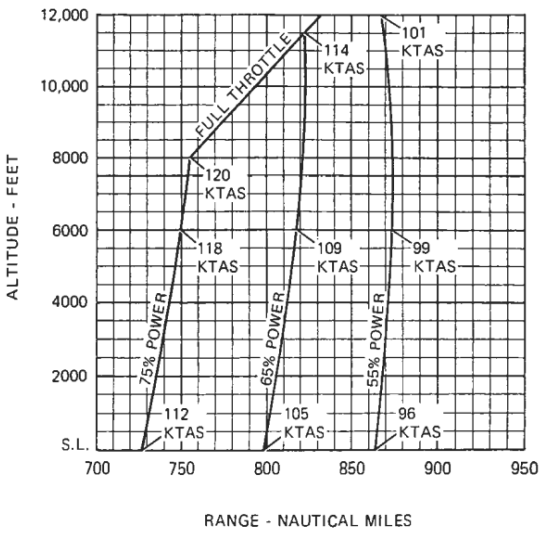
Performance and Limitations

Objective	
To ensure the applicant learns the importance of memorizing important aircraft limitations and how to calculate performance.	
Purpose	
Airplanes are designed to be as safe as possible and perform well under a variety of circumstances, but this safety and performance is based on pilots remaining within the published limitations and performance envelopes. This lesson introduces pilots to the procedures for calculating the various factors which affect airplane performance, as well as how to consider airplane performance and limitations during flight planning.	

Schedule	**Equipment**
• **Ground Lesson**: 30 minutes • **Student Q&A**: 10 minutes	• Airplane Checklist • Airplane POH • Calculator • Whiteboard / Markers (optional)
Student Actions	**Instructor Actions**
• Ask any questions, receive study material for the next lesson. • Watch linked video. • Review listed references.	• Deliver the ground lesson (below). • Answer student questions.

Completion Standards

- Student can explain the following concepts:
  - How to compute Weight and Balance, the dangers of being out of the envelope
  - How to compute takeoff, landing, and cruise performance
  - List airplane V speeds and what they represent
  - Effects of density altitude, wind, runway surfaces, etc.
  - Importance of calculating required performance, differences from actual performance, safety margin

References

- Cyndy Hollman - “Takeoff Performance (Private Pilot Lesson 7c)”
  - YouTube - https://www.youtube.com/watch?v=3OKXUl5le30
- Airplane POH - Section 2 [Limitations], Section 5 [Performance], Section 6 [Weight & Balance]
- FAA-H-8083-25B (Pilot’s Handbook of Aeronautical Knowledge) - Chapter 4, Page 4-5 [Density Altitude], Chapter 5, Page 14-15 [Static and Dynamic Stability], Chapter 5, Page 15-17 [Longitudinal Stability], Chapter 5, Page 19-20 [Directional Stability], Chapter 5, Page 25-26 [Stalls], Chapter 5, Page 34 [Load Factors and Stalling Speeds], Chapter 5, Page 37 [Vg Diagram], Chapter 10, Page 2 [Effects of Weight], Chapter 10, Page 2-4 [Balance, Stability, Center of Gravity], Chapter 10, Page 4-5 [Terms and Definitions], Chapter 10, Page 5-11 [Computing W&B], Chapter 11, Page 16-18 [Landing Performance], Chapter 11, Page 19-28 [Performance Charts]
- FAA-S-ACS-6B (Private Pilot ACS) - Area I Task F
- FAA-S-ACS-7A (Commercial Pilot ACS) - Area I Task F
- FAA-S-8081-6D (CFI PTS) - Area I Task F

Ground Lesson Outline

- Computing Weight and Balance - Airplane POH Section 6 [Weight & Balance]
  - POH, Empty Weight, Fuel, Passengers, Cargo
  - CG, Dangers of Out-of-CG Condition
- POH Performance Charts - Airplane POH Section 5 [Performance]
  - Takeoff Performance, Climb Performance, Cruise Performance, Landing Performance
  - Fuel Burn, TAS, Endurance
- Airplane Limitations - Airplane POH Section 2 [Limitations]
  - V Speeds - Airplane, Flaps Extended, Gear Extended Max Speeds
  - Max Demonstrated Crosswind - Not a true limitation
  - Vg Diagram, Load Factor
  - Dangers of Exceeding Limitations
- Effects of Atmospheric Conditions on Performance
  - Wind, Temperature, Pressure
  - True Altitude, Pressure Altitude, Density Altitude
  - Effect on Takeoff and Landing Speeds
- Required Performance
  - Determining sufficient airplane performance for planned flight
    - Also consider: Hard/Soft Surface, Airport Environment (Runway Slope)
  - Effects of Configuration
  - Calculated Performance vs. Actual Performance
    - Pilot Skill, Aircraft Condition, Improper Leaning
    - Safety Margin

Ground Lesson Content

- **Computing Weight and Balance** - See your Airplane POH Section 6 [Weight & Balance]
  - See related lesson on *Airplane Weight and Balance* (Area II Task F)
  - W&B must be computed using data from the POH. The POH will include the Empty Weight/Balance data. Pilots add Fuel, Passengers, and Cargo to determine the loaded airplane W&B data.
  - **Flying out of the Weight/CG envelope is extremely dangerous!**
- **POH Performance Charts** - See your Airplane POH Section 5 [Performance]
  - **Takeoff Performance** - Use tables for calculations, take note of conditions and configuration!
    - **Important Note:** Table below is an *Example Only*. Use data from *your* airplane POH.

TAKEOFF DISTANCE
MAXIMUM WEIGHT 2400 LBS
SHORT FIELD

CONDITIONS:
Flaps 10°
Full Throttle Prior to Brake Release
Paved, Level, Dry Runway
Zero Wind

NOTES:
1. Short field technique as specified in Section 4.
2. Prior to takeoff from fields above 3000 feet elevation, the mixture should be leaned to give maximum RPM in a full throttle, static runup.
3. Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots.
4. For operation on a dry, grass runway, increase distances by 15% of the "ground roll" figure.

WEIGHT LBS	TAKEOFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	51	56	S.L.	795	1460	860	1570	925	1685	995	1810	1065	1945
			1000	875	1605	940	1725	1015	1860	1090	2000	1170	2155
			2000	960	1770	1035	1910	1115	2060	1200	2220	1290	2395
			3000	1055	1960	1140	2120	1230	2295	1325	2480	1425	2685
			4000	1165	2185	1260	2365	1355	2570	1465	2790	1575	3030
			5000	1285	2445	1390	2660	1500	2895	1620	3160	1745	3455
			6000	1425	2755	1540	3015	1665	3300	1800	3620	1940	3990
			7000	1580	3140	1710	3450	1850	3805	2000	4220	- - -	- - -
			8000	1755	3615	1905	4015	2060	4480	- - -	- - -	- - -	- - -

  - **Climb Performance** - Use tables for calculations, take note of conditions and configuration!
    - **Important Note:** Table below is an *Example Only*. Use data from *your* airplane POH.

MAXIMUM RATE OF CLIMB

CONDITIONS:
Flaps Up
Full Throttle

NOTE:
Mixture leaned above 3000 feet for maximum RPM.

WEIGHT LBS	PRESS ALT FT	CLIMB SPEED KIAS	RATE OF CLIMB - FPM			
			-20°C	0°C	20°C	40°C
2400	S.L.	76	805	745	685	625
	2000	75	695	640	580	525
	4000	74	590	535	480	420
	6000	73	485	430	375	320
	8000	72	380	330	275	220
	10,000	71	275	225	175	- - -
	12,000	70	175	125	- - -	- - -

TIME, FUEL, AND DISTANCE TO CLIMB

MAXIMUM RATE OF CLIMB

CONDITIONS:
Flaps Up
Full Throttle
Standard Temperature

NOTES:
1. Add 1.1 gallons of fuel for engine start, taxi and takeoff allowance.
2. Mixture leaned above 3000 feet for maximum RPM.
3. Increase time, fuel and distance by 10% for each 10°C above standard temperature.
4. Distances shown are based on zero wind.

WEIGHT LBS	PRESSURE ALTITUDE FT	TEMP °C	CLIMB SPEED KIAS	RATE OF CLIMB FPM	FROM SEA LEVEL		
					TIME MIN	FUEL USED GALLONS	DISTANCE NM
2400	S.L.	15	76	700	0	0.0	0
	1000	13	76	655	1	0.3	2
	2000	11	75	610	3	0.6	4
	3000	9	75	560	5	1.0	6
	4000	7	74	515	7	1.4	9

- **Landing Performance** - Use tables for calculations, take note of conditions and configuration!
  - **Important Note:** Table below is an *Example Only*. Use data from *your* airplane POH.

LANDING DISTANCE

SHORT FIELD

CONDITIONS:
Flaps 30°
Power Off
Maximum Braking
Paved, Level, Dry Runway
Zero Wind

NOTES:
1. Short field technique as specified in Section 4.
2. Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots.
3. For operation on a dry, grass runway, increase distances by 45% of the "ground roll" figure.
4. If a landing with flaps up is necessary, increase the approach speed by 7 KIAS and allow for 35% longer distances.

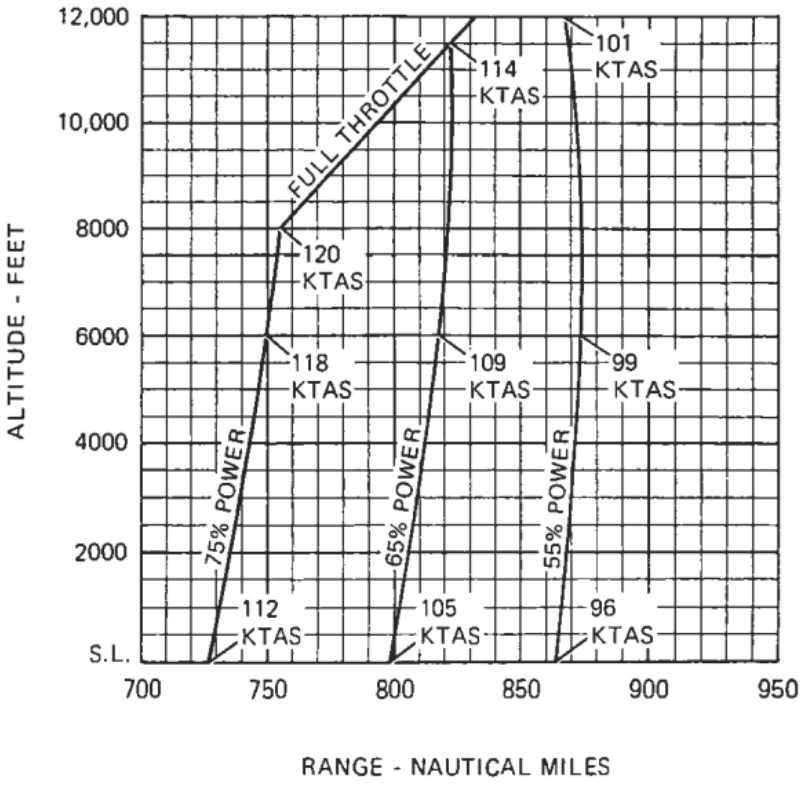
WEIGHT LBS	SPEED AT 50 FT KIAS	PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
			GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS	GRND ROLL FT	TOTAL FT TO CLEAR 50 FT OBS
2400	61	S.L.	510	1235	530	1265	550	1295	570	1325	585	1350
		1000	530	1265	550	1295	570	1325	590	1360	610	1390
		2000	550	1295	570	1330	590	1360	610	1390	630	1425
		3000	570	1330	590	1360	615	1395	635	1430	655	1460
		4000	595	1365	615	1400	635	1430	660	1470	680	1500
		5000	615	1400	640	1435	660	1470	685	1510	705	1540
		6000	640	1435	660	1470	685	1510	710	1550	730	1580
		7000	665	1475	690	1515	710	1550	735	1590	760	1630
		8000	690	1515	715	1555	740	1595	765	1635	790	1675

- **Cruise Performance, Fuel Burn, TAS, Endurance** - Use tables for calculations, take note of conditions and configuration!

CRUISE PERFORMANCE

CONDITIONS:
2400 Pounds
Recommended Lean Mixture (See Section 4, Cruise)

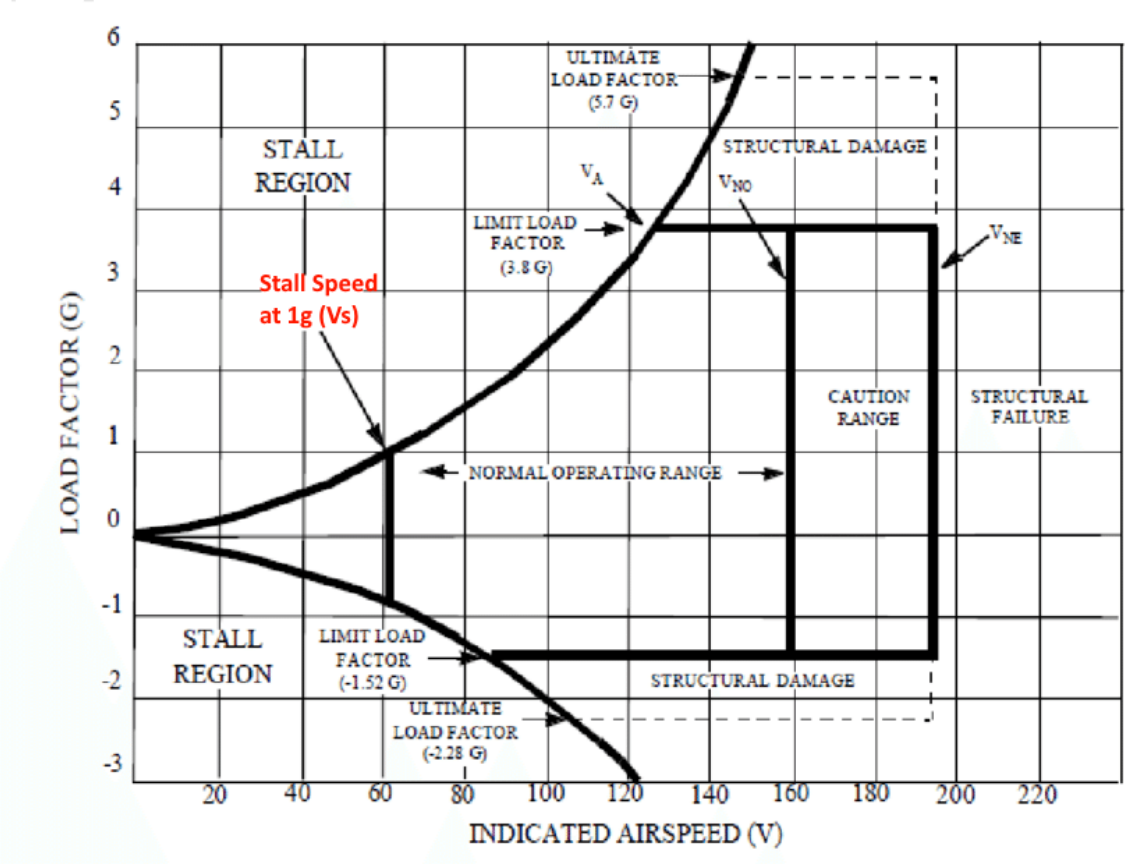
PRESSURE ALTITUDE FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
2000	2500	- - -	- - -	- - -	76	114	8.5	72	114	8.1
	2400	72	110	8.1	69	109	7.7	65	108	7.3
	2300	65	104	7.3	62	103	6.9	59	102	6.6
	2200	58	99	6.6	55	97	6.3	53	96	6.1
	2100	52	92	6.0	50	91	5.8	48	89	5.7
4000	2550	- - -	- - -	- - -	76	117	8.5	72	116	8.1
	2500	77	115	8.6	73	114	8.1	69	113	7.7
	2400	69	109	7.8	65	108	7.3	62	107	7.0
	2300	62	104	7.0	59	102	6.6	57	101	6.4
	2200	56	98	6.3	54	96	6.1	51	94	5.9
	2100	51	91	5.8	48	89	5.7	47	88	5.5



- **Airplane Limitations** - See your Airplane POH Section 2 [Limitations]
  - **V Speeds** - It is crucial for pilots to ***memorize*** and stay within the V speeds of their airplane. Some important V-Speeds that pilots should know:
    - **Vs** - Stall speed (generally in clean configuration)
    - **Vs_0** - Stall Speed in landing configuration
    - **Vx** - Best Angle of Climb
    - **Vy** - Best Rate of Climb

- **Vg** - Best Glide
- **Vfe** - Max Flaps Extended
- **Vle** - Max Gear Extended Speed / Vlo - Max Gear Operating Speed
- **Va** - Maneuvering Speed
- **Vno** - Max Normal Operating Speed (Top of Green Arc)
- **Vne** - Never Exceed Speed
- **Max Demonstrated Crosswind** - Max Demonstrated Crosswind is not a true limitation, it is simply the maximum value that was demonstrated during certification. **However, pilots should consider their own proficiency with crosswind techniques when deciding how much crosswind is allowable.** There is an aerodynamic limit (unpublished) to how much crosswind is possible in an airplane.

- **Vg Diagram** - The Vg Diagram visually illustrates the various airplane speed limitations and how *Load Factor* affects stall speed, etc.



- **Dangers of Exceeding Limitations** - Exceeding published airplane limitations is extremely dangerous and can lead to in-flight structural failure!

- **Effects of Atmospheric Conditions on Performance**
  - **Wind, Temperature, Pressure** - POH Performance Charts generally account for these variables, as they can increase, or decrease performance.
  - **Measures of Altitude**
    - **True Altitude** - Actual altitude above Mean Sea Level (MSL) in absolute terms.
    - **Pressure Altitude** - Altitude above MSL corrected for non-standard pressure. (Std Pressure = 29.92") Each 0.01" of deviation accounts for **10 feet** of correction. **When the atmospheric pressure is higher than standard, the pressure altitude is lower than the true altitude.**
    - **Density Altitude** - Altitude above MSL corrected for non-standard pressure *and* temperature. **This altitude is used primarily in performance calculations** since it

represents the “equivalent altitude” in the standard atmosphere (29.92” and 15° Celcius) where the same performance would be achieved.
        - This is computed because both airplane aerodynamic performance *and* engine performance are affected by reduced density of the atmosphere.
    - **Effect on Takeoff and Landing Speeds** - When Density Altitude is high, takeoff and landing *true airspeed* will be higher, although the airspeed indicator will display the same indicated airspeeds. **This equates to longer takeoff and landing distances!**
- **Required Performance**
    - It is crucial that pilots determine *before every flight* that the airplane has sufficient performance for the planned flight. Other factors to consider:
        - **Soft Runway Surfaces** increase takeoff rolls, and decrease landing rolls
        - **Airport Environment** - Upward sloping runways increase takeoff rolls, and decrease landing rolls. Obstacles in the approach or departure path may require a longer takeoff or landing roll.
    - **Effects of Configuration** - POH performance values are valid only for the specified configurations. If the POH specifies to use Flaps, Flaps must be used to meet the stated performance!
    - **Calculated Performance vs. Actual Performance** - The POH performance numbers should be treated as *best case* values. It is generally best to add some ‘safety margin’ to the computed numbers to account for things like:
        - **Pilot Skill** - Meeting calculated landing or takeoff distances requires good pilot technique. Any mistakes can increase these values.
        - **Aircraft Condition** - Airplanes which are older frequently fail to exactly match ‘book values’.
        - **Improper Leaning** - It is very easy to perform the mixture leaning procedure improperly, which can make a large difference in actual fuel burn.
    - **Safety Margin** - Add 10-20% to takeoff or landing distances. Add 10-20% to fuel burn figures. Do not plan to conduct flights that require maximum performance, such as in extreme crosswinds, etc.