ISLAND BREEZE TECHNICIAN CERTIFICATION PROGRAM

Heat, Temperature, and Comfort Science

MODULE F3 **FOUNDATIONS** **PREREQ F1**

You are standing in a customer's living room in July. The thermostat says 78. The customer says "it feels like a swamp in here." The air temperature is fine, so what is the complaint actually about? By the end of this module you will know, because comfort is not just temperature. It is temperature plus moisture plus how heat moves through a house. Every diagnosis you will ever make starts with the science in this module.

Short Version

Heat is energy, and it always moves from hot to cold on its own, never the other way. Temperature measures how hot something is; heat measures how much energy is there. Sensible heat changes temperature. Latent heat changes state (like water turning to vapor) without changing temperature. We measure heat in BTUs, and one ton of cooling moves 12,000 BTU per hour. Heat enters a house three ways: conduction (through solid stuff), convection (carried by moving air), and radiation (beamed across space, like the sun). Humidity matters because your body cools itself by evaporating sweat, and wet air slows that down. An air conditioner does two jobs: it removes sensible heat (lowers temperature) and latent heat (pulls moisture out of the air). In Phoenix, the air is usually so dry that almost all the work is sensible, until monsoon season flips the table.

Key Values

VALUE	NUMBER	WHAT IT MEANS
BTU (British Thermal Unit)	Heat to raise 1 pound of water 1 degree F	The basic unit of heat in HVAC. A kitchen match burned completely releases about 1 BTU.
1 ton of refrigeration	12,000 BTU/h	The rate of cooling. Comes from melting 1 ton (2,000 lb) of ice in 24 hours.
Latent heat of fusion (water)	144 BTU/lb	Heat absorbed to melt 1 lb of ice at 32 F with no temperature change.
Latent heat of vaporization (water)	About 970 BTU/lb	Heat absorbed to boil 1 lb of water at 212 F with no temperature change. This huge number is why phase change is the engine of air conditioning.
Specific heat of water	1.0 BTU/lb per degree F	The definition the BTU is built on. Ice is about 0.5.
Comfort envelope (typical)	68 to 78 F, 30 to 60 percent RH	Where most people report feeling comfortable. ACCA design targets sit inside this box.
Standard indoor design (cooling)	75 F, 50 percent RH	The indoor condition load calculations aim for.

VALUE	NUMBER	WHAT IT MEANS
Phoenix outdoor design (cooling)	112 F dry bulb	The 1 percent design condition used for Phoenix load calculations. Not the record high; the design point.
Phoenix typical summer RH (pre-monsoon)	Often 10 to 20 percent outdoors	Very low latent load. Most of the cooling job here is sensible.
Sensible heat formula for air	BTU/h = 1.08 x CFM x temperature difference	Example: 400 CFM with a 20 F drop across the coil = 1.08 x 400 x 20 = 8,640 BTU/h of sensible cooling.

Field Checklist

Comfort complaints are science problems wearing customer clothing. Map them:

- ☐ "Too hot upstairs" = sensible heat problem. Hot air rises (convection), the upstairs sits under a radiant-baked attic, and supply ducts running through that attic pick up heat before the air reaches the rooms. Check attic duct condition, insulation, and airflow balance before touching the equipment.
- ☐ "It feels clammy" or "sticky" = latent heat problem. The system is dropping temperature but not pulling enough moisture. Common cause: oversized equipment that satisfies the thermostat fast and shuts off before the coil has time to wring water out of the air.
- ☐ "Dry throat, static shocks, cracked skin" = humidity too low. In Phoenix this is the normal state of the air for most of the year. Long runtimes in very dry air drive indoor RH down further.
- ☐ "It never catches up in the afternoon" = heat gain exceeds capacity at peak. Check radiant gain paths (west windows, attic), duct losses, and airflow before assuming the unit is undersized or low on charge.
- ☐ "One room is always cold in winter, hot in summer" = that room has a different gain and loss picture (more exterior wall, more window, longer duct run). Room comfort follows room load.

PHOENIX FIELD NOTE

During monsoon weeks (roughly July through September) outdoor dew points jump from the 30s into the 60s. A house that felt fine all June can suddenly feel clammy at the same thermostat setting because latent load showed up. Expect "it stopped working right" calls when nothing is broken. The climate changed, not the equipment.

Full Breakdown

What heat actually is

Heat is energy stored in the motion of molecules. Every solid, liquid, and gas is made of molecules jiggling, sliding, or flying around. The faster they move, the more heat energy the substance holds. "Cold" is not a thing you can add to a room. Cold is just the absence of heat, the same way dark is the absence of light. An air conditioner does not make cold. It removes heat from inside the house and dumps it outside.

One law runs this entire trade: heat always flows from hotter to colder, on its own, every time. It never flows uphill from cold to hot by itself. Your whole career is built on putting something colder than the room inside the house (the indoor coil) and something hotter than the outdoors outside the house (the outdoor coil), so heat flows where you want it. How we make a coil colder than the room and hotter than a 110 F afternoon is the subject of module F4. For now, lock in the direction rule: hot to cold, always.

Temperature is not heat content

Temperature measures average molecular speed. Heat content measures total energy. These are different, and confusing them causes real misdiagnoses.

Picture a cup of coffee at 180 F and a bathtub of water at 100 F. The coffee is hotter (higher temperature), but the bathtub holds far more total heat energy because there is so much more water. Drop an ice cube in each: the coffee cools dramatically, the tub barely notices.

This matters in the field because a thermometer only tells you temperature. It does not tell you how much heat the system is actually moving. Two houses can both be at 80 F inside, but the one full of moist air holds much more total heat energy, and the system has to work harder to make it comfortable.

Sensible heat vs latent heat

Sensible heat is heat you can sense. Add it and the temperature goes up; remove it and the temperature goes down. A dry bulb thermometer (a regular thermometer) measures the result of sensible heat changes.

Latent heat is hidden heat. It is energy absorbed or released when a substance changes state (solid to liquid, liquid to vapor, or back) while the temperature holds still. The energy goes into rearranging the molecules instead of speeding them up.

The cleanest way to see both is to walk one pound of ice all the way to steam:

1. **Ice at 0 F warming to 32 F.** Sensible heat. Ice has a specific heat of about 0.5, so each degree takes 0.5 BTU. From 0 to 32 is 32 degrees: 32 x 0.5 = 16 BTU. The thermometer moves the whole time.
2. **Ice melting at 32 F.** Latent heat. The thermometer freezes at 32 while the ice absorbs 144 BTU to become water. All 144 BTU went into breaking the solid structure, none into temperature.
3. **Water warming from 32 F to 212 F.** Sensible heat again. Water's specific heat is 1.0, so 180 degrees takes 180 BTU.
4. **Water boiling at 212 F.** Latent heat again, and here is the showstopper: turning that pound of water into steam takes about 970 BTU while the thermometer sits dead still at 212. The latent step is more than five times bigger than heating the water all the way from freezing to boiling.
5. **Steam above 212 F.** Sensible heat once more. Vapor that is heated above its boiling point is called superheated, a word you will live with for the rest of your career starting in F6.

Add it up: 16 + 144 + 180 + 970 = 1,310 BTU to take one pound of ice at 0 F to steam at 212 F, and 1,114 of those BTUs (144 + 970) were latent, invisible to any thermometer. Phase change is where the big energy moves, which is exactly why refrigeration systems boil and condense a fluid instead of just blowing air over something cool. That story is F4.

Now connect it to the house. When your indoor coil runs colder than the dew point of the room air, water vapor in the air condenses on the coil and runs down the drain. Every pound of water you pull out of the air released roughly 1,000 BTU of latent heat into your coil. That is capacity spent on moisture instead of temperature. A muggy house eats your capacity without moving the thermometer much.

> **PHOENIX FIELD NOTE**
>
> In a dry Phoenix June, the condensate drain on a system may run nearly dry because there is almost no moisture to remove. Nearly all the system's capacity goes to sensible cooling. Do not assume a dry drain line means a problem in this climate. In Florida it might; here it is often just physics.

BTU and the ton of refrigeration

The BTU (British Thermal Unit) is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Small unit, so HVAC talks in thousands: a typical residential system moves tens of thousands of BTUs per hour.

The "ton" is a history lesson that stuck. Before mechanical refrigeration, America cooled things with harvested lake ice, sold by the ton. When refrigeration machines arrived, buyers wanted to compare them to what they knew, so capacity was rated against melting ice. Melting one ton (2,000 lb) of ice takes 2,000 x 144 BTU = 288,000 BTU. Spread over 24 hours: 288,000 / 24 = 12,000 BTU per hour. So one ton of refrigeration = 12,000 BTU/h. A "3 ton" air conditioner moves about 36,000 BTU of heat per hour out of the house. Note that a ton is a rate (BTU per hour), not an amount. It tells you how fast a system moves heat, the way horsepower tells you how fast an engine does work.

Worked field example with the air formula from the Key Values table: a system moving 1,200 CFM (cubic feet per minute of airflow) with air entering the coil at 78 F and leaving at 58 F has a 20 F temperature drop. Sensible capacity = 1.08 x 1,200 x 20 = 25,920 BTU/h, a bit over 2 tons of sensible cooling. You will use this exact arithmetic on real jobs in C12.

The three ways heat moves

Heat transfers by exactly three mechanisms. Every heat problem in every house is some mix of the three.

Conduction is heat moving through a material by direct molecular contact, like a pan handle getting hot. In a house: heat conducts through walls, ceilings, windows, and doors whenever it is hotter on one side than the other. Insulation works by being bad at conduction. The R-value on insulation is literally a rating of resistance to conductive heat flow: higher R, slower heat.

Convection is heat carried by a moving fluid (liquid or gas; in houses, air). Warm air expands, gets lighter, and rises; cool air sinks. That is why the upstairs runs hot and the basement runs cool, and why your supply registers and returns are placed where they are. Infiltration (outside air leaking in through cracks, can lights, and door gaps) is convection sneaking heat and humidity into the house. Your duct system is forced convection: a blower deliberately moving heat around in air.

Radiation is heat traveling as invisible infrared energy across open space, no contact and no air required. The sun heats your face through 93 million miles of vacuum by radiation. In a house: sunlight through west-facing glass, a roof deck baking the attic, a hot ceiling radiating down onto the people below. Radiant heat does not show up on an air thermometer until it lands on a surface and warms it, which is why a room can measure 75 F and still feel hot when a big sun-soaked window is beaming at you.

House walk-through, all three at once: the sun radiates onto the roof. The roof deck conducts heat into the attic framing and radiates into the attic air space, which convects heat around the attic. The attic floor conducts heat down through the ceiling drywall, which then radiates and convects into the rooms below. Meanwhile, attic supply ducts soak up attic heat by conduction through the duct walls, and the blower convects that stolen heat straight into the bedrooms.

PHOENIX FIELD NOTE

On a 115 F day a Phoenix attic commonly runs 140 to 160 F, driven by radiation off the roof deck. Equipment and ductwork up there sit in that oven. A duct carrying 58 F supply air through a 150 F attic is fighting a 90 plus degree temperature difference across a thin insulated wall. Radiant barrier, duct insulation quality, and duct sealing are not upsells in this market; they are physics. This is also a safety review from F1: that same attic is a heat injury environment for you.

Humidity: the moisture side of the job

Air is a sponge for water vapor, and the warmer the air, the more vapor it can hold. Two ways to describe how much water is in air:

Absolute humidity (in psychrometrics, humidity ratio) is the actual amount of water in the air, expressed as grains of moisture per pound of dry air. There are 7,000 grains in a pound. This number does not change when temperature changes; it only changes when you add or remove water.

Relative humidity (RH) is a percentage: how full the sponge is compared to how much it could hold at its current temperature. Here is the trap: heat air and RH drops even though the water content did not change, because a warmer sponge is a bigger sponge. Cool air and RH climbs. Same water, different percentage.

Dew point is the temperature at which air becomes 100 percent full and water starts condensing out as liquid. It is the most honest moisture number because it does not move with temperature. Cold drink can sweating on the patio: the can's surface is below the air's dew point, so vapor condenses on it. Your evaporator coil is that drink can, on purpose. Coil surface below the room air's dew point = condensation = latent heat removal = water down the drain.

Dry bulb vs wet bulb. Dry bulb temperature is what a regular thermometer reads: pure sensible information. Wet bulb temperature is read with a thermometer whose sensor is covered by a wet sock with air moving across it. Evaporation off the sock cools the sensor, and the drier the air, the more evaporation, so the wet bulb reads lower than the dry bulb in anything but saturated air. Wet bulb bakes the moisture information into one number, which is why charging charts and airflow targets ask for it. The gap between dry bulb and wet bulb is a quick humidity gauge: big gap means dry air, small gap means humid air, no gap means 100 percent RH.

Reading a psychrometric chart (the simple version)

Psychrometrics is the study of air and water vapor mixtures, and the psychrometric chart is the whole subject drawn on one page. The full chart looks like a plate of spaghetti, so start with just three things (see figure F3-3):

- **Bottom axis: dry bulb temperature.** Move right, the air is warmer.
- **Right axis: humidity ratio** (grains of moisture per pound of dry air). Move up, the air is wetter.
- **Curved lines sweeping up and to the right: relative humidity.** The big outer curve is 100 percent RH, called the saturation curve. Air cannot exist above it.

Any air condition is a single dot on this chart. Once you plot the dot, everything else can be read off: RH, dew point (slide straight left from the dot to the saturation curve, then read the temperature there), and wet bulb. Air conditioning processes are just moves on the chart: sensible cooling slides the dot straight left (cooler, same moisture). Dehumidification pulls the dot down (same temperature, less moisture). A real evaporator coil does both at once: the dot moves left and down. The comfort zone is a box on the chart, roughly 68 to 78 F and 30 to 60 percent RH. Your job, described in one sentence: take the dot wherever you find it and move it into the box.

PHOENIX FIELD NOTE

Evaporative coolers (swamp coolers) only make sense on a psych chart. Evaporating water into air trades sensible heat for latent heat: the dot slides left (cooler) while climbing up (wetter), roughly along a constant wet bulb line. In dry pre-monsoon Phoenix air there is plenty of room to slide before the air gets uncomfortably humid, so swamp coolers work. When monsoon moisture arrives, the starting dot is already high on the chart, there is nowhere left to slide, and every swamp cooler in town quits cooling at the exact moment people need it most. Same machine, different starting dot.

Human comfort: why your body cares

Your body is a heat machine. At rest it produces roughly 400 BTU/h of waste heat, more when active, and it must shed that heat continuously to hold its core temperature. It sheds heat using the same three transfer modes you just learned, plus evaporation:

- **Convection:** air moving across skin carries heat away. This is why a fan feels cooling even though it does not lower the air temperature one bit.
- **Radiation:** your skin radiates to cooler surrounding surfaces. Hot surfaces (a sun-baked window, an uninsulated ceiling) radiate back at you and cancel this channel, which is why a room can feel hot at a normal air temperature.
- **Evaporation:** sweat absorbs body heat to evaporate, about 1,000 BTU per pound of sweat, the latent heat of vaporization working for you.

Now the punchline for our trade: as air temperature climbs toward skin temperature (low 90s F), convection and radiation fade out, and evaporation becomes the only working channel. Evaporation depends on the air being able to accept more vapor. Humid air accepts vapor slowly, so sweat sits on skin instead of evaporating, and you feel hot and sticky even at a moderate temperature. That is the entire mechanism behind "it feels clammy": the air temperature is fine but the latent channel is jammed. It is also why 105 F in dry Phoenix feels more survivable than 95 F in humid Houston, and why the comfort envelope is a two-dimensional box (temperature and humidity), not a single thermostat number.

One more comfort lever: mean radiant temperature, the average temperature of the surfaces around a person. A 75 F room under a 95 F ceiling feels warm because the radiation channel is running backward. This is why attic insulation is a comfort fix, not just an energy fix.

How heat gets into a home

Cooling load is the sum of every heat path into the conditioned space at design conditions. The major paths (see figure F3-4):

1. **Roof and ceiling:** radiation loads the attic, conduction brings it through the ceiling. In hot climates this is a top contributor.
2. **Windows (solar gain):** radiation straight through glass, strongest on west and east exposures. Often the largest single sensible gain in the afternoon.
3. **Walls and doors:** conduction driven by the indoor-to-outdoor temperature difference.
4. **Infiltration:** outdoor air leaking in through cracks and penetrations, carrying both sensible heat and (in humid weather) latent moisture.
5. **Duct gains and leakage:** ducts in unconditioned attics absorb heat by conduction, and leaky ducts dump bought-and-paid-for cool air into the attic. A load on the system that the thermostat never sees directly.
6. **Internal gains:** people (about 400 BTU/h each, part sensible, part latent), cooking, ovens, lighting, TVs, computers. A packed living room on game night is a real load change.

Professionals quantify all of this with ACCA Manual J, the residential load calculation standard, using the 1 percent cooling design condition for the location rather than record extremes. You will run Manual J yourself in M37. For now you need the concept: equipment capacity should match calculated load, and every comfort complaint traces back to one or more of these paths.

> **IB STANDARD**
>
> Island Breeze sizes equipment from a load calculation, not from square footage rules of thumb and not by matching whatever was there before. A like-for-like swap repeats the original sizing mistake. When you see short cycling, poor humidity control, or comfort complaints at design conditions, treat "wrong size" as a live suspect and say so in your notes.

Why bigger is not better

The instinct says a bigger air conditioner cools better. The science says otherwise. An oversized unit slams the dry bulb temperature down and satisfies the thermostat in a few minutes, then shuts off. Short runtimes mean the coil barely got cold and wet before quitting, so latent removal is poor: cool but clammy. Short cycling also means more starts per hour, and starts are the hardest moments of a compressor's life. Oversizing buys you worse comfort, worse humidity control, and shorter equipment life. Right-sized equipment runs long, steady cycles: better dehumidification, better room-to-room evenness, less stress.

> **PHOENIX FIELD NOTE**
>
> Phoenix's tiny latent load makes oversizing slightly more forgivable here than in humid climates, and you will meet plenty of oversized systems that the owners think are fine. The penalties still apply: short cycling stress, temperature swings, and a unit that handles monsoon weeks poorly because its latent performance was never there. Dry climate hides the symptom most of the year; it does not repeal the science.

Common Mistakes

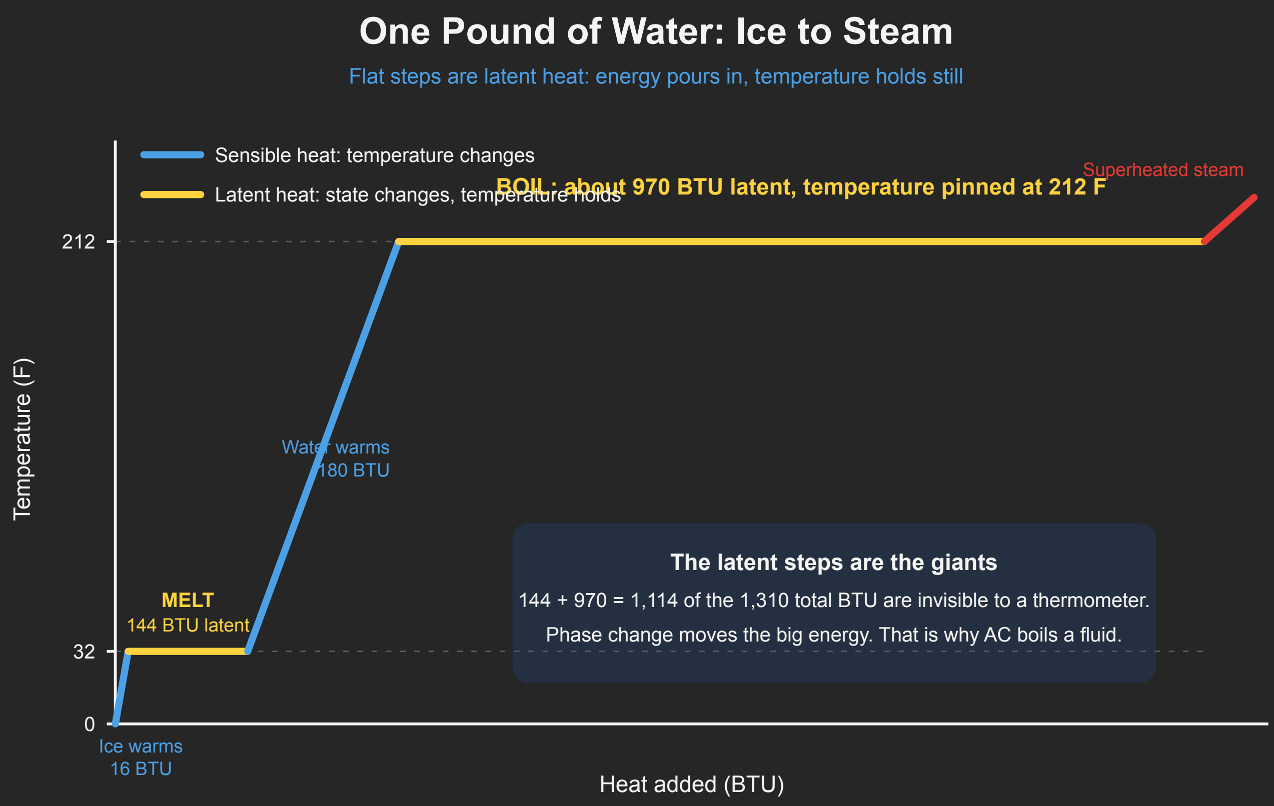
1. **Confusing temperature with heat.** Temperature is intensity; heat is quantity. A reading on a thermometer tells you nothing about how many BTUs are moving. Capacity questions are always BTU questions.
2. **Ignoring latent load.** Diagnosing comfort by dry bulb alone misses half the picture. A system can hit 75 F and still leave a miserable house if moisture stays high. Always think in both dimensions: temperature and humidity.
3. **Assuming bigger equipment means more comfort.** Oversizing causes short cycling, poor moisture removal, and equipment stress. Match capacity to calculated load.
4. **Blaming equipment for envelope problems.** "Too hot upstairs" is usually attic radiation, duct gain, and convection stacking, not a failing condenser. Check the heat paths before condemning hardware.
5. **Treating RH as a fixed property of the air.** RH changes with temperature even when moisture does not. Use dew point when you need the honest moisture number.
6. **Forgetting that a fan does not remove heat.** Moving air improves convective and evaporative cooling off skin, so people feel cooler, but the room's heat content is unchanged (the fan motor actually adds a little). Never present air movement as a substitute for heat removal.
7. **Reading a dry condensate line as a fault in a dry climate.** In low dew point conditions there may simply be no moisture to remove. Confirm with the psychrometrics before chasing a phantom problem.

What Is Next

F4 takes the two biggest ideas from this module, latent heat and "hot flows to cold," and shows you the machine built on them: the refrigeration cycle. Everything you just learned about boiling, condensing, and moving heat is about to become a loop of copper with a fluid inside.

Module Visuals

1 SENSIBLE LATENT STAIRCASE



One Pound of Water: Ice to Steam

Flat steps are latent heat: energy pours in, temperature holds still

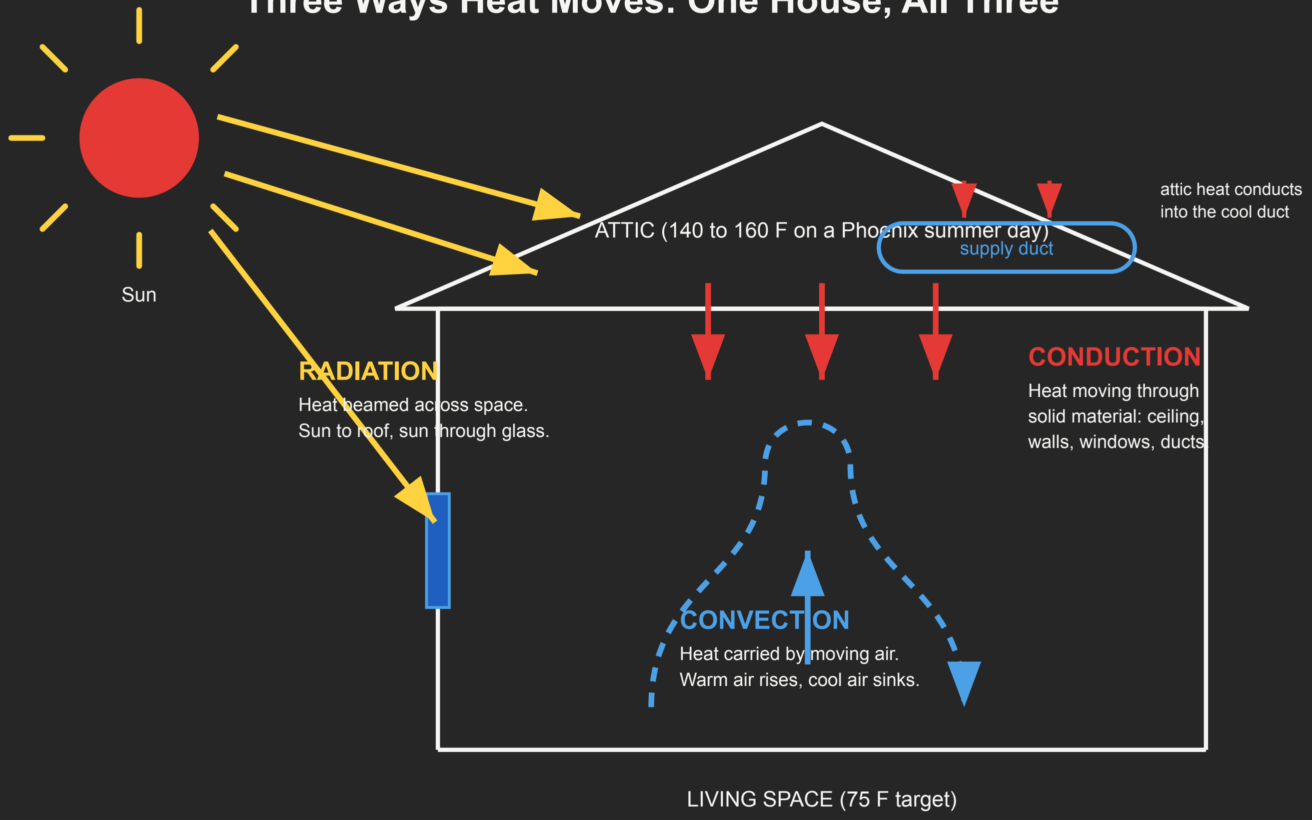
The latent steps are the giants

144 + 970 = 1,114 of the 1,310 total BTU are invisible to a thermometer.

Phase change moves the big energy. That is why AC boils a fluid.

2 HEAT TRANSFER MODES

Three Ways Heat Moves: One House, All Three



RADIATION

Heat beamed across space.
Sun to roof, sun through glass.

CONDUCTION

Heat moving through
solid material: ceiling,
walls, windows, ducts

CONVECTION

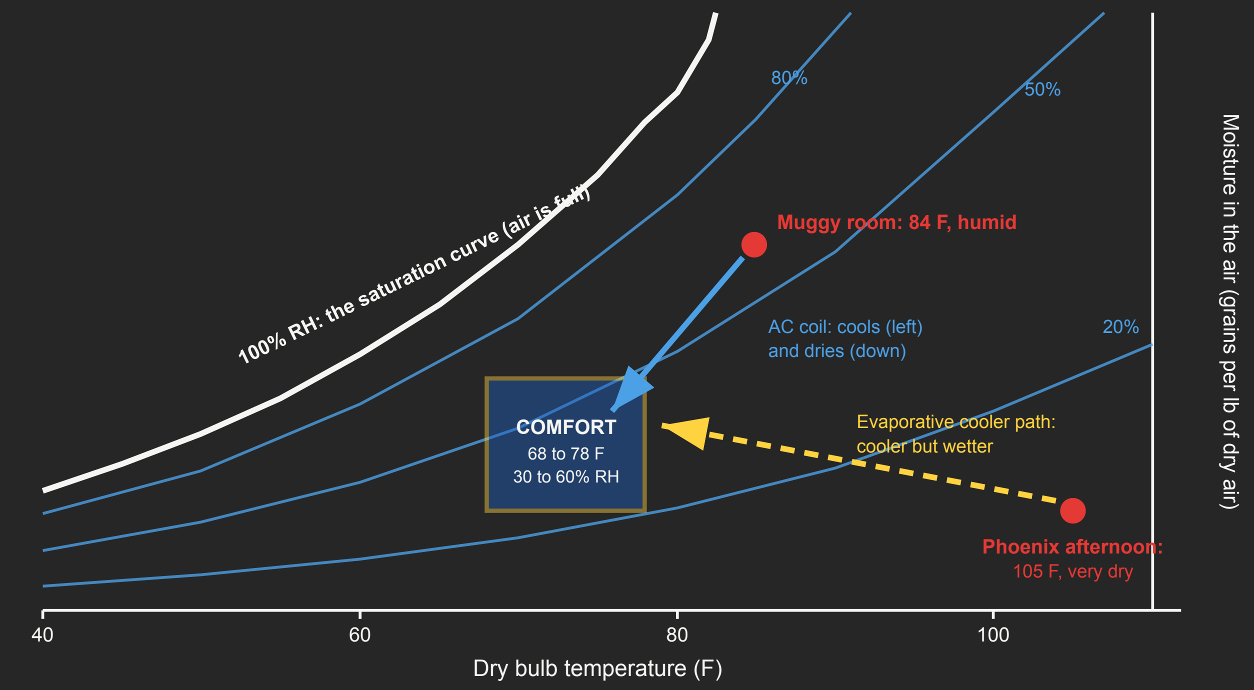
Heat carried by moving air.
Warm air rises, cool air sinks.

Every comfort complaint is some mix of these three paths. Find the path before blaming the equipment.

3 PSYCHROMETRIC COMFORT ZONE

The Psychrometric Chart, Simplified

Any air condition is one dot. Comfort is a box. Your job: move the dot into the box.

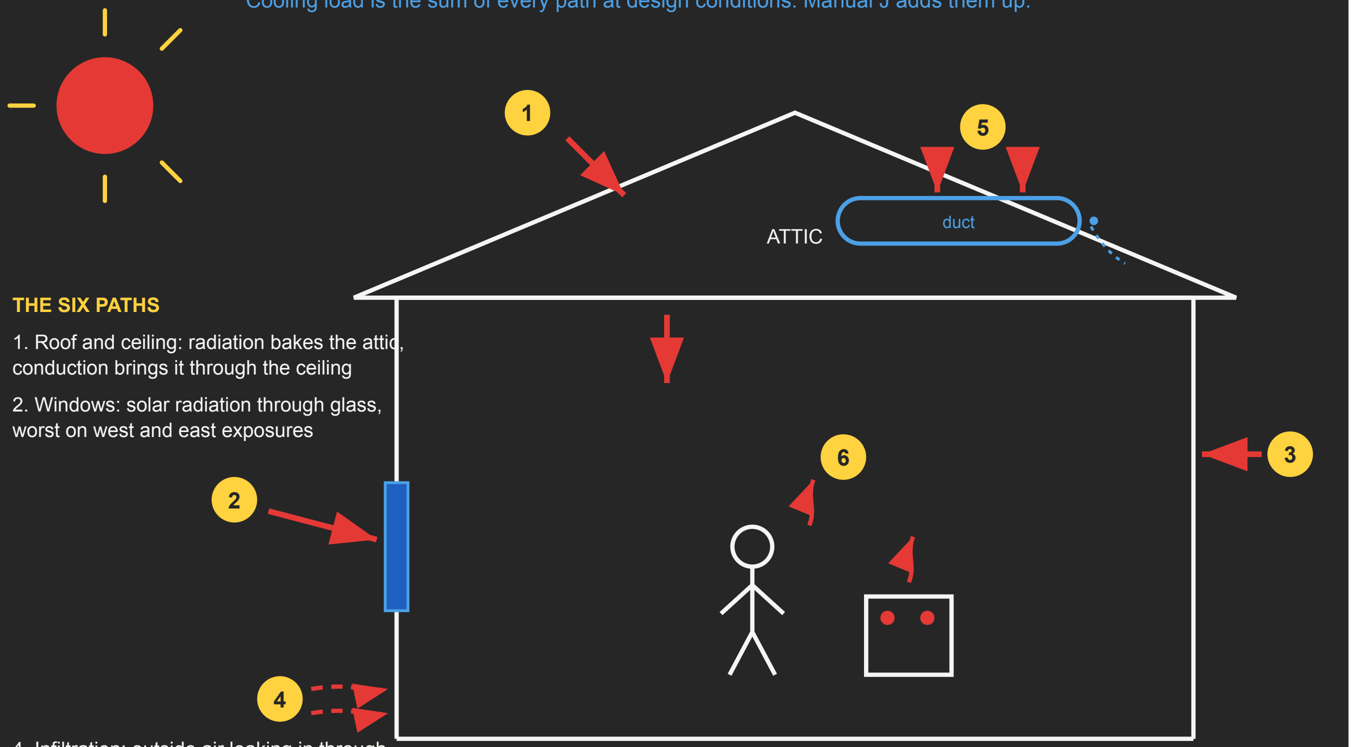


Dew point: slide any dot straight left until it hits the saturation curve, then read the temperature below.

4 HEAT GAIN PATHS

Six Paths Heat Takes Into a Home

Cooling load is the sum of every path at design conditions. Manual J adds them up.



THE SIX PATHS

1. Roof and ceiling: radiation bakes the attic, conduction brings it through the ceiling

2. Windows: solar radiation through glass, worst on west and east exposures

4. Infiltration: outside air leaking in through cracks, gaps, and penetrations

3. Walls and doors: conduction from the temperature difference

5. Duct gain and leakage in the hot attic 6. Internal gains: people, cooki

A person at rest adds about 400 BTU/h. A full living room is a real load change.