

CEE 4674: Airport Planning and Design

Quiz 1 : Open Notes and Take Home

Solution

Fall 2025

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Instructions

Write your solutions in the spaces provided. Add any additional pages with calculations as needed. Make sure each additional page has your name.

Honor Code Pledge

The information provided in this exam is my own work. I have not received information from another person while doing this exam.

_____ (your signature/name)

Problem 1 (35 Points)

An low-cost airline would like to operate **Boeing 737-8 Max** between Colorado Springs (COS) and Punta Cana (PUJ), Dominican Republic. The Boeing 737-8 Max (see Figure 1) operated by the airline has 178 seats in a two-class seating configuration. The airline uses the **CFM Leap 1B28B1 engine** and the Maximum Takeoff Weight is rated at 182,700 lbs. The operating weight of the aircraft is 99,000 lbs.



Figure 1. Boeing 737-8Max Landing at Punta Cana International Airport (PUJ). Source: A. Trani.

- a) Find the runway length needed to operate at **both airports** to satisfy FAA/EASA runway length requirements. Use the airport design temperatures at both locations. You can find worldwide weather and temperature data at: <https://weatherspark.com/>. Clearly state all your assumptions and show your intermediate calculations including payload and takeoff weight calculations. In your analysis consider future climate change temperature effects if available (i.e., higher emissions). For Punta Cana assume climate change will raise the temperature by the same amount as in Colorado Springs. Also, consider the runway grade effects in your analysis.

Colorado Springs to Punta Cana Analysis

Colorado Springs (COS) airport elevation is 6,187 feet above mean sea level conditions.

The longest runway is 17L/35R is 13,500 feet long.

COS design temperature is 86.9 degrees Fahrenheit (higher emissions 2010-2040). The temperature is 2.9 deg. Fahrenheit above the historical average.

ISA temperature at 6,187 feet is 36.9 degrees Fahrenheit.

Difference in temperatures between ISA conditions and the design temperature is 50 degrees Fahrenheit.

Use ISA + 50 deg. Fahrenheit takeoff performance charts in your analysis.

Note: Boeing offers charts for ISA+ 45 deg.F. and ISA + 65 deg.F. ISA+45 deg.F. is more than 3 deg. F. From the design temperature so that start cannot be used in the analysis. Interpolation is not allowed so **use the highest chart (ISA + 63 deg.F.)**.

Great circle distance = 2,245 nautical miles

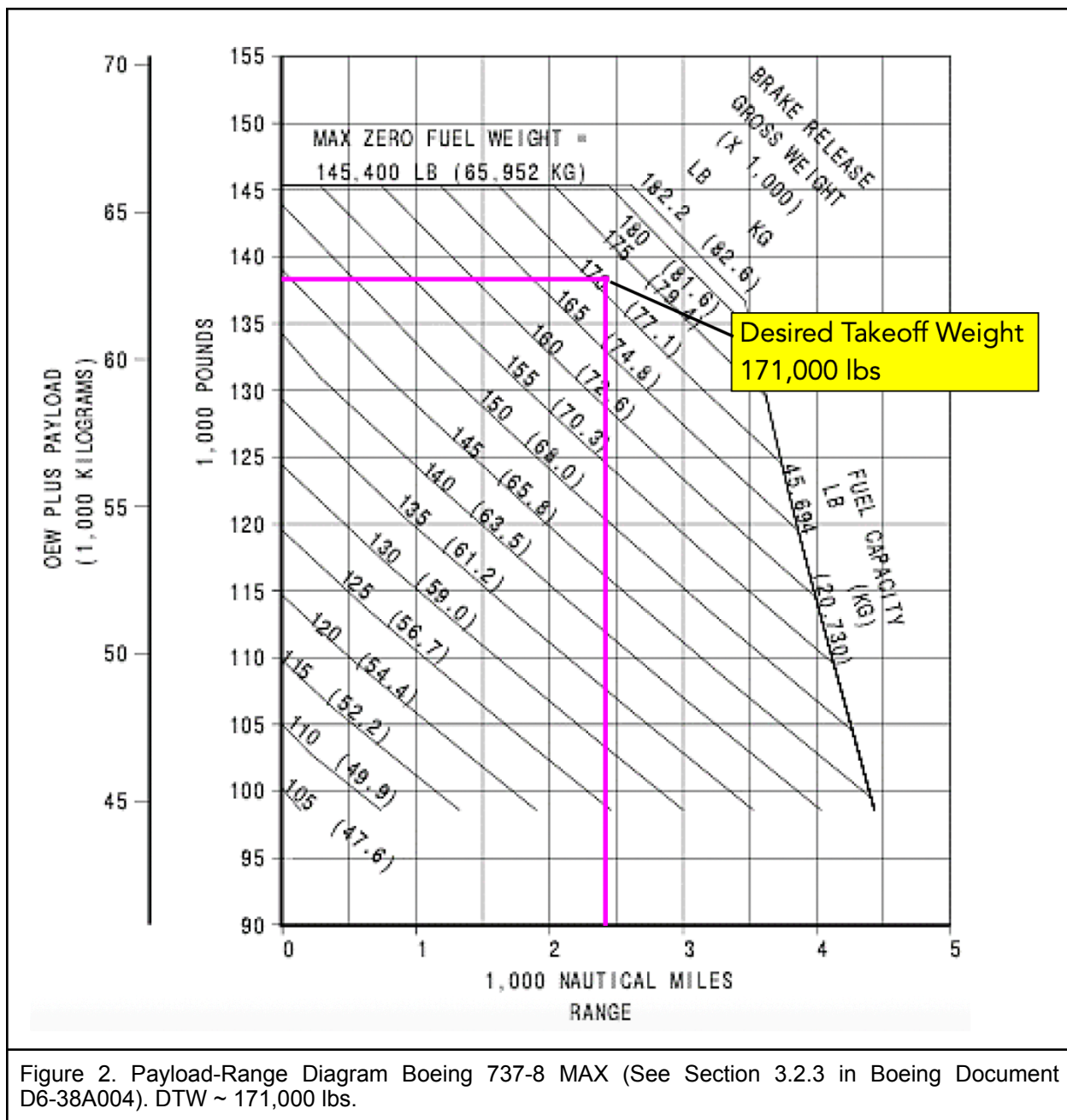
Adjusted distance for planning = 2,380 nautical miles

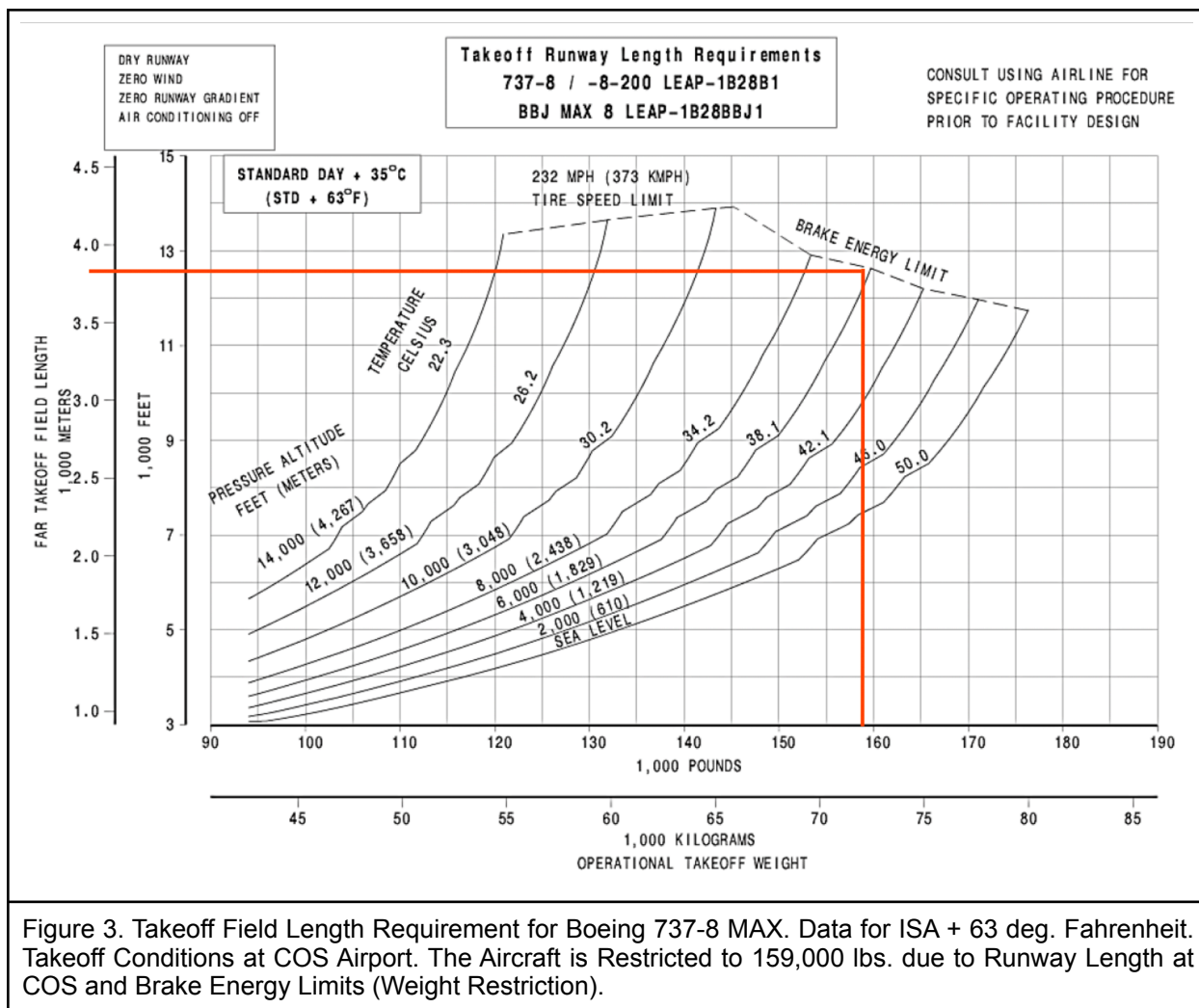
Table 1 shows the calculations for the Colorado Springs to Punta Cana Route. Use Boeing Document D6-38A004 (July 2025) in the Analysis.

Table 1. Boeing 737-Max 8 Analysis with 100% Load Factor. Desired Takeoff Weight is Restricted by Brake Energy Limits and Runway Length Available.		
Parameter	Kilograms	Pounds
OEW	45,000	99,000
PYL	17,800	39,160
OEW + PYL	62,800	138,160
DTW (from Payload-Range Diagram)	77,727	171,000
FW	14,927	32,840
Passengers	178	

Table 1. Boeing 737-Max 8 Analysis with 100% Load Factor. Desired Takeoff Weight is Restricted by Brake Energy Limits and Runway Length Available.

Parameter	Kilograms	Pounds
Takeoff Field Length (feet)	12700	12700
Weight and Brake Energy Limitation Note	Aircraft is restricted to 159,000 lbs. from COS	Aircraft is restricted to 159,000 lbs. from COS
Difference in Centerline Elevations (feet) From Airnav for longest runway	84.3	84.3
Additional runway length (feet)	843	843
Corrected Takeoff Field Length (feet)	13,543	13,543
Runway Length Restriction Note	Aircraft is technically restricted by runway length. Uncorrected takeoff file length is limited to 12,657 feet.	Aircraft is technically restricted by runway length. Uncorrected takeoff file length is limited to 12,657 feet.
Max. Allowable Landing Weight	69,455	152,800
Wet Pavement Landing Distance (feet)	6,500	6,500
Longest Runway Available (feet)	13,500	13,500
Route Distance (nm)	2245	2245
Adjusted Route Distance (nm)	2380	2380





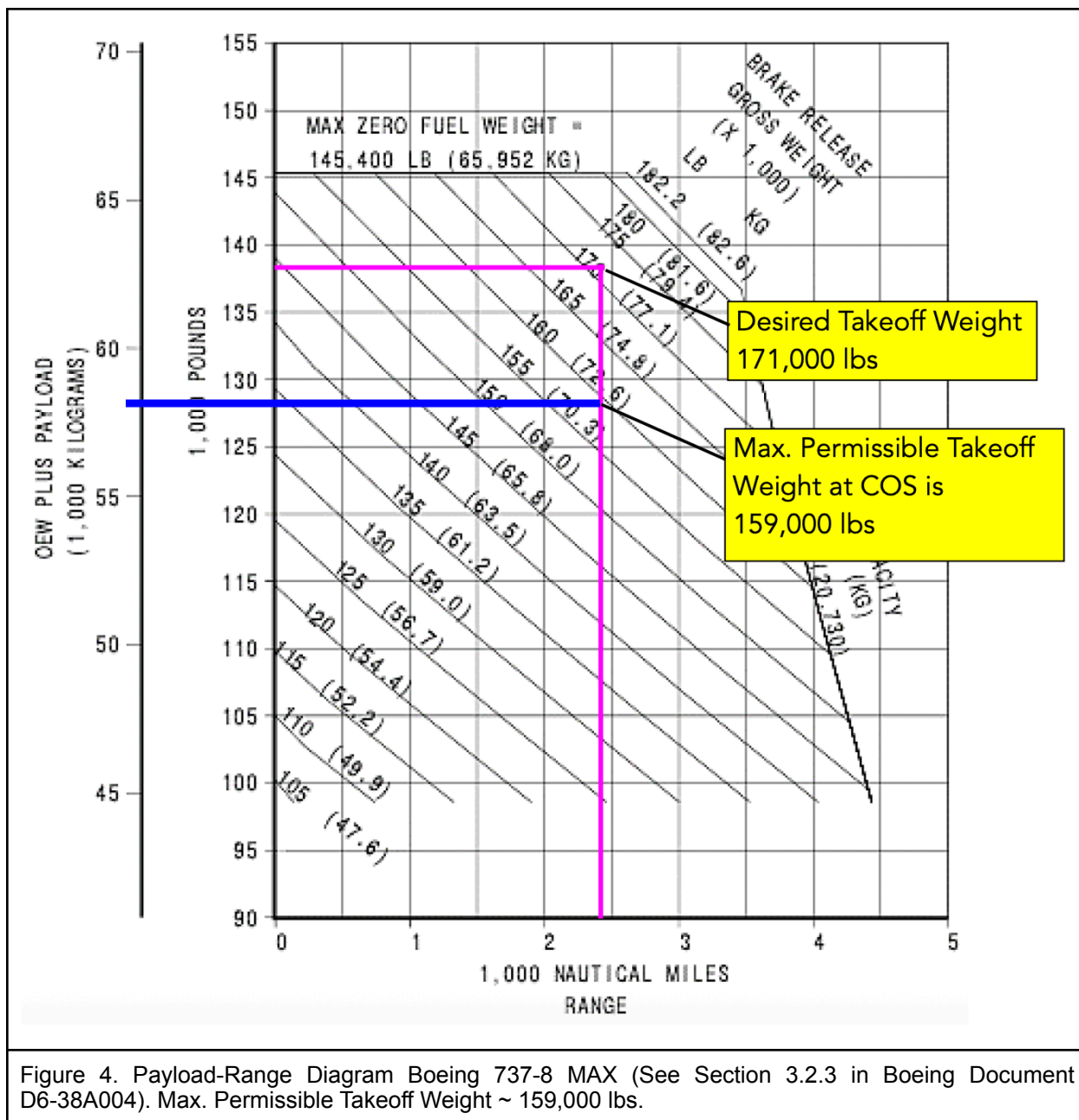


Figure 4. Payload-Range Diagram Boeing 737-8 MAX (See Section 3.2.3 in Boeing Document D6-38A004). Max. Permissible Takeoff Weight ~ 159,000 lbs.

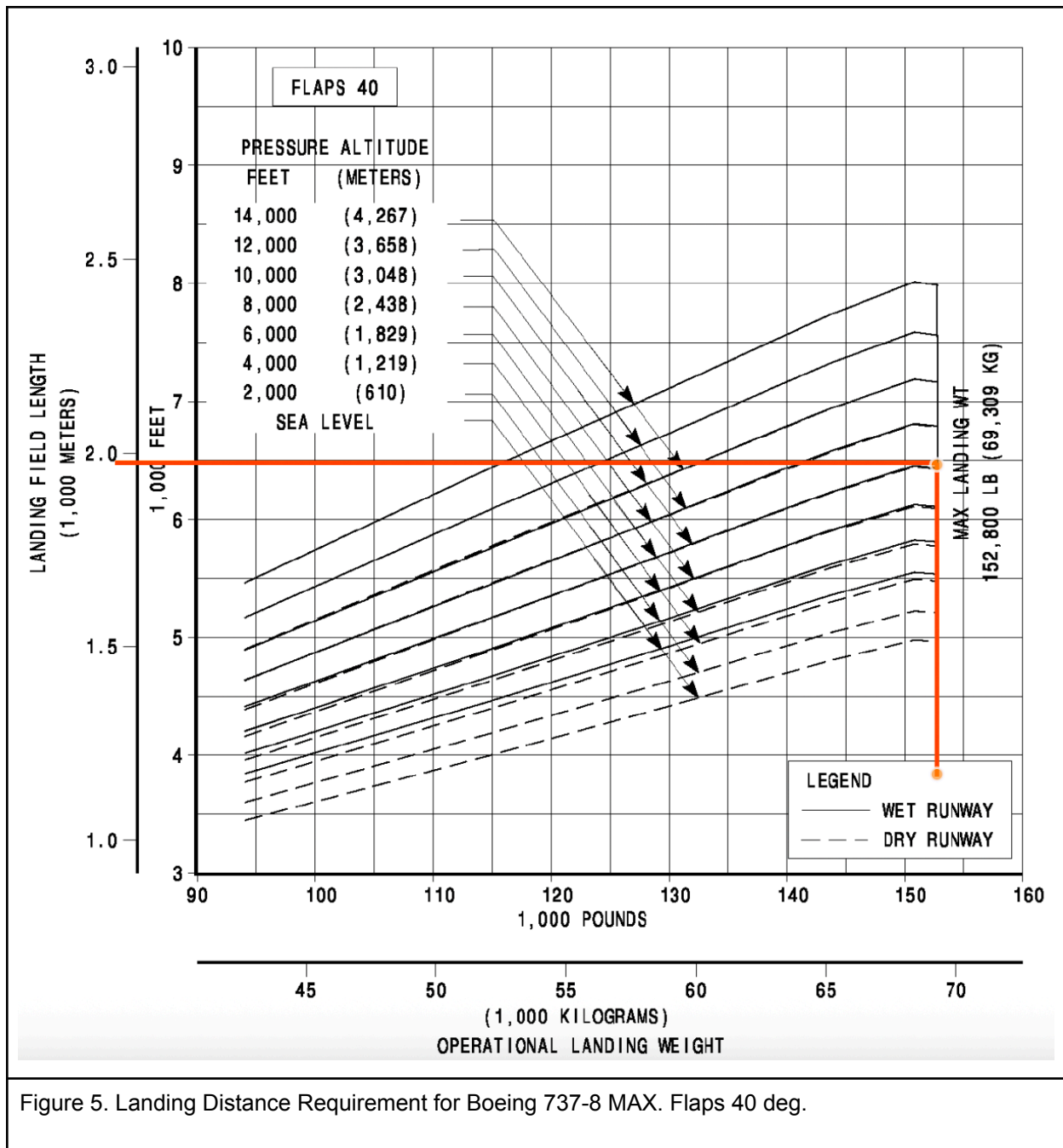


Figure 5. Landing Distance Requirement for Boeing 737-8 MAX. Flaps 40 deg.

b) Estimate the amount of fuel used for the flight between COS and PUJ.

The fuel amount is 32,840 lbs if the DTW = 171,000 lbs. is used.

Considering the aircraft weight and runway length restrictions at the airport, the maximum permissible takeoff is 159,000 lbs.

DTW = 159,000 lbs.

OEW = 99,000 lbs.

Payload (weight restricted by aircraft performance and runway length) = 29,000 lbs.

OEW + PAY = 128,000 lbs. (see Figure 4)

Fuel used considering weight restrictions = 31,000 lbs (see Figure 4).

Punta Cana to Colorado Springs Analysis

Punta Cana airport (PUJ) airport elevation is 40 feet above mean sea level conditions.

The longest runway is 08/26 is 10,171 feet long.

PUJ average temperature of the hottest month is 88 degrees Fahrenheit (Source: Weather Spark). Assuming higher emissions (2010-2040) the corrected temperature is 90.9 (or 2.9 deg. Fahrenheit above the baseline temperature).

ISA temperature at 40 feet is 58.9 degrees Fahrenheit.

Difference in temperatures between ISA conditions and the design temperature is **32 degrees Fahrenheit**.

Use ISA + 32 deg. Fahrenheit takeoff performance charts in your analysis.

Note: Boeing offers charts for ISA+ 45 deg.F. and ISA + 27 deg.F. ISA+27 deg.F. is more than 3 deg. F. from the design temperature so that start cannot be used in the analysis. Interpolation is not allowed so **use the highest chart (ISA + 45 deg.F.)**.

Great circle distance = 2,245 nautical miles

Adjusted distance for planning = 2,380 nautical miles

Table 2 Calculations for the Punta Cana to Colorado Springs Route. Use Boeing Document D6-38A004 (July 2025) in the Analysis.

Table 1. Boeing 737-Max 8 Analysis with 100% Load Factor. PUJ to COS Route.		
Parameter	Kilograms	Pounds
OEW	45,000	99,000
PYL	17,800	39,160
OEW + PYL	62,800	138,160
DTW (from Payload-Range Diagram)	77,727	171,000
FW	14,927	32,840
Passengers	178	
Takeoff Field Length (feet)	7000	7000

Table 1. Boeing 737-Max 8 Analysis with 100% Load Factor. PUJ to COS Route.		
Parameter	Kilograms	Pounds
Weight and Brake Energy Limitation Note	None	None
Difference in Centerline Elevations (feet) From Skyvector for runway 08/26	6.0	6.0
Additional runway length (feet)	60	60
Corrected Takeoff Field Length (feet)	7,060	7,060
Runway Length restriction Note	No restriction	No restriction
Max. Allowable Landing Weight	69,455	152,800
Wet Pavement Landing Distance (feet)	5,800	5,800
Longest Runway Available (feet)	10,171	10,171
Route Distance (nm)	2245	2245
Adjusted Route Distance (nm)	2380	2380

The Punta Cana - Colorado Springs route can be flown with 100% of the seats used. The Punta Cana runway offer plenty of flexibility for this route.

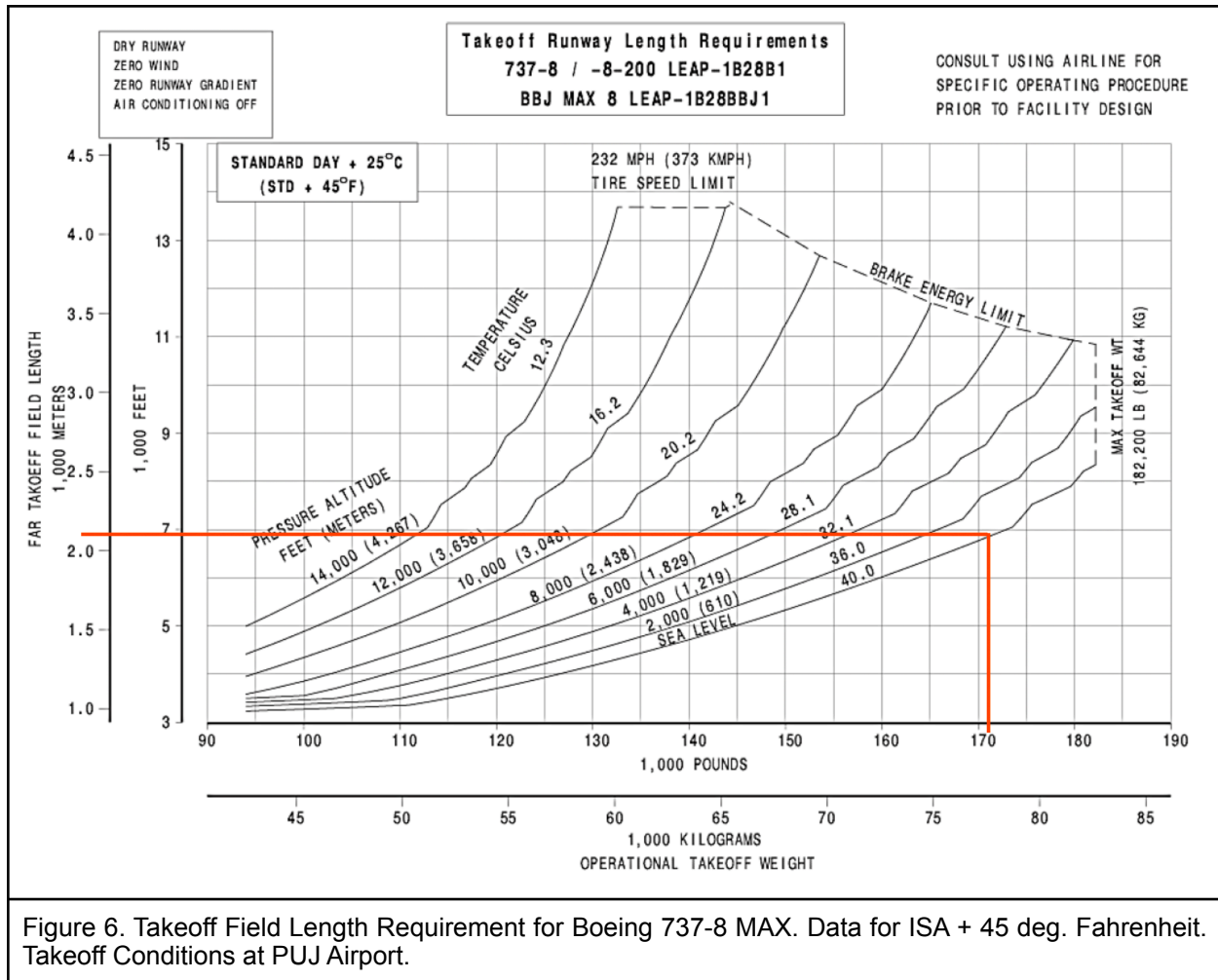


Figure 6. Takeoff Field Length Requirement for Boeing 737-8 MAX. Data for ISA + 45 deg. Fahrenheit. Takeoff Conditions at PUJ Airport.

- c) Can the Boeing 737-8 Max operate in the route COS-PUJ with 100% of the seats full at the airport design temperature? Explain.

No. The aircraft is restricted to a maximum permissible weight of 159,000 lbs. The restriction is due to brake energy limits and to a lesser extend runway length available.

With a permissible payload of 29,000 lbs, the aircraft could carry 132 passengers (74% load factor) in the Colorado Spring - Punta Cana route.

- d) Do you consider the Boeing 737-8 Max a good fit to fly the route? Comment on any payload or runway length limitations or weight restrictions for the aircraft.

Probably not a good fit. The fact that only 74% of the seats can be sold is a major limitation for the airline. The operation from Colorado Springs is difficult due to the high airfield elevation and high design temperature.

- e) Explain the observed differences in performance at COS and PUJ using the basic equation of motion explained in class.

The takeoff runway length required in Colorado Springs is 91% higher than Punta Cana. The departure from COS can only carry 74% of the seats full. From Punta Cana, the aircraft can carry 100% of the seats.

Looking at the basic differential equation of motion, the density effect at COS reduces the acceleration of the aircraft substantially and hence increases. The runway length needed to depart at the same weight. The density of air reduces the amount of thrust produced and also increases the takeoff speeds. Both contributions increase runway length.

Problem 2 (35 Points)

Use the Small Aircraft Runway Length Analysis Tool (SARLAT) to evaluate the existing runway conditions at Southern West Virginia Regional Airport (EBD) in West Virginia. The airport serves single, multi-engine piston, turboprop and jet powered aircraft (see Table 3). Table 3 was generated as part of a new master plan for the airport.

Table 3. Aircraft Fleet Mix for Problem 2.

Aircraft Type	Aircraft	Annual Operations
Piston	Cirrus SR20	1200
Piston	Cessna 421	450
Turboprop	Beechcraft King Air C90	400
Turboprop	Cessna 208 Caravan	560
Jet	Cessna 560 XL	350
Jet	Embraer Phenom 100	550
Total		3510

- a) Is the existing runway length available suitable for corporate jet and turboprop operations at 80% useful load when the runway pavement is dry? Explain.

Design temperatures

Historical = 85.4 deg. Fahrenheit (use 86 deg.F. in SARLAT)

Higher emissions = 88.6 deg. Fahrenheit (use 89 deg.F. in SARLAT)

Elevation = 1,883 feet above mean sea level conditions

Runway gradient = 1.1% (using Airnav)

56 feet difference in elevation between runway thresholds for runway 8/26

The runway falls short of covering the very light jet (Phenom 100) at 80% useful load. The existing runway can support Phenom 100 operations at 71% useful load under dry runway conditions (see Table 4). All other aircraft are covered at useful load greater than 80%.

Table 4. SARLAT results for EBD Airport. Runway Length 5,001 feet.

EBD_example

Runway Takeoff and Landing Restrictions

Pressure Altitude: 1883 ft

Air Temperature: 89 F

Wind Speed: 0 kts

Runway Length: 5001 ft

Gradient: 1.1 %

Aircraft Name	Aircraft Mix	NBAA IFR Maximum Range		Useful Load (Takeoff Weight)	
		Dry	Wet	Dry	Wet
Piston					
C421 - Cessna 421 Golden Eagle	13%			100 % 7450 lbs	100 % 7450 lbs
SR20 - Cirrus SR 20	34%			100 % 3150 lbs	100 % 3150 lbs
Turboprop					
BE9L - Beechcraft King Air C90	11%			100 % 10485 lbs	100 % 10485 lbs
C208 - Cessna 208 Caravan	16%			100 % 8000 lbs	100 % 8000 lbs
Jet					
C56X - Cessna 560 XL	10%	100 % FLIGHTS IN NAS 1389 nm / 4 pax	92 % FLIGHTS IN NAS 895 nm / 4 pax	89 % 19362 lbs	69 % 17922 lbs
E50P - Phenom 100	16%	63 % FLIGHTS IN NAS 367 nm / 4 pax	✗	71 % 9435 lbs	53 % 8781 lbs

b) Name the most critical aircraft operating at the airport.

The Embraer Phenom 100 is the most critical aircraft operating from EBD from a useful load viewpoint.

c) If the future aircraft operations do not meet the requirement in part (a), propose an improvement that the FAA will pay for. Explain.

An extension of 350 feet would allow the Phenom 100 to operate at 80% useful load under dry pavement conditions (see Table 5).

Table 5. SARLAT results for EBD Airport. Runway Length 5,350 feet.

Runway Takeoff and Landing Restrictions					
Pressure Altitude: 1883 ft Air Temperature: 89 F Wind Speed: 0 kts Runway Length: 5350 ft Gradient: 1.1 %					
Aircraft Name	Aircraft Mix	NBAA IFR Maximum Range		Useful Load (Takeoff Weight)	
		Dry	Wet	Dry	Wet
Piston					
C421 - Cessna 421 Golden Eagle	13%			100 % 7450 lbs	100 % 7450 lbs
SR20 - Cirrus SR 20	34%			100 % 3150 lbs	100 % 3150 lbs
Turboprop					
BE9L - Beechcraft King Air C90	11%			100 % 10485 lbs	100 % 10485 lbs
C208 - Cessna 208 Caravan	16%			100 % 8000 lbs	100 % 8000 lbs
Jet					
C56X - Cessna 560 XL	10%	100 % FLIGHTS IN NAS 1587 nm / 4 pax	100 % FLIGHTS IN NAS 1119 nm / 4 pax	98 % 20074 lbs	78 % 18616 lbs
E50P - Phenom 100	16%	82 % FLIGHTS IN NAS 520 nm / 4 pax	32 % FLIGHTS IN NAS 196 nm / 4 pax	80 % 9765 lbs	61 % 9090 lbs

- d) State the dimensions of the RSA and ROFA needs at the airport. The runway is a non-precision runway with approach visibility minima of 1.25 miles for AAC A and B class aircraft. Clearly state the RDC Code used in the design.

Critical ADG group = II

Critical AAC group = B

Critical TDG = 2A

RDC code is II-B-6600

1.25 statute miles = 6,600 feet

The RSA and ROFA dimensions can be obtained in the FAA AC 150/5300-13B Table G-4. Note that the Cessna 560XL is not a small aircraft according to the FAA criteria. The Cessna 560XL has a maximum takeoff weight of 20,200 lbs. Use the column "Not Lower than 1 mile visibility" consistent with a non-precision runway.

Table 6. RSA and ROFA Dimensions for RDC II-B-6600.	
Item	Dimension (feet)
RSA Length beyond departure end	300
RSA Length prior to threshold	300

Table 6. RSA and ROFA Dimensions for RDC II-B-6600.	
Item	Dimension (feet)
RSA width	150
ROFA Length beyond runway end	300
ROFA Length prior to threshold	300
ROFA width	500

Problem 3 (30 points)

Short answer or true/false. Show your calculations.

	Question	Short Answer
1	The AAC group for the Airbus A330-900.	C
2	The Gulfstream 650 taxiway design group.	2B
3	Runway 19 at Reagan National Airport (DCA) is a precision runway with approach lights. (True/False)	TRUE
4	Change in the length of the RSA dimension when the airport transitions from A-II to C-II. Assume visibility is not lower than 3/4 miles.	700 feet for the length beyond departure end 300 feet for the length prior to threshold
5	Height of the inner transitional OFZ surface at a point 630 feet from the runway centerline. The critical aircraft is the Boeing 747-8 and the airport elevation is 2,160 feet above mean sea level. The airport has instrument flight procedures (IFP) lower than 1/2 mile (0.8 km) visibility,	105.1 feet IT OFZ starts 200 feet laterally from runway centerline.
6	Charleston, WV airport has a EMAS able to stop a Gulfstream GIII traveling at 70 knots and overrunning the runway after landing on runway 23. (True/False)	False CRW EMAS is 320 feet long. 430-foot EMAS needed
7	Approach speeds used to designate AAC groups are measured at the maximum allowable landing weight. (True/False)	TRUE
8	Aircraft design group for the Cessna Caravan.	II
9	Height of the approach OFZ for a precision runway at a location 1,100 feet from the runway threshold. The approach lights are 1,400 feet in length.	18 feet IA-OFZ starts 200 feet from runway end
10	Average grade of runway 28 at Falwell Airport (W24) in Virginia.	4.7%

IT OFZ calculation

Wingspan = 224.4 feet

Elevation = 2,160 feet

$H = 53 - 0.13(224.4) - 0.0022(2160) = 19.1 \text{ feet}$

$Y = 440 + 1.08(224.4) - 0.024(2160) = 630.5 \text{ feet}$

The slope of 5:1 applies to the location in question.

Height of IT OFZ is :

$$H_{IT} = H + (630-200)/5 = 19.1 + 86 = 105.1 \text{ feet}$$