Ballooning Basics

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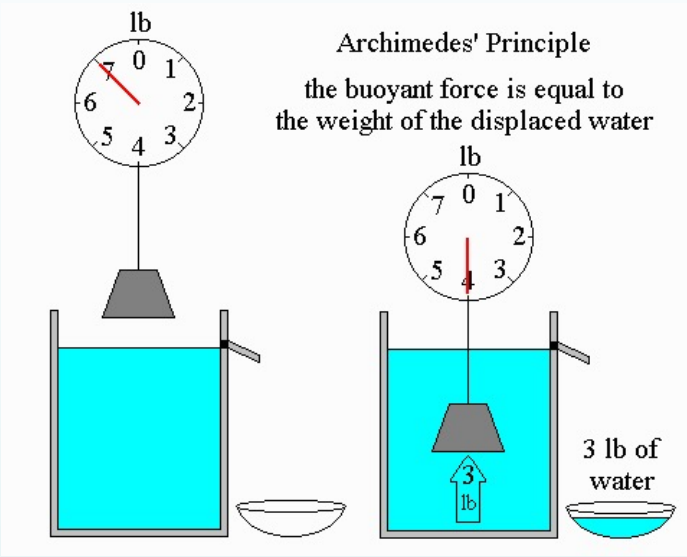
Outline

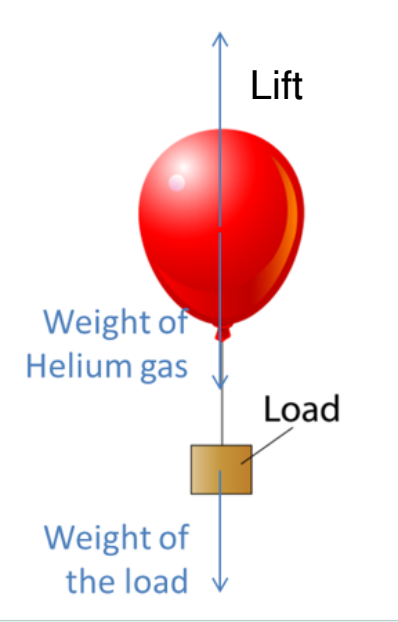
- Why Balloons Float
- Journey of a Scientific Balloon
  - Phase I: Pre-Flight and Inflation
  - Phase II: Launch
  - Phase III: Ascent
  - Phase IV: Burst & Descent
  - Phase V: Landing and Recovery
- Payloads – good design features
  - Typical Payloads
  - Payload Prep and Tie-On

Buoyancy: Archimedes was right!

- Archimedes Principle holds in air as well as water: the lift force on a helium balloon is equal to the weight of air displaced by the balloon
- So as long as this lift force is greater than the combined weight of the balloon skin, the enclosed helium, and the payloads, the balloon will go up



physics.weber.edu/carroll/archimedes/principle.htm



- If you know how much weight you want to lift, you can calculate how big a balloon you need
- This is complicated by ambient air density, which depends on pressure and temperature, which change with altitude
- So best procedure: measure payload weight W, measure lift at neck of balloon L, verify L > W → release balloon!

spmphysics.onlinetuition.com.my/2013/06/archimedes-principle-structure-question_1043.html

Scientific Ballooning

- Typical Flight Line-Up
  - Balloon
  - Cut-Down Device
  - Parachute
  - Tracking Module
  - Payload(s)
- Flight Operations
  - Once balloon is released, it ascends to higher and higher altitudes and gets bigger and bigger until it bursts
  - After burst, the payload string falls until parachute inflates and slows descent
  - Payload string is tracked to landing site so payloads can be recovered

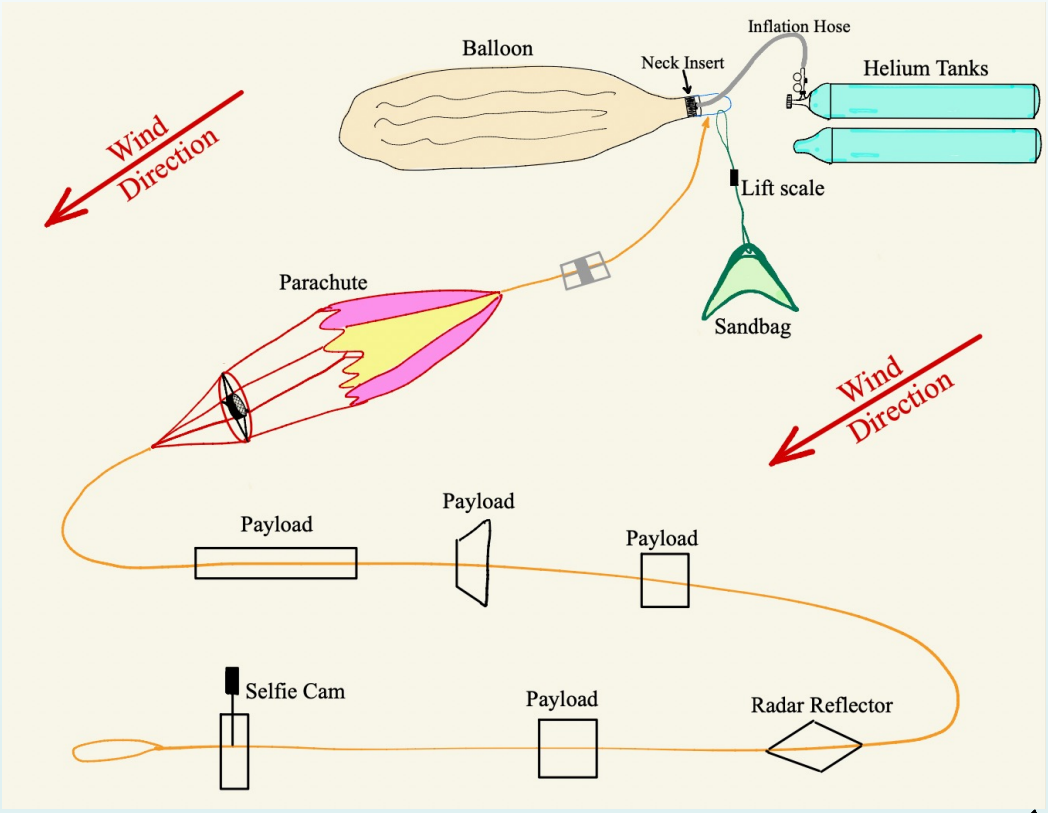
PreFlight Preparations

- Preparing for a launch starts days ahead of time (especially if launch site is some distance away from main base of operations):
  - 3 days: personnel and launch operation planning (ie, who's doing what)
  - 2 days: weather check, trajectory prediction, and launch site selection
  - 1 day before: final flight readiness review and packing of vehicles
  - Launch day: crack o'dawn departure to launch site
- Checklists are an essential part of every step:
  - Packing Checklist and Payload Emergency Toolbox
  - Launch Day Operations Checklist and Inflation Checklist
  - Each payload should have their own checklist for preflight prep
- Good Advice from a NASA Mission Director: "Figure out the worst case reasonable scenario, and then plan for it!"

Launch Site Set-Up

- Helium tanks and balloon should be located upwind of everything else
- Balloon neck should be anchored to something heavy during inflation
- Balloon should be handled with cotton or latex/nitrile gloves
- Make sure parachute is untangled before attaching
- Payloads can be tied on flight line the night before

It's a good idea to have a large tarp to lay everything out on prior to inflation



Balloon Inflation

- Balloon must be handled carefully (use gloves, lay out on clean sheet)
- Inflation is done through hose to neck insert
- Neck is anchored to ground and stabilized using tethers
- Helium pressure is monitored as balloon is inflated until desired lift is obtained
- Lift is measured with inline luggage scale

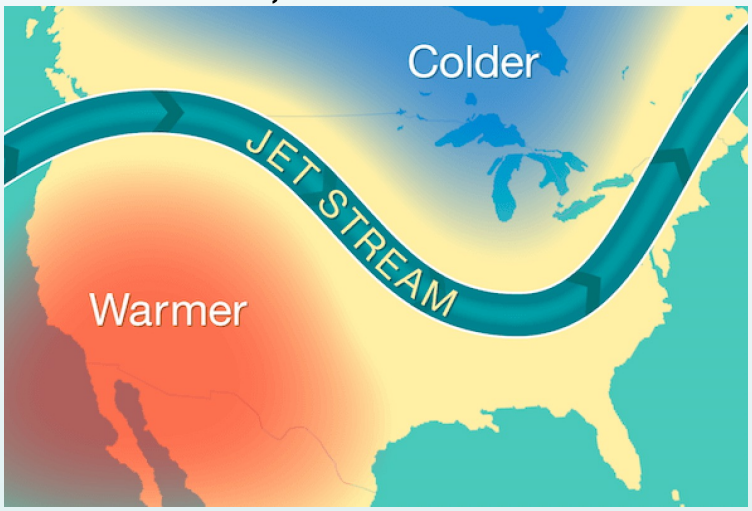
Final Launch Checklist and Release

- Before release of any balloon in any weather, it is essential to go through final checklist for positive verification:
  - Clearance from Tower (if needed)? Look and listen for air traffic (and birds!)
  - All payloads turned on? All cameras turned on?
  - All comm links functional? Is tracking good?
- Different ways of releasing balloon and payloads:
  - **Hand-over-hand Walkup** [low wind]: one or two people gradually raise the balloon, parachute, and stack of payloads off the ground until all are hanging, then let go
  - **Tethered Release** [moderate wind]: payload stack is raised off the ground by paying out tether lines that run through a ring at neck of balloon; let go of one end of each tether line to release balloon
  - **Horizontal Launch** [high wind]: once balloon is inflated and payloads ready, balloon is held upwind by one person on neck who then lets go (works best for short payload string and balloon with extra lift)
- Release of balloon and payloads gets more and more difficult, risky, and stressful with high winds and gusty winds.

LAUNCH: Walkup and Tethered Release (2min 20 sec)

Ascent Phase

- Once released, the balloon will travel with prevailing winds
- Winds shift direction and speed at different altitudes
- The **Jet Stream** is a dominant effect over North America and will affect the balloon trajectory primarily between 30,000 ft and 50,000 ft altitude
- In the jet stream, balloon velocity can easily exceed 100 mph
- Severe turbulence can occur in the shear layers above and below the jet stream
- Generally the winds are more calm at higher altitudes - often a wild ride regardless!



- End of ascent phase is determined by balloon burst or cut-down
- For balloon flights that have a short ground track it may be possible to chase the balloon and be close to the predicted landing; but when the jet stream is involved, it's good to have a recovery team in place

Descent Phase

- Immediately after burst, payloads fall very quickly through the first 20,000 to 30,000 ft because air is very thin
- Parachute acts like a streamer initially, then inflates by about 60,000 ft altitude
- Payload string descent is slowed to roughly 15 ft/sec before touchdown
- No control over exact landing spot

Fundamental Rule of Ballooning: If there is a wide-open field, the payloads will get stuck on top of the tallest tree!

Rules for Payload Recovery

- Send out a small party to locate payloads
- Make a good faith effort to contact property owner
- Always bring all your recovery gear

  (professional arborist sling shot, extendable painting poles, ropes, saw, bright colored vests, hard hats, gloves, creative solutions)
- Have a professional tree climber on call!

Interesting Payloads

The best payloads are those that are simple and take advantage of some unique feature of the high altitude balloon flight:

- Atmospheric sensing: temp, pressure, winds aloft, humidity, composition, contaminants, biological / microbial lifeforms, dust particle distribution, radiation (all of these quantities can be measured as a function of altitude)
- Engineering demonstration: deployment mechanism, solar cell efficiency, battery performance, insulation materials, active thermal control, load cell , degradation of 3D-printed material
- Communications: position reporting, tracking aids, uplink and downlink radio communications, data or live video downlink, comm link between payloads
- Imaging: still pictures or video, looking up, down, or toward horizon, visible or IR wavelengths, camera on a boom, object on a boom
- Operations: cut-down device, venting system, ballasting system, stabilization system, de-spin mechanism
- Dropped Payloads (not recommended): gliders, parafoils, lifting body

Payload Design Rules

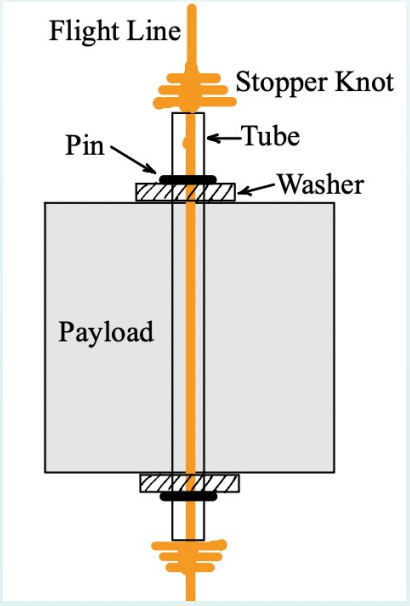
- Mandatory Payload Requirements
  - total weight of all payloads on a flight < 12 lbs
  - no single payload > 6 lbs
  - no payload shall create a hazard
- Good Payload Practices
  - keep all payloads as light weight as possible
  - build payload enclosures out of foamcore or polyethylene foam
  - no sharp edges or sharp points (other than flexible antennas)
  - every payload should have an external on-off switch
  - payloads should open from the side for easy access on the pad
  - don't fly liquids or any living creatures
- Most important: Safety first!
  - make sure all payloads are tied securely to flight line

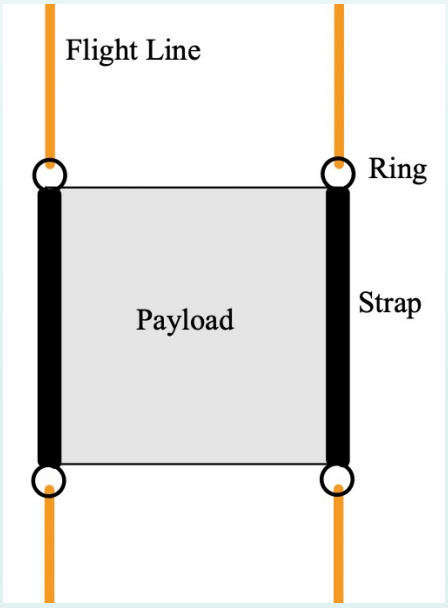
Payload Stringing

There are at least two methods of stringing payloads:

– one continuous line runs through a tube installed through the center of each payload which is secured to the flight line using knots above and below the tube

– multiple lines are used to connect all the payloads together using rings above and below each payload; the rings are attached to straps which carry the load rather than the payload enclosure itself





Maryland

Montana

Common Knots

Knot Tying is a life skill that is particularly useful for people who fly high altitude balloons

square knot

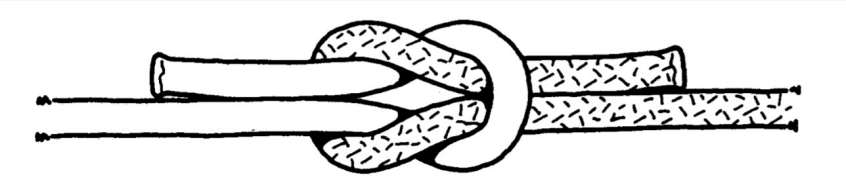
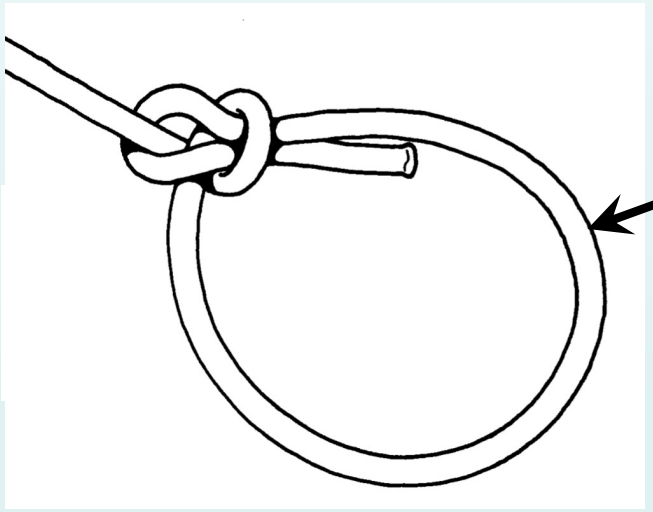
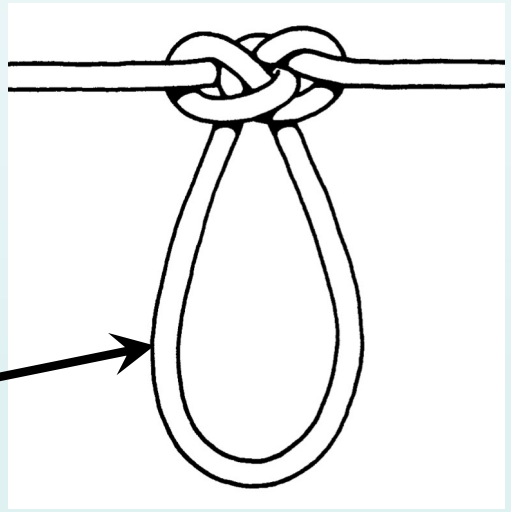


figure-8 bend



bowline loop

alpine butterfly



Reference: *The Ultimate Book of Knots* by Peter Owen

Resources

Links for knot-tying videos

- square knot: https://www.youtube.com/watch?v=LOAxiQk8wj8
- figure-8 bend: https://www.youtube.com/watch?v=w6x-TK6L2Tk
- bowline loop: https://www.youtube.com/watch?v=QIIMsyvtDwg
- alpine butterfly: https://www.animatedknots.com/alpine-butterfly-loop-knot

Questions?

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Thank You!