

Translation: **while** arcing out of the base, **simultaneously** zero the left arm upward and the right arm downward. Three actions, one time slot. The program continues to the next line only when all three finish.

6.4 The one rule of multitask

You can't ask the same motor to do two things at once (just like you can't walk forward and backward at the same time). Multitask different *devices*: drive base + left arm + right arm = fine. Two commands to `larm` in one multitask = broken.

6.5 The full skeleton of every run file

```
from pybricks.parameters import Stop
from pybricks.tools import multitask, wait, run_task
from setup import hub, robot, larm, rarm, timer

async def run():
    print("***** Starting Run X *****")
    hub.display.number(X)          # show run number on hub display
    robot.settings(970, 400, 600, 400)

    # ... mission moves ...

    robot.use_gyro(False)          # relax so we can pick the robot up

if __name__ == '__main__':
    run_task(run())
```

That last `if` is a classic Python idiom: `__name__` equals `'__main__'` **only when this file is run directly** (not when imported by the menu program). So during practice you can run `run5.py` by itself and it launches itself with `run_task(run())` – but on competition day, the master menu imports it and stays in control. Two behaviors, one file. Very slick.

PART 7

The Master Program (Color Menu)

7

On competition day we don't want to fumble through the hub's program list. Our master program:

1. 1. **Reads the color of the attachment currently mounted** with the color sensor.
2. 2. **Reorders the menu** so the run that uses that attachment is first.
3. 3. Shows a **number menu on the hub display** – kid presses buttons to pick, presses center to launch.

The color sensor – it reads which attachment is mounted

7.1 Reading the color

```
sensor.detectable_colors([Color.WHITE, Color.NONE, Color.BLUE,
                          Color.GREEN, Color.RED, Color.MAGENTA,
                          Color.YELLOW])
attachment_color = sensor.color()
```

`detectable_colors` narrows the sensor's guesses to only the colors we actually use – hugely improves reliability.

PRO TIP · MEASURE YOUR COLORS FIRST

Gym lighting is different from home. Before competition, hold each attachment tag to the sensor and `print(sensor.color())` to make sure the robot reads it correctly. Adjust tags until every one is rock-solid.

7.2 The menu

```
selected = hub_menu(*menu)
```

`hub_menu` (from `pybricks.tools`) displays each item on the hub's light matrix; left/right buttons cycle, center button selects. It returns the chosen item into `selected`.

7.3 Launching a run with import

```
if selected == 1:
    import run1
    run_task(run1.run())
    print(f"RUN 1: ", timer.time())
    break
```

`import run1` loads the file `run1.py`; `run1.run()` creates its coroutine; `run_task` executes it. Then `break` exits the `while True` loop... which is actually a problem we'll fix in Part 10!

PART 8

Timing Your Runs

8

Every run tracks time because **FLL is a race against a 2:30 clock**.

```
timer = StopWatch()      # created once in setup.py
timer.reset()            # zero it at the start of a run
print(f"Heavy lift completed in {timer.time()}")           # milliseconds!
print(f"Run 2 Complete! Time: {timer.time()/1000} seconds") # seconds — nicer
```

`timer.time()` returns **milliseconds**. Notice our old code is inconsistent — some prints show raw milliseconds, some divide by 1000. Part 10 fixes that.

During practice, these printouts tell you exactly where a run is slow: if "Forge — completed in 41000" but the whole run budget is 30 seconds, you know which segment to attack.

PART 9

Bug Hunt! Real Bugs in Last Year's Code

9

Time to level up from *reading* code to *reviewing* it. All of these are genuinely in the binder. Try to spot each one yourself before reading the answer.

Bug 1: The run that lies about its name

Open **Run 9** (Site Marking — Last Flag). Look at what it prints and displays:

```
# Run 7: deliver the last flag (M15)
print("***** Starting Run 7 *****")
hub.display.number(8)
...
print(f"Run 7 Complete! in {timer.time()} seconds")
```

This is **Run 9**, but it says Run 7 in the comment and prints, and shows **8** on the display. Run 7's file has the same disease (its comment says `# Run 5`). Why? **Copy-paste.** Someone duplicated an old file and forgot to update all the places the run number appears. On competition day, a kid glancing at the hub display could launch the wrong run.

Lesson: when a fact appears in 4 places, someone will forget to update 3 of them. Fix: store it once — `RUN_NUMBER = 9` at the top — and use the variable everywhere. (Full fix in Part 10.)

Bug 2: The phantom function

End of **Run 4**:

```
if __name__ == '__main__':
    run_task(gray())
    run_task(run())
```

There's no `gray()` defined anywhere in the file — it was probably split into `run()` during cleanup. Run this file directly and it **crashes with** `NameError: name 'gray' is not defined` before the robot moves an inch. It only escaped notice because on competition day the menu imports the file, and the `if __name__` block never executes.

Lesson: test files the same way they'll actually be used — but also test them standalone, because that's how you'll debug at practice.

Bug 3: The menu that quits after one run

The master program's `while True:` loop has a `break` after **every** run. So: pick a run, it executes, `break` exits the loop, `main()` ends, program over. To do the next mission you must restart the whole master program (and Pybricks import caching means a simple "remove the break" isn't quite enough — see Part 10.4 for the right redesign).

Bug 4: Timer says "seconds," shows milliseconds

Run 9 prints `f"Run 7 Complete! in {timer.time()} seconds"` — but `timer.time()` is milliseconds. "Complete in 24831 seconds" would be almost 7 hours. Harmless, but sloppy — and it makes practice timing data confusing.

Bug 5 (style): stray trailing commas

A few lines end with a lone comma:

```
await robot.turn(20),
await larm.run_angle(speed=350, rotation_angle=160, then=Stop.HOLD),
```

These happen when a line is copy-pasted **out of** a `multitask(...)` list, where commas separate the items. Python doesn't crash — it quietly builds a 1-item tuple and throws it away — but the comma is noise and confuses readers. Delete them.

Bug 6 (style): duplicate imports

Run 3 imports from `pybricks.tools` **twice** on separate lines. Harmless but messy — merge them.

Bug 7 (waste): the unused voltage

setup.py reads `current_voltage = hub.battery.voltage()` and never uses it. Low battery = weaker pushes and different stall behavior = inconsistent runs. Print it, and complain loudly when it's low!

WATCH OUT · THE CLASSIC GOTCHAS CHECKLIST

Beyond our seven, here are the mistakes every rookie makes — check these first when code misbehaves:

- Forgot to `import` something → "name is not defined."
- Messy indentation → Python gets confused about what's inside what.
- Used `=` instead of `==` when checking.
- Mixed up port letters → the wrong motor moves.
- Wrong `wheel_diameter` / `axle_track` → every distance is off.
- Waited for the **center** button → it stops the program instead.

PART 10

Making It Better — This Year's Upgrades

10

Here's how we restructure last year's code into this year's cleaner version. Each upgrade is a mini-lesson in a real programming principle.

10.1 DRY: Don't Repeat Yourself — constants at the top

Before (facts scattered and duplicated → Bug 1):

```
print("***** Starting Run 7 *****")
hub.display.number(8)
```

After (each fact lives in exactly one place):

```
RUN_NUMBER = 9
MISSIONS = "M15 (Site Marking - Last Flag)"

async def run():
    print(f"***** Starting Run {RUN_NUMBER}: {MISSIONS} *****")
    hub.display.number(RUN_NUMBER)
```

ALL-CAPS names are a Python convention meaning "constant — set once, never change." Now the run number literally cannot disagree with itself.

10.2 Named settings profiles instead of magic numbers

You met the profiles in Part 3.5 — `PRECISE`, `NORMAL`, `FAST`, defined once in setup.py. Here's how a run uses them:

```
from setup import robot, PRECISE, FAST

robot.settings(*PRECISE)   # * unpacks the tuple into the 4 arguments
# ... do the delicate mission work ...
robot.settings(*FAST)
await robot.straight(-720)   # sprint home
```

Now tuning is centralized: make FAST faster in one place and every run gets faster.

10.3 A finish_run() helper

Every run ends with the same ritual (gyro off, print time). Repeated code → make it a function in setup.py:

```
# In setup.py
def finish_run(run_number):
    robot.use_gyro(False)
    print(f"Run {run_number} complete in {timer.time()/1000:.1f} seconds")
```

(`:.1f` formats the number to 1 decimal place – "24.8 seconds", always in seconds. Fixes Bug 4 everywhere at once.) Each run file's last line becomes `finish_run(RUN_NUMBER)`.

10.4 The big one: a menu that doesn't quit (and a dictionary!)

Two problems to fix at once: the `break` bug (Bug 3), and the 60-line wall of `elif selected == N: import runN ...` repetition.

There's a subtlety: `import run1` **executes run1.py only the first time**. Python caches imported modules, so the old "import inside the loop" style only works once per module anyway. The robust pattern – the one used by experienced Pybricks FLL teams – is: **import all runs at the top, store their run functions in a dictionary, loop forever.**

```python
# main.py — new and improved
from pybricks.tools import hub_menu, run_task
from pybricks.parameters import Color
from setup import hub, sensor, timer

import run1, run2, run3, run4, run5, run6, run7, run8, run9

# A dictionary: each menu number maps to that run's function.
RUNS = {
    1: run1.run,  2: run2.run,  3: run3.run,
    4: run4.run,  5: run5.run,  6: run6.run,
    7: run7.run,  8: run8.run,  9: run9.run,
}

# Which run each attachment color should put FIRST in the menu
FIRST_RUN_FOR = {
    Color.WHITE: 1, Color.YELLOW: 3, Color.RED: 5,
    Color.GREEN: 6, Color.BLUE: 7,
}

def build_menu():
    """Read the attachment color and reorder the menu to match."""
    color = sensor.color()
    start = FIRST_RUN_FOR.get(color, 1)   # .get() = lookup with a fallback
    print(f"Sensor color: {color} -> starting menu at run {start}")
    # rotate (1..9) so 'start' comes first, e.g. start=5 -> (5,6,7,8,9,1,2,3,4)
    return tuple(((start - 1 + i) % 9) + 1 for i in range(9))

def main():
    while True:                       # after each run, come BACK to the menu
        selected = hub_menu(*build_menu())
        timer.reset()
        run_task(RUNS[selected]())    # look up the run and execute it
        print(f"RUN {selected}: {timer.time()/1000:.1f} s")

main()
```

What we gained:

- **~90 lines became ~30.** Adding run 10 next season = two tiny edits (import + one dictionary line), not a new 7-line elif block.
- **The menu returns after every run** — swap the attachment, and `build_menu()` even re-reads the color each time. No restarting between missions on competition day (those seconds count!).
- A **dictionary** (`{key: value}`) is the perfect tool whenever you catch yourself writing a ladder of `elif x == something` — you're really just doing a lookup.

- One trade-off to know: importing everything up front means a syntax error in *any* run file stops the whole menu from starting. That's actually a feature — you find out at practice, not mid-match.

(The `% 9` in build_menu is the "remainder" operator — it makes the numbers wrap around 9 back to 1. Ask a coach to draw it; it's a fun 5-minute whiteboard moment.)

10.5 Print the battery voltage (Bug 7)

In setup.py:

```
voltage = hub.battery.voltage()   # millivolts
print(f"Robot initialized. Battery: {voltage} mV")
if voltage < 7600:
    print("*** LOW BATTERY - runs may be inconsistent! Charge or swap. ***")
```

Consistency is everything in FLL; a fresh battery vs. a tired one measurably changes stall behavior and stopping distances.

10.6 Descriptive names for mission phases

Run 4 already does something great — copy it everywhere:

```
print("Phase 1: Exiting base")
print("Phase 2: Turn towards gears and Activate gears")
print("Phase 3: Repositioning to pull pan")
```

When the robot misbehaves at practice, the console tells you exactly which phase it died in. Cheap, priceless debugging.

PART 11

Accurate Every Time

11

Doing all the missions **once** is great. Doing them **every game** is how you win. The difference isn't luck — it's hunting down anything that's a little bit random and making it reliable. The team checklist:

WINNING MOVE · START FROM THE EXACT SAME SPOT

If the robot doesn't begin in the same place and direction every launch, nothing after it can be accurate. Build a little alignment jig at base so placement is identical every time, by every teammate.

WINNING MOVE · LET THE ROBOT FIX ITS OWN ERRORS

Self-zero attachments with `run_until_stalled` + `reset_angle(0)`, then use `run_target` (exact positions) instead of piling up `run_angle` guesses. Keep the gyro on. Re-square against a wall partway through a long run to reset any drift.

WINNING MOVE · MEASURE, DON'T GUESS

Run each mission 10 times and watch where it lands. The step that's different each time is your weak link — slow it down, add a wall-square, or redesign it. The phase printouts (10.6) and the Video Lab (Appendix D) turn "I think it drifts" into numbers.

WINNING MOVE · MIND THE BATTERY

A tired battery makes motors slower, which changes your distances and stall behavior. Practice and compete at a similar charge — the setup.py battery warning (10.5) is your guard dog.

Notice the pattern: make every step either **self-correcting** or **re-checked against something real**, then measure and fix the shakiest one. Repeat. That's the whole secret to winning consistency.

PART 12

Your Turn — The Practice Ladder

12

Reading about code teaches you *about* code. Typing code teaches you code. Climb these levels in order at practice — and type everything yourself. No copy-paste. Your fingers learn Python faster than your eyes do.

1 **Paper Python**

No robot needed. (a) Make a variable `points` worth 20, add 15, print the total. (b) With `brightness = 55`, predict which line this prints: `if brightness < 20: print("LINE!")` / `else: print("mat")`. (c) Write `countdown()` — a function that prints 3, 2, 1, "GO!". *(Worked answers in Appendix C.)*

Done when: your paper answers match Appendix C.

2 **Hello Robot**

Make the hub display your favorite number, glow green, and print `"TEAM 71494!"` to the console.

Done when: your message appears on your laptop screen and the number glows on the hub.

3 **Shapes**

Drive a 300 mm square: four straights, four turns. Then a triangle. Then rewrite the square using a `for` loop and count how many lines you saved.

Done when: the robot ends up where it started, facing the way it started.

4 **Curves**

Replace two sides and one corner of your square with a single `robot.arc(...)`. Time both versions with `timer`. Which is faster, and by how much?

Done when: you have two measured times written down.

5 **Arms**

With a test attachment on `rarm`: use `run_until_stalled` (low `duty_limit`!) to find the arm's bottom, `reset_angle(0)`, then `run_target` it to exactly 90°.

Done when: the arm lands at 90° every single time, no matter where it started.

6 **Multitask**

Drive straight 400 mm *while* raising the arm 90°. Then break it on purpose: put two `larm` commands in one multitask and watch what happens. Safe crash, good learning.

Done when: you can explain the one rule of multitask to a teammate.

7 **Bug fixer**

Take last year's Run 9 file and apply the 10.1 and 10.3 fixes for real: `RUN_NUMBER` constant, `finish_run()` helper.

Done when: the printout says Run 9, the display shows 9, and the time is in seconds.

8 **Plan a mission on paper**

Pick one BIOGLOW mission. Before any code: write the mission name, the attachment it needs, and a numbered move list (drive / turn / arc / arm, one row per move). Great coders plan first, then type.

Done when: a teammate can walk your plan on the mat with a finger.

9 **Your first mission run**

Turn the Level 8 plan into `run1.py` for the new robot using the Part 6 skeleton: settings → multitask launch → mission moves → `finish_run()`. Get it working standalone, then wire it into the new dictionary menu.

Done when: you can launch it from the color menu and it scores.

★ **Consistency**

Run your mission ten times in a row and count successes. Anything below 8 out of 10 is not competition-ready. Figure out *why* it fails — battery? starting-position jig? gyro drift? too fast near the model? — and fix the cause, not the symptom.

Done when: 8/10 or better, and you can name the failure cause you eliminated.

PRO TIP · WHAT THE BOSS LEVEL IS REALLY TEACHING

Tournament judges see one run. Your practice table sees a hundred. The teams that win aren't the ones whose robot *can* score — they're the ones whose robot scores *every time*. Consistency is a skill you build, run by run, exactly like this.

APPENDIX A

Cheat Sheet

A

One page to tape next to the practice table. When you forget a command mid-practice, it's here.

Driving (mm, degrees; + is forward/right, − is backward/left)

```
await robot.straight(300)
await robot.turn(-90)
await robot.arc(radius=200, distance=300)   # +radius curves right
await robot.arc(radius=-60, angle=-45)      # -radius left; -angle/distance = reverse
robot.settings(speed, accel, turn_rate, turn_accel)
robot.settings(*PRECISE)                    # named profile from setup.py
robot.use_gyro(True_or_False)
robot.stop()
```

Arm motors

```
await larm.run_angle(speed=500, rotation_angle=90, then=Stop.HOLD)
await larm.run_target(speed=500, target_angle=90)    # go TO a position
await larm.run_until_stalled(speed=500, duty_limit=20, then=Stop.COAST)
larm.reset_angle(0)
larm.control.limits(speed=1000, acceleration=4000, torque=1000)
```

Multitasking

```
async def run(): ...
await multitask(task_a(), task_b())    # different devices only!
run_task(run())
await wait(500)          # pause 500 ms (async-friendly)
```

Hub & tools

```
hub.display.number(3)          # fits -99 to 99 only
hub.display.icon(Icon.HAPPY)
hub.light.on(Color.GREEN)
hub.speaker.beep()
hub.battery.voltage()          # millivolts
timer.reset(); timer.time()    # milliseconds!
selected = hub_menu(1, 2, 3)
sensor.color()
```

Python quickies

```
name = value                   # variable
if a == b: ...                 # elif ...: ... else: ...
for i in range(3): ...
while True: ...   # break exits
def my_function(argument): ...
RUNS = {1: run1.run}           # dictionary: RUNS[1]
print(f"time: {timer.time()/1000:.1f} s")
```

APPENDIX B

Glossary & Documentation Links

B

The words that make you sound like you've been doing this for years.

- **argument** – a value you pass into a function's parentheses
- **boolean** – a True/False value; the answer to a yes/no question
- **constant** – an ALL_CAPS variable that is set once and never changed
- **coroutine** – an `async def` function that can pause (`await`) so other tasks can run
- **dictionary** – a `{key: value}` lookup table
- **f-string** – `f"text {variable}"` – text with live values embedded
- **function** – a named, reusable block of instructions, made with `def`
- **import** – pull in code from another file or library
- **indentation** – leading spaces that define what's "inside" what – in Python, this is grammar
- **stall** – when a motor pushes but can't move; used deliberately to find an arm's physical limits
- **string** – text in quotes
- **tuple** – an ordered, unchangeable bundle of values: `(1, 2, 3)`

Documentation links

- **Pybricks API reference** (the truth): **docs.pybricks.com**

- DriveBase – straight / turn / arc / settings / use_gyro: *robotics* page - Motors – run_angle, run_target, run_until_stalled, control.limits: *pupdevices → Motor* page - multitask / run_task / hub_menu / StopWatch / wait: *tools* page

- **Pybricks guided lessons** (great homework): **pybricks.com/learn**
- **Pybricks code editor**: **code.pybricks.com**

APPENDIX C

Answer Key (No Peeking Until You Tried!)

C

Level 1a

```
points = 20
points = points + 15   # take what's in the box, add 15, put it back
print(points)          # shows: 35
```

Level 1b

```
brightness = 55

if brightness < 20:
    print("LINE!")
else:
    print("mat")
```

It prints `mat` — 55 is not under 20, so Python takes the `else` road.

Level 1c

```
def countdown():
    for n in range(3, 0, -1):   # counts 3, 2, 1
        print(n)
    print("GO!")

countdown()
```

Level 3 (the loop version of the square)

```
from setup import robot

for side in range(4):
    robot.straight(300)     # no await — this is a top-level test, not a run file
    robot.turn(90)
```

Bonus thought: after those four turns the robot should face exactly the way it started. If it doesn't, your `axle_track` needs tuning — see Part 3.4.

Level 5

```
from pybricks.parameters import Stop
from setup import rarm

rarm.run_until_stalled(-200, then=Stop.HOLD, duty_limit=20)
rarm.reset_angle(0)
rarm.run_target(speed=500, target_angle=90)
```

PRO TIP · DIFFERENT ANSWER, STILL RIGHT?

If your code looks different but does the same job – that's fine! There are many correct ways to write a program. What matters is: does it do what you wanted, every time?

APPENDIX D

The Video Lab

D

The boss level said it: anything below 8 out of 10 isn't competition-ready. But how do you find out *why* a run fails 3 times out of 10? You measure. This appendix turns the family phones into measuring instruments, using a free tool called ffmpeg. If building robots isn't your favorite job on the team, this chapter might be — every team needs a data engineer.

Two rules make practice video worth analyzing, and they're both free:

- **The camera never moves.** Build a LEGO phone clamp for the table edge, aimed at the mission model. Same spot, same angle, every practice. Comparing videos only works when the only thing that changed is the robot.
- **Every run announces its own start.** One beep from the hub right before launch gives every recording a sharp audio spike to line up on. In the new menu from Part 10.4, add one line before the launch:

```
hub.speaker.beep(880, 200)      # one short beep = "run starts NOW"
run_task(RUNS[selected]())
```

Now the robot, the video, and the `timer` printouts all share the same starting gun. Congratulations — you've built a telemetry sync system. (That's what grown-up engineers call it. You can call it the beep.)

> **CORE CONCEPT · MEASURE, DON'T ARGUE**
>
> "I think it drifts left" is an opinion. "At 5 seconds, the robot's position varies by two grid squares across ten runs" is a measurement. Opinions start debates; measurements end them. Everything below exists to replace arguing with measuring.

D.1 Getting ffmpeg

ffmpeg is a free command-line video tool — no windows, no buttons, just commands you type. Ask a parent to install it (on Windows: `winget install ffmpeg`; on Mac: `brew install ffmpeg`), copy the run videos from the phone into a folder, and open a terminal there. Each recipe below is one command. You don't need to understand every symbol — you need to know what each recipe is *for*, the same way you use `print()` without reading how it works inside.

D.2 Recipe 1: Burn a stopwatch into the video

```
ffmpeg -i run.mp4 -vf "drawtext=text='%{pts\:hms}':fontsize=48:fontcolor=yellow:x=20:y=20"
timed.mp4
```

This stamps a running clock onto every frame. Scrub to "arm touches the model" and read the exact time — then compare it with the phase printouts from Part 10.6. If the console says Phase 2 ended at 8.1 seconds but the video shows the arm arriving at 9.0, that missing 0.9 seconds is real information: the wheels slipped, or the robot hesitated, somewhere in Phase 2.

D.3 Recipe 2: A pass and a fail, side by side

Trim both clips so they start at the beep, then glue them into one split-screen video:

```
ffmpeg -i pass.mp4 -i fail.mp4 -filter_complex hstack sxs.mp4
```

Here's the secret this recipe reveals: **the failure almost never happens where it appears to happen.** The missed mission model at 18 seconds usually traces back to a heading error two degrees wide at 6 seconds. Play the pass and the fail in lockstep and find the *first frame where they differ* — that's where the real bug lives. Fix where the runs diverge, not where the run dies.

D.4 Recipe 3: The ghost overlay

Blend two synced runs into one see-through video:

```
ffmpeg -i run1.mp4 -i run2.mp4 -filter_complex "blend=all_mode=average" ghost.mp4
```

If the robot is perfectly consistent, the two ghosts sit exactly on top of each other and you see one robot. If it isn't, you see a blurry double robot — and the moment the ghosts split apart is the moment inconsistency entered the run. Nine times out of ten it's the launch position or the first turn. This is the Part 12 boss level, drawn as a picture.

D.5 Recipe 4: The spread montage

Pull a photo from the same moment of every run — say, 5 seconds after the beep:

```
ffmpeg -ss 5.0 -i run3.mp4 -frames:v 1 t5_run3.png
```

Repeat for all ten runs (change the file names), line the photos up, and because the camera never moved, you can *count mat squares* to measure the spread: "at 5 seconds we're anywhere in a 40 mm window." Now run the real experiment — change exactly one thing (the starting jig, a slower `settings()` profile, a

fresh battery) — take ten more runs, and re-measure. Did the window shrink? You just did science to your robot.

WATCH OUT · CHANGE ONE THING AT A TIME

If you change the jig AND the speed AND the battery, and the spread shrinks... which one fixed it? You can't know. One change per experiment. It feels slower; it's actually faster.

D.6 Recipe 5: Slow-motion the contact moment

```
ffmpeg -i run.mp4 -vf "setpts=4*PTS" -an slow4x.mp4
```

Four-times slow motion of the attachment meeting the model shows what full speed hides: the arm flexing before it lifts, the claw bouncing once before it grips, the model getting nudged out of reach by the approach itself. When a mission "randomly" fails, it's rarely random — it's just fast.

D.7 The Video Lab workflow

1. 1. **At practice:** clamp the phones, hit record once, leave them running. Every run beeps its own start mark.
2. 2. **That evening:** the data engineer trims the clips at the beeps and makes two things — a ghost overlay and a spread montage.
3. 3. **Next practice opens with two pictures** and one question: what single thing do we change this week?
4. 4. **Save the best before/after clips.** Robot Design judges love documented iteration — "here's the failure, here's our diagnosis, here's the fix working" is exactly the story they're hoping to hear.

PRO TIP · PHONE CAMERA SETTINGS

Lock focus and exposure (press and hold the screen on iPhone) so the camera doesn't refocus mid-run, plug the phones in, and film the whole practice block instead of starting and stopping. Storage is cheap. The one take you didn't record is always the interesting one.

FIRST LEGO League Challenge

Built for Habitat Hackers #71494 from the 2025–26 season binder. Now go make BIOGLOW glow.