

OPENING ORATION — THE INVISIBLE OCEAN (9:30 · ~3 min · full text: *Opening Oration.pdf*)

Beats: empty hands → the fat “bag of nothing” pushes back → air is real stuff hiding → you live at the bottom of an invisible ocean pressing from every side → a balloon caught from my own chest → today we put air on trial: trap it, weigh it, watch it crush a can. The bag passes the circle; the last child pops it (“THAT is the sound of the something getting out”).

ACTIVITIES (KIDS DO — GUIDE-ONLY, NO PRINTED CARDS)

These three are free-form play with real gear, not step procedures — deliberately no experiment cards. All six experiments have cards.

A1 · Trap the Nothing

9:45 · 15 min · zip bags, balloons + hand pump

Kids race to “catch nothing”: swoop a bag through the air, zip it fat, squeeze it; pump balloons and hold them shut. Then everyone sits — gently — on a captured bag: it holds you up. Air caught from the pump or from running — same stuff, caught anywhere.

Say: “You just caught something invisible. It fills the bag, it pushes back, it holds you up. Empty things squash flat — this is NOT empty.”

Failure modes: cheap bags split at the zip when sat on — double-bag, or make sitting a supervised finale. Balloons burst or uninflated are a choking hazard: the pump keeps balloons off mouths; burst scraps straight to the bin.

A2 · Bubble Play

10:50 · 30 min · outdoors, calm air · giant-bubble kit, dipping tray, pro solution, stainless wands, wire frames, straws + squeeze bottles

Three stations, rotate freely: **(1) Giant bubbles** — the rope wand makes bubbles bigger than the kids; each is a bag of caught air in a soap skin (“what’s inside? where did it come from?”). **(2) Wire frames** — dip the cube slowly: flat films meet in the middle and a small square-ish bubble can form where they join; dip every shape. **(3) Underwater bubbles** — straws in the basin; squeeze an “empty” bottle mouth-down under water and watch the glugs race up (“what comes out — and what goes IN as it leaves?”).

Say: “Every bubble is air you trapped. Air pushes out, the skin pulls in, and where they balance — a bubble.”

Failure modes: wind shreds giant bubbles — morning calm or a sheltered corner. Grass pops bubbles; keep the tray on a table. Homemade solution must rest overnight. Sunscreen-greasy hands pop everything — wands only at the giant station.

A3 · Suction-Cup Tug

11:20 · 15 min · jumbo suction cups; smooth table, window, or fridge door

Press, squeeze flat, and pull — it fights back hard. The argument: **nothing is inside the cup holding it** — pressing squeezed the air OUT; the outside air pushes it against the glass. Slide a fingernail under the rim, let air in — it falls off by itself. Then the book’s cheek demo: suck your cheeks in hard. “You pushed air out of your mouth. Your cheeks caved IN — who pushed them? The air outside your face!”

Say: “Nothing in this world sucks. When air is missing on one side, the air on the other side pushes. Say it with me: the outside air pushes.”

Failure modes: dusty/textured surfaces leak — wipe first; a drop of water on the rim seals a stubborn cup. Cheek-suck alternatives: palm over mouth, breathe in gently for two seconds — the palm gets pushed in the same way.

EXPERIMENTS (TEACHER RUNS; KIDS PREDICT → WATCH → EXPLAIN)

E1 · Dry Paper Under Water — Card 1

10:00 · 20 min · card: [experiment-cards/01-dry-paper-under-water.pdf](#)

Run explicitly as the scientific method, naming each step aloud: **Question** → **Predict** → **Test** → **Observe** → **Conclude**. Wad a paper towel tight into the bottom of the glass; predict on the worksheet back (band 1); push the glass mouth-down, dead level, all the way under; count to five; lift, wipe, pull out the paper — bone dry. Ask WHY before telling. Repeat tilted: bubbles plug out, water floods in, paper soaked. Conclude in their words: air takes up space; water can't come in until air goes out. Then every child gets a dunk turn.

Say: "The glass was never empty. It was FULL — full to the brim with air. Water knocked, and air would not give up its seat."

Failure modes: paper falls out at inversion — wad bigger, truly wedge it. Tilting on the way down leaks air early — mouth dead-level. Basin must sink the whole glass — use the deepest tub you have.

E2 · The Balloon Balance — Card 2 (Nebel's core experiment)

10:20 · 20 min · card: [experiment-cards/02-balloon-balance.pdf](#) · BUILT AND LEVELED THE NIGHT BEFORE

Show the balance hanging level (clips at 0/6/12; deflated balloon on each end loop). Predict (worksheet band 2) — most young kids vote "stays level; air weighs nothing." Unhook one balloon, pump it full, tie with no extra string, re-hang on its same loop: **the full side sinks**. Reason: everything identical but the air — the extra weight IS the air's weight. Then MEASURE: clip paper clips to the light end until level, counting aloud; write the number in the worksheet count box. Older-kid objection ("air floats in air!"): the pump *squeezed extra air in* — more air in that space than normal; the balance feels the extra.

Say: "You cannot see air. You cannot grab air. But the balance just WEIGHED it. Only real stuff has weight — so air is real stuff."

Failure modes: drafts swing everything — windows shut, fan off, bodies back. Both balloons start attached so the knot difference never matters. Static sticks the balloon to hair/walls and fakes readings. Won't start level? Tape bits on the light end (the book's own trick).

E3 · The Candle and the Cup — Card 3

11:35 · 25 min · card: [experiment-cards/03-candle-and-cup.pdf](#) · SAFETY: open flame — adult lights and lowers; kids at arm's length

Candle mid-dish; an inch of colored water; predict (worksheet band 3); light; lower the glass straight down until the rim seals under the waterline. Flame shrinks, dies... then the water climbs up inside and stops. Argue: who pushed the water up? Nothing inside is left to pull — nothing sucks. The flame **warmed** the air; when it died the trapped air **cooled and pushed less**; the unchanged outside air shoved water into the weaker place. Run encores.

Say: "The air outside never stopped pushing. When the air inside got weaker, the outside push won — and shoved the water up. Nothing sucked. The outside air PUSHED."

Failure modes: candle taller than the glass = no result — test the pairing the night before. Water too deep drowns the flame; about an inch. Rim must seal below the waterline all the way around. Keep the explanation to warmed-then-cooled air (honest and observable — the climb happens as it cools), not "the flame ate the air."

E4 • The Can Crush — Card 4

12:40 · 15 min · card: [experiment-cards/04-the-can-crush.pdf](#) · SAFETY: adult-only; tongs + mitt; kids behind the tape line

First pass a spare can: “crush it flat between your flat palms” — nobody can. Predict (worksheet band 4). One tablespoon of water in the crush can; heat until a **steady steam plume** pours from the mouth (the steam is pushing the air out — say so). Tongs low; ONE fast smooth flip, mouth-straight-down into the ice water. BANG — crushed flat, inward from every side. Stand it next to its un-crushed twin. Reason: cold sealed the mouth and shrank the steam to drops; almost nothing inside pushed out, while the whole atmosphere pushed in. Do the encore.

Say: “Nothing touched that can but air. The push was always there — on the can, on you, on everything, from every side. The can only found out when it lost the push INSIDE that was holding it open.”

Failure modes: flipping before a committed plume = weak crush. Slow or tilted flip lets air sneak back — one fast motion, mouth dead-down. Too much water mutes it; a dry can scorches. Steam burns are silent: only the adult’s hands cross the line.

E5 • Magdeburg Hemispheres — Card 5

12:55 · 15 min · card: [experiment-cards/05-magdeburg-hemispheres.pdf](#) · walk POSTER 1 right after — all three panels have now happened

Halves apart: clap, pull — easy. The story: Magdeburg, 1654 — Otto von Guericke pumped the air from two big metal bowls and **two teams of horses** couldn’t part them. Press together, pump out the air. Strongest kid pulls — fails; two-kid straight tug-of-war — fails. What holds them? The missing air can’t hold anything — **the outside air squeezes them together**. Open the valve — hisss — they fall apart by themselves. Connect back to the morning’s suction cups.

Say: “No glue. No magnet. No trick. Just the whole sky, pressing two little bowls together from every side — until we let the air walk back in.”

Failure modes: dusty/dry seal ring leaks — wipe with a damp cloth. Half-hearted pumping = weak hold. Sideways yanks shear the seal — straight tug, one axis, seated on the floor so failure is safe and funny.

E6 • The Vacuum Jar Show — Card 6

1:10 · 20 min · card: [experiment-cards/06-vacuum-jar-show.pdf](#) · kids take turns pumping

Five acts, one jar; **predict before every act:** (1) **Marshmallows** swell into giants, then shrivel smaller than they started when air returns. (2) **The lazy balloon** — barely-blown, it inflates itself. (3) **Shaving cream** billows into a mountain. (4) **Warm water** streams bubbles — the air’s push helps keep water liquid (the act a hand pump sometimes can’t fully reach; bubbles = win). (5) **The timer** fades muffled and far away, then swells back with the air — **sound needs air to carry it**; in space, no one can hear a beep (it won’t go perfectly silent — some sound sneaks through the glass and base).

Say: “A vacuum isn’t a thing — it’s a MISSING thing. A space with the air taken out. Watch what everything does when the push goes away.”

Failure modes: gasket must be clean and moist or nothing holds. Little arms tire — rotate pumpers each act. Marshmallows never fail — open with them (and return to them if attention wobbles). Warm water only — hot softens seals.

THE ATMOSPHERE (1:30 · 15 min · circle — guide-only · walk POSTER 2)

- **Satellite photo** (“Earth atmosphere from space photo”): the thin glowing blue rind on the Earth’s edge is ALL of it — our whole invisible ocean, seen from outside.
- **What holds the air on?** Gravity (D-1 callback). Air has weight — we *weighed* it this morning — and whatever has weight, gravity holds down.
- **Climb Poster 2 bottom to top:** birds, clouds, and all weather in the lowest band (the **troposphere** — where we live); jets at its top edge; the weather balloon higher, in the calm; shooting stars burn higher still; the space station glides where almost no air is left; then black — space, no air at all.
- **Astronaut photo:** why the suit? He brought his air WITH him — there is none out there.
- **The Moon question:** small Moon, weak gravity — too weak to hold an ocean of air down. No air, no wind, no sound; footprints forever.
- **Helium balloons** (they’ll ask): helium weighs *less than air* — it floats to the top of the air ocean like a cork in water. Hot air weighs less than cool air — hot-air balloons too.
- **Four spheres, named once, pointing:** rock below (geosphere), water on it (hydrosphere), air around it (atmosphere), living things woven through all three (biosphere).
- Close with the song chorus as call-and-response (song/Song — The Ocean of Air.md; audio not yet generated).

STRETCH (ranch, adult-run — NOT part of the core day): (1) electric vacuum pump + polycarbonate chamber (~\$100) — water boils cold, marshmallows become monsters; (2) deep-water pressure at the stock tank/pool — push a capped empty bottle down on a pole and watch it crush with depth and re-expand rising (the water version of the can crush); push a clear cup mouth-down and watch its air pocket shrink; (3) 50-ft black solar tube balloon (~\$20) tethered over the pasture on a calm sunny morning — anchor seriously; an escaped one flies for miles.

PROMPTS & QUESTIONS (USE ALL DAY — BOOK PP. 62–63)

- Is air real stuff, or really nothing at all? How could we PROVE it?
- How can you show that air takes up space? That air has weight?
- Why can’t you feel the weight of all that air? (*It pushes from every side at once — even up.*)
- What do all solids, liquids, and gases have in common? (*Take up space, have weight.*) What do we call them all together? (*Matter.*)
- Suppose someone says air is really nothing. What evidence would you show them?
- What keeps the atmosphere from floating off into space? What if air were truly weightless?
- Why does the Moon have no atmosphere? Why does an astronaut wear a space suit?
- Water won’t go into an upside-down bottle in the bath — why not?
- Why did the can crumple when nobody touched it? Who crushed it?
- What is a vacuum — a thing, or a missing thing?
- How do solids, liquids, and gases each show up on planet Earth? (*Rock, sea, sky — and living things use all three.*)

WHAT TO WATCH FOR IN DAILY LIFE (SEND HOME WITH PARENTS)

- Bath and sink play with clear jars and bottles: water can't get in until air gets out. Ask "*why not?*" and expect "*air is taking up the space.*"
- Press a suction cup on the fridge — *what is holding it there?* (Nothing inside — the outside air pushes.)
- Squeeze a sealed bag or a pumped-up ball — *what pushes back?*
- Ears popping on a big hill or drive — *the air's push on your ears changed.*
- Wind on your face: air is real stuff you can FEEL when it moves.
- Re-build the balloon balance at home and weigh other things on it (the book asks parents to do exactly this; teeter-totters count).
- Periodically: what two things are true of ALL solids, liquids, and gases? (*They take up space and have weight — they're matter.*)

PREP-AHEAD CHECKLIST

3–7 days before

- ☐ Order TO-BUY supplies (Supply List.md) — vacuum pump kit, Magdeburg hemispheres, and bubble gear all ship; allow a week
- ☐ Test the vacuum pump kit once (seal, pump count, marshmallow dry-run)

The day before

- ☐ **Build and level the balloon balance** — fiddly; never build it live. Hang it where it will be used; trim level with tape bits
- ☐ **Test-run E1 and E3 with your actual glasses** — deep enough basin? glass taller than candle? rim seals under the waterline?
- ☐ Stage the can-crush kit: 2+ rinsed cans, tongs, oven mitt, ice-water bowl, hot plate, tape line on the floor
- ☐ Mix/rest homemade bubble solution overnight (or verify the pro bottle); stage tray, wands, frames
- ☐ Wipe the Magdeburg seal ring; find the pump/valve; dry-run one tug
- ☐ Freeze ice; check the timer battery (loud beep?)
- ☐ Print student sheets ×5 and cards ×1 if stock is low

The morning of

- ☐ Seal the "bag of nothing" drum-tight just before circle; balloon in pocket
- ☐ Fill the basin deep; wad spare paper towels beside it
- ☐ Zip bags + balloons + pump in a bin (A1); suction cups in a bin (A3)
- ☐ Colored water + candle staged in the dish; long lighter up high
- ☐ Queue the two photos (atmosphere from space · astronaut suit) on a tablet or clip printouts to Poster 2
- ☐ Hang both posters rolled/covered until their walk moments (12:55 and 1:30)

REVIEW HOOKS

- **Back:** A-2 — air was named a gas among the three states; today it earned the title by the two tests of matter. B-2 — natural vs. human-made things all turn out to be matter. D-1 — gravity gives air weight and holds the atmosphere down.

- **Forward:** A-4 — what IS air made of? Tiny particles, jiggling — that’s what was bumping the can. A-6 — air pressure and vacuums return, bigger and quantitative. A-7 — air turns out to be a mixture of gases. D-7 — weight vs. mass gets untangled there; today we say “weight” plainly (the book’s own note).

Opening Oration — The Invisible Ocean

Air Is a Substance • read aloud, ~3 minutes

Prop: A gallon zip-seal bag zipped shut FAT with plain air — “a bag of nothing” — hidden behind your back, plus one uninflated **balloon** in your pocket to blow up mid-speech. (Prep: seal the bag just before you sit down so it is drum-tight; keep a spare — the last child in the circle is allowed to pop it.)

I have a question for you, and I want you to really think before you answer. What is in my hands... right now?

(Hold up your empty, open hands. Let them say “nothing!”)

Nothing? Are you sure? Watch this. *(Whip out the zip bag — fat, sealed, drum-tight.)*

Now what’s in the bag? It looks like nothing. But squeeze it — go on, when it comes around, squeeze it gently. It pushes BACK. It’s fat. It’s springy. If it were really nothing, the bag would be flat as paper. Something is in there. Something you cannot see... but your hands can feel it push.

That something is **air**. And here is the secret of today: air is not nothing. Air is real stuff — as real as water, as real as rock. It is just very, very good at hiding.

You have lived inside it your whole life. Right now you are at the bottom of an ocean — an invisible ocean of air, taller than the clouds, taller than any airplane can fly, wrapped all the way around the whole Earth. Fish swim at the bottom of the sea and never think about the water. You walk at the bottom of the sky and never think about the air. It presses on you this very moment — on your head, your shoulders, your cheeks — from every side at once, and it presses so evenly that you can’t feel it at all.

(Take out the balloon. Blow it up slowly as you speak, then hold it high.)

Look — I just caught some. Where did the fat part of this balloon come from? Out of my chest! Air went in flat and came out round, because air takes up room. Real stuff always takes up room.

But you don’t have to believe me — that’s not how scientists do it. Scientists say PROVE IT. So today we are going to put air on trial. We will trap it. We will weigh it. We will watch it hold water back, and snuff a candle, and crush a metal can flat with nobody touching it. And by the end of the day you will know something most grown-ups never think about even once: the nothing all around you... is something.

(Pass the bag of nothing around the circle. Everyone squeezes. Whoever holds it last may pop it — and when it bangs, say: “THAT is the sound of the something getting out.”)

A-3 Supply List — Air Is a Substance

Everything for the full 9:30–2 day. Prices are rough. **Order-ahead flags matter:** the vacuum pump kit, Magdeburg hemispheres, and bubble gear all ship — allow a week.

ALREADY HAVE (TYPICAL HOUSEHOLD)

☐	ITEM	USED IN
☐	Gallon zip-seal bags (several; 2 for the prop)	Oration prop, A1
☐	Clear drinking glass (taller than the candle; sinkable)	E1, E3
☐	Paper towels	E1
☐	Dishpan / deep basin (3+ in over the glass rim)	E1, A2 underwater station
☐	12-inch ruler	E2 balance beam
☐	Paper clips (3 + a pile for counting)	E2
☐	Tape (masking) + string/thread	E2 · E4 floor line
☐	Shallow dish / pie plate	E3
☐	Tealight or short candle + long-nose lighter	E3
☐	Food coloring (a drop, optional)	E3 (makes the climb visible)
☐	Empty aluminum soda cans ×3+ (rinsed)	E4 (crush + twin + encores)
☐	Hot plate or kitchen stove	E4
☐	Long kitchen tongs + oven mitt	E4
☐	Shallow bowl + ice	E4
☐	Marshmallows	E6 act 1
☐	Shaving cream + small cup	E6 act 3
☐	Small cup of warm tap water	E6 act 4
☐	Loud beeping kitchen timer + folded cloth pad	E6 act 5
☐	Drinking straws + squeeze bottles	A2 underwater bubbles
☐	Damp cloth	E5 seal wipe
☐	Tablet or printouts: "Earth atmosphere from space" + "astronaut space suit" photos	Atmosphere block

TO BUY

☐	ITEM	QTY	~PRICE	WHY	ORDER AHEAD?
☐	Hand vacuum pump + jar kit	1	\$25	E6 — the workhorse: marshmallows swell, balloon self-inflates, cream billows, warm water bubbles, timer goes quiet	YES — ships
☐	Magdeburg hemisphere set (toy)	1	\$12	E5 — the whole family loses a tug-of-war against the sky	YES — ships
☐	Giant-bubble kit — Dr. Zigs / Uncle Bubble class: hardwood handles, cotton-rope wand	1	\$30–45	A2 — durable pro gear, lasts years; the rope wand is what pros actually use (no junky plastic)	Yes
☐	Wide shallow dipping tray	1	\$15	A2 — giant-wand loading	Yes
☐	Concentrated pro bubble solution (or guar gum + glycerin to mix)	1	\$20	A2 — giant bubbles need real solution	Yes
☐	Stainless-steel bubble wands (set)	1	\$12	A2 — station wands that don't snap	Yes
☐	Wire geometry frames (cube, tetrahedron, helix)	1 set	\$25	A2 — dip the cube: soap films meet in a square-ish middle bubble; real minimal-surface science	Yes
☐	Jumbo suction cups	5 (1/kid)	\$8	A3 — the tug that nothing (but air) is holding	Yes
☐	Quality 12-inch balloons + hand balloon pump	1 bag + 1	\$10	E2 (two identical), E6 act 2, A1 — pump keeps balloons off mouths	Yes

Total new spend: ~\$162 (with the bubble kit at ~\$35).

CHECK-YOU-OWN-IT NOTES

- **Hot plate** — the kitchen stove works fine for E4. A basic hot plate (~\$25, A-2 also

uses one for its Melt Race) only if the lesson runs away from the kitchen.

- **Soda cans** — thin-walled aluminum only (standard soda cans). Steel food cans will not crush.

- **Timer** — must beep loudly on its own (not a phone; the phone shouldn't go in the jar).

STRETCH PURCHASES (ONLY IF PURSUING THE RANCH INSTALLS — SEE TEACHER GUIDE STRETCH)

☐	ITEM	~PRICE	FOR
☐	Electric vacuum pump + polycarbonate chamber	~\$100	Hard-vacuum upgrade of E6
☐	50-ft black solar tube balloon	~\$20	Tethered pasture launch
☐	(Pole + capped bottles assumed owned)	—	Deep-water bottle crush

Tick the box beside each item as it goes in the box. Anything flagged **order ahead** ships — buy it a week before the lesson.

Dry Paper Under Water

TEACHER, THEN KID TURNS

RUN AT 10:00

20 MIN

The point

Air takes up space. The glass is never empty — it is full of air, and the water cannot come in until the air goes out. Run it as the scientific method, naming each step aloud: **Question** → **Predict** → **Test** → **Observe** → **Conclude**.

Materials

- Clear drinking glass
- Paper towels
- Dishpan / deep basin of water (3+ in over the rim)

Steps

- 1 **QUESTION:** “Will the paper get wet under water?” Wad a paper towel and **wedge it tight in the bottom** of the glass.
- 2 **PREDICT:** everyone circles a guess on the worksheet back (band 1) first.
- 3 **TEST:** glass mouth-down, held **perfectly level** — push it slowly all the way under. Count to five.
- 4 **OBSERVE:** lift straight out, wipe the rim, pull the paper — **bone dry**. Pass it around.
- 5 Ask **why** before telling. Watch through the glass wall: water climbs only a little, then stops.
- 6 Repeat **tilted**: silver bubbles glug up, water floods in, paper soaked. What left — and what moved in?
- 7 **CONCLUDE** in their words, then give **every child a dunk turn**.

Say: “The glass was never empty. It was FULL — full to the brim with air. Water knocked, and air would not give up its seat.”

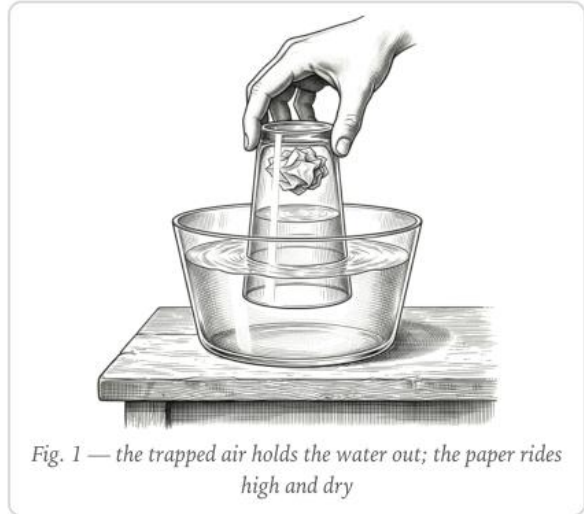


Fig. 1 — the trapped air holds the water out; the paper rides high and dry

TEACHER PREP — THE DAY BEFORE

Test with **your actual glass and basin**: the basin must be deep enough to sink the whole glass. Wad the paper big enough that it cannot fall out inverted.

What to watch for

- Water visibly stops a little way inside the mouth
- The tilted repeat: bubbles OUT, water IN — a trade
- Kids saying “the air is in the way” unprompted

EXPECTED RESULT

Straight down: paper stays dry — **trapped air occupies the space**, so water cannot enter.
Tilted: air escapes as bubbles and water takes exactly the room the air gives up.

The Balloon Balance

TEACHER DEMO, KIDS MEASURE

RUN AT 10:20

20 MIN

The point

Air has weight — and a homemade balance can measure it. This is Nebel's core experiment: everything on both sides is identical **except the air**.

Materials

- 12-inch ruler · 3 paper clips (+ a pile for counting)
- Tape · string
- Two identical new balloons · balloon pump
- A draft-free table edge to hang from

Steps

- 1 Show the **pre-built balance hanging level**: clips at 0, 6, and 12 in; center clip carries the hanging string; a deflated balloon hangs on a short loop at each end.
- 2 **PREDICT** on the worksheet back (band 2): fill one balloon — down, level, or up?
- 3 Unhook one balloon, **pump it full**, tie the neck with no extra string, re-hang it on its same loop.
- 4 Watch it settle: **the full side sinks**. Let every child sight along the beam.
- 5 Reason: same ruler, clips, string, balloon — **only the air is new**. The extra weight is the air's weight.
- 6 **MEASURE**: clip paper clips to the light end one at a time until level. Count aloud; write the number in the worksheet count box.

Say: "You cannot see air. You cannot grab air. But the balance just **WEIGHED** it — about ____ paper clips of air. Only real stuff has weight."

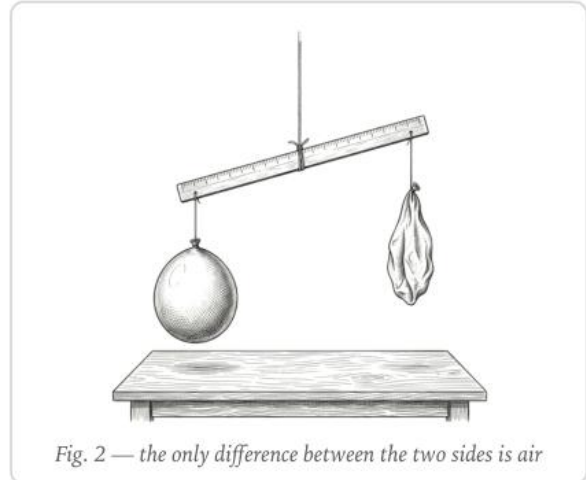


Fig. 2 — the only difference between the two sides is air

TEACHER PREP — THE NIGHT BEFORE

Build and level it in advance — it is fiddly. Tape clips at 0 / 6 / 12 with the hook ends protruding; trim level with bits of tape on the light end. Hang it where it will be used.

What to watch for

- A genuinely level start (this is the whole argument)
- The tip the moment the full balloon re-hangs
- The beam creeping back level as clips are counted on

EXPECTED RESULT

The inflated side sinks; a few paper clips re-level it. **The pump squeezed extra air in** — more air in the same space — and the balance feels that extra. If a child objects "air floats in air!", that squeezed-in extra is the answer.

The Candle and the Cup

TEACHER DEMO

RUN AT 11:35

25 MIN

The point

The outside air pushes water UP into the glass.
Nothing sucks — ever. When the air inside pushes less, the air outside wins.

Materials

- Shallow dish or pie plate
- Tealight or short candle • long-nose lighter
- Clear glass, taller than the candle
- Water (+ a drop of food coloring)

Steps

- 1 Stand the candle mid-dish; pour about **one inch** of colored water around it.
- 2 **PREDICT** on the worksheet back (band 3): burning on / flame out and water climbs / cup pops off?
- 3 Light the candle. Lower the glass **straight down over it** until the rim sits on the dish, under the waterline all the way around.
- 4 Watch in silence: flame shrinks, gutters, dies... **then the water climbs** up inside and stops.
- 5 Argue it out: who pushed the water up? Nothing inside is left to pull — **nothing sucks**.
- 6 Explain: the flame **warmed** the air; when it died the trapped air **cooled and pushed less**; the outside air, pushing as hard as ever, shoved water into the weaker place.
- 7 Lift the glass — hear the little glug — and **run encores** on request.

Say: "The air outside never stopped pushing. When the air inside got weaker, the outside push won — and shoved the water up. Nothing sucked. The outside air PUSHED."



Fig. 3 — flame out first, THEN the climb — the order is the clue

TEACHER PREP — THE DAY BEFORE

Test the pairing: the glass must be **taller than the candle** and its rim must seal **below the waterline**. About an inch of water — deeper drowns the flame on the way down.

SAFETY

Open flame: **adult lights and lowers**; kids at arm's length; hair tied back; matches and lighter live out of reach.

What to watch for

- The order: flame dies **FIRST**, the water climbs after, as the air cools
- Water rises only inside the glass, then holds steady

EXPECTED RESULT

The flame goes out and water climbs partway up inside. **Cooled air inside pushes less; the unchanged outside air pushes water up** until the pushes balance. (Keep it honest: warmed-then-cooled air — not "the flame ate the air.")

The Can Crush

TEACHER DEMO

RUN AT 12:40

15 MIN

The point

Air pressure is **STRONG**. A can the kids cannot crush by squeezing gets flattened by the sky, instantly, with nobody touching it. **THIS** is what “air pushes from every side” means.

Materials

- 2+ empty aluminum soda cans (rinsed; + spares for encores)
- About 1 tablespoon of water
- Hot plate or stove • long kitchen tongs • oven mitt
- Shallow bowl of ice water • tape line on the floor

Steps

- 1 Pass the spare can: “**crush it flat between your flat palms**” — no thumbs, just squeeze. Nobody can.
- 2 **PREDICT** on the worksheet back (band 4): nothing / crushed flat / pops open bigger?
- 3 Put ~1 **tablespoon of water** in the crush can; set it upright on the hot plate.
- 4 Wait for a **steady plume of steam** from the mouth — the steam is pushing the air out; say so while you wait.
- 5 Grip low with tongs; in **one fast smooth motion** flip it **mouth-straight-down** into the ice water.
- 6 **BANG** — crushed flat, inward from every side. Fish it out and stand it next to its **un-crushed twin**.
- 7 Reason it out, then **do the encore** — they will beg.

*Say: “Nothing touched that can but air. The push was always there — on the can, on you, on everything, from every side. The can only found out when it lost the push **INSIDE** that was holding it open.”*



Fig. 4 — before and after: the steam leaves, the sky moves in

TEACHER PREP — THE DAY BEFORE

Stage everything: rinsed cans, tongs, mitt, ice in the freezer, bowl, hot plate at its station, **tape line on the floor**. If induction, confirm a compatible setup or use the stove.

SAFETY

Adult-only. Steam burns are silent and fast: tongs + mitt, kids behind the tape line, only the adult’s hands cross it. The crushed can cools quickly in the water — check before passing.

What to watch for

- The can crumples **inward from all around**, not just one side
- The twin can beside it: same can, one difference — the air inside

EXPECTED RESULT

Instant loud implosion. **Steam pushed the air out; cold sealed the mouth and shrank the steam to drops; almost nothing inside pushed out while the whole atmosphere pushed in.** Weak crush = flip earlier next time? No — wait for a prouder plume and flip faster.

Magdeburg Hemispheres

KIDS HANDS-ON

RUN AT 12:55

15 MIN

The point

Take the air OUT of two joined bowls and the air still outside squeezes them together harder than the whole family can pull. No glue, no magnet — just sky.

Materials

- Magdeburg hemisphere set (toy) + its pump or valve
- Damp cloth (wipe the seal ring)

Steps

- 1 Show the halves apart: clap together, pull apart — **easy**. Nothing holds them.
- 2 Tell the story fast: **Magdeburg, 1654** — Otto von Guericke pumped the air out of two big metal bowls, and **two teams of horses** could not pull them apart.
- 3 Press the halves together and **pump the air out**.
- 4 Strongest kid pulls — fails. Two kids, **straight tug-of-war** — fails. Adults may strain too.
- 5 Ask: what is holding them? The missing air inside can't hold anything...
- 6 **Open the valve** — hisss — and the halves fall apart in your hands, all by themselves.

Say: "No glue. No magnet. No trick. Just the whole sky, pressing two little bowls together from every side — until we let the air walk back in."



Fig. 5 — muscle against sky — the sky wins

TEACHER PREP — THE DAY BEFORE

Wipe the seal ring with the damp cloth (a faintly moist ring seals best), find the pump/valve, and **dry-run one tug** so you know your set's grip.

What to watch for

- The same object, transformed only by removing the air inside
- The instant the valve opens, the "grip" vanishes
- Kids connecting it to the suction cups from this morning

EXPECTED RESULT

Pumped down, the halves resist a genuine two-kid tug; valve open, they fall apart. **The outside air pushes the halves together** once the inside push is gone — nothing sucks. Weak grip? Re-wipe the ring, pump to firm resistance, and pull straight, not sideways.

The Vacuum Jar Show

KIDS PUMP, TEACHER STAGES

RUN AT 1:10

20 MIN

The point

A vacuum is a space with the air taken out — a MISSING thing, not a thing. Five acts, one cause: watch what everything does when the pushing air goes away... and comes back.

Materials

- Hand vacuum pump + jar kit
- Marshmallows · one barely-inflated tied balloon
- Shaving cream + small cup
- Small cup of warm (not hot) tap water
- Loud beeping kitchen timer + folded cloth pad

Steps

- 1 **Predict before every act;** kids take turns pumping (the effort IS the lesson).
- 2 **Marshmallows:** they swell into giants... and shrivel smaller than they started when air returns.
- 3 **The lazy balloon:** a barely-blown balloon inflates itself — nobody blowing.
- 4 **Shaving cream:** a small blob billows into a mountain (a thousand tiny bubbles swelling at once).
- 5 **Warm water:** bubbles stream up from water that is only warm — the air's push helps keep water liquid.
- 6 **The timer:** beeping on its cloth pad, sealed in... the beep fades far away, and swells back with the air. **Sound needs air to carry it.**
- 7 After each act, **let the air hiss back in** and watch everything reverse.

Say: "A vacuum isn't a thing — it's a MISSING thing. A space with the air taken out. Watch what everything does when the push goes away."



Fig. 6 — the air inside them pushes out when the jar stops pushing in

TEACHER PREP — DAYS BEFORE

Test the kit once (seal, pump count, marshmallow dry-run) so there are no on-stage surprises. Moisten the gasket; stage the five acts in cups; fresh timer battery.

SAFETY

Use only the kit's own jar (made for vacuum) — never an ordinary glass jar. Warm water only; hot softens the seals. Marshmallows out of the jar are still snacks — ration accordingly.

What to watch for

- Everything reverses the instant air returns
- Pumping gets harder as the jar empties — the air fights to stay

EXPECTED RESULT

Marshmallows and balloon swell (their trapped air pushes out unopposed); cream billows; warm water streams bubbles (*the act a hand pump sometimes can't fully reach — bubbles streaming = win*); the beep goes **quieter and far away, not perfectly silent** — some sound sneaks through the glass and base.



*Air seems like nothing at all — but air is **real stuff**. It takes up space, it has weight, and it pushes on you from every side, right now.*

THE BIG IDEA

Anything that takes up space and has weight is **matter** — real stuff. Rocks are matter. Water is matter. And air passes both tests too, even though we can't see it. All the air together makes the **atmosphere**, an ocean of air wrapped around the whole Earth, held down by **gravity**. It gets thinner as you go up, until it runs out — and that is where space begins.

THREE PROOFS AIR IS REAL



IT TAKES UP SPACE — the upside-down glass stayed full of air, so the water could not get in and the paper stayed dry.



IT HAS WEIGHT — the balloon full of air pulled its side of the balance down. We even counted its weight in paper clips.



IT PUSHES FROM EVERY SIDE — when the air inside was gone, the air outside crushed a metal can flat. Nobody touched it.

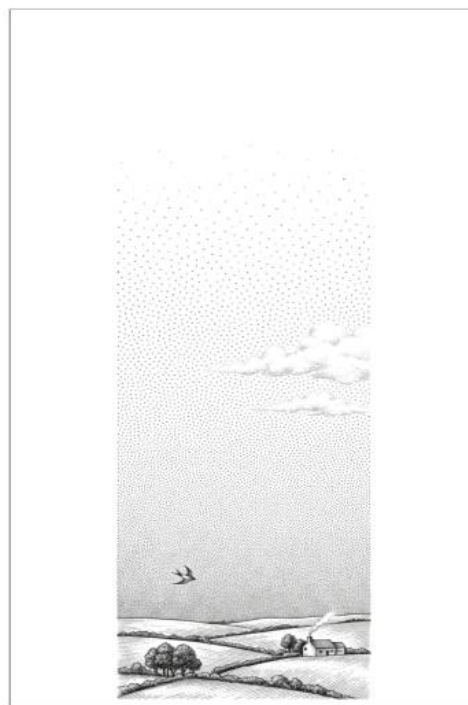


Fig. 1 — **the atmosphere**: you live at the bottom of an ocean of air. It thins as you climb — past the birds, the clouds, the jets — until space, where there is none.

WORDS TO KNOW

air

space

weight

pressure

vacuum

atmosphere

gravity

air — real stuff all around you that you can't see · **space** — the room something takes up · **weight** — how hard gravity pulls something down · **pressure** — air pushing on everything from every side · **vacuum** — a space with the air taken out · **atmosphere** — the ocean of air wrapped around Earth · **gravity** — the pull that holds everything down

WATCH FOR THIS IN EVERYDAY LIFE

- Playing in the bath, push a jar upside-down under the water. *Why won't the water go in?*
- Press a suction cup on the fridge and tug. *Nothing is inside it — so what is holding it on?*
- Squeeze a sealed bag of “nothing” or a pumped-up ball. *What is pushing back at you?*
- Your ears pop on a big hill or a long drive. *What just changed its push on your ears?*
- Feel the wind on your face. *What is bumping into you that you cannot see?*



air

air

space

space

weight

weight



1 • MATCH EACH THING TO ITS HOME IN THE SKY

The air ocean has layers. Draw a line from each picture's little circle to the circle of the layer where it belongs. The dots inside each layer show how much air is there.

SPACE
no air at all — the black sky begins

THERMOSPHERE
almost no air left up here

MESOSPHERE
shooting stars burn up here

STRATOSPHERE
calm, clear, and very quiet

TROPOSPHERE
where we live — all the weather is here. Lightly color this layer.

jet plane

shooting star

bird

space station

cloud

weather balloon



Gravity holds the whole ocean of air down onto the Earth — air has weight, so gravity can hold it. That is why it doesn't float away into space.



A guess is never wrong — it's a prediction, and predictions get tested. Circle one picture *before* each experiment.

1 • DRY PAPER UNDER WATER



A dry paper ball is wedged inside the glass. The glass goes upside-down, **all the way under the water**. What happens to the paper?



soaked through



stays dry



glass fills right up

draw what really happened

2 • THE BALLOON BALANCE



Two empty balloons hang level. We fill **ONE** with air and hang it back. What does the balance do? *After: how many paper clips to make it level again?*



full side sinks down



stays level



full side floats up

draw what really happened

3 • THE CANDLE AND THE CUP



A candle burns in a dish of water. We lower a glass right over it, rim under the water. What happens?



flame keeps burning



flame out, water climbs in



the cup pops off

draw what really happened

4 • THE CAN CRUSH



The can is hot and full of steam. We flip it upside-down into icy water. Nobody touches it. What happens?



nothing happens



crushed flat — from every side



pops open bigger

draw what really happened

Think like a scientist: for each experiment, tell someone **WHO** did the pushing. Hint: it is always the same invisible somebody.

**(VERSE 1)**

You can't see it, can't hold it, but it's everywhere
you go,
It fills up your balloon and every bubble that you
blow.
It kept the paper dry inside the glass beneath the
sea —
The glass was never empty... it was full as full can
be!

(CHORUS — CALL AND RESPONSE)

Air is real! (Air is real!)
It takes up space — that's how we know!
Air is real! (Air is real!)
It has a weight — the balance told us so!
It pushes every side of me, it pushes high and low
—
We live down at the bottom of an ocean of air,
heigh-ho!

(VERSE 2)

It tipped the balance over when we pumped one
balloon fat,
It crushed a can of metal — BANG! — as quick as
that!
It squeezes from all around us, but we never feel
it squeeze,
'Cause it pushes up and down and sideways, even
on our knees!

(CHORUS)**(VERSE 3)**

Take the air out of a space and a vacuum's what
you've made —
The marshmallows puff up giant, and the beeper
starts to fade.
And gravity holds our blanket down, way up until
it's gone —
The atmosphere, our ocean of air... so breathe,
and sing along!

(CHORUS — BIG FINISH)

How to use it. Play the recording once while everyone just listens. Play it again and join in on the chorus only — that is the part carrying the lesson. By the third time most children have the chorus. Then close the binder and ask what the words actually mean; a child who can sing it and explain it has the idea for good.