

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.