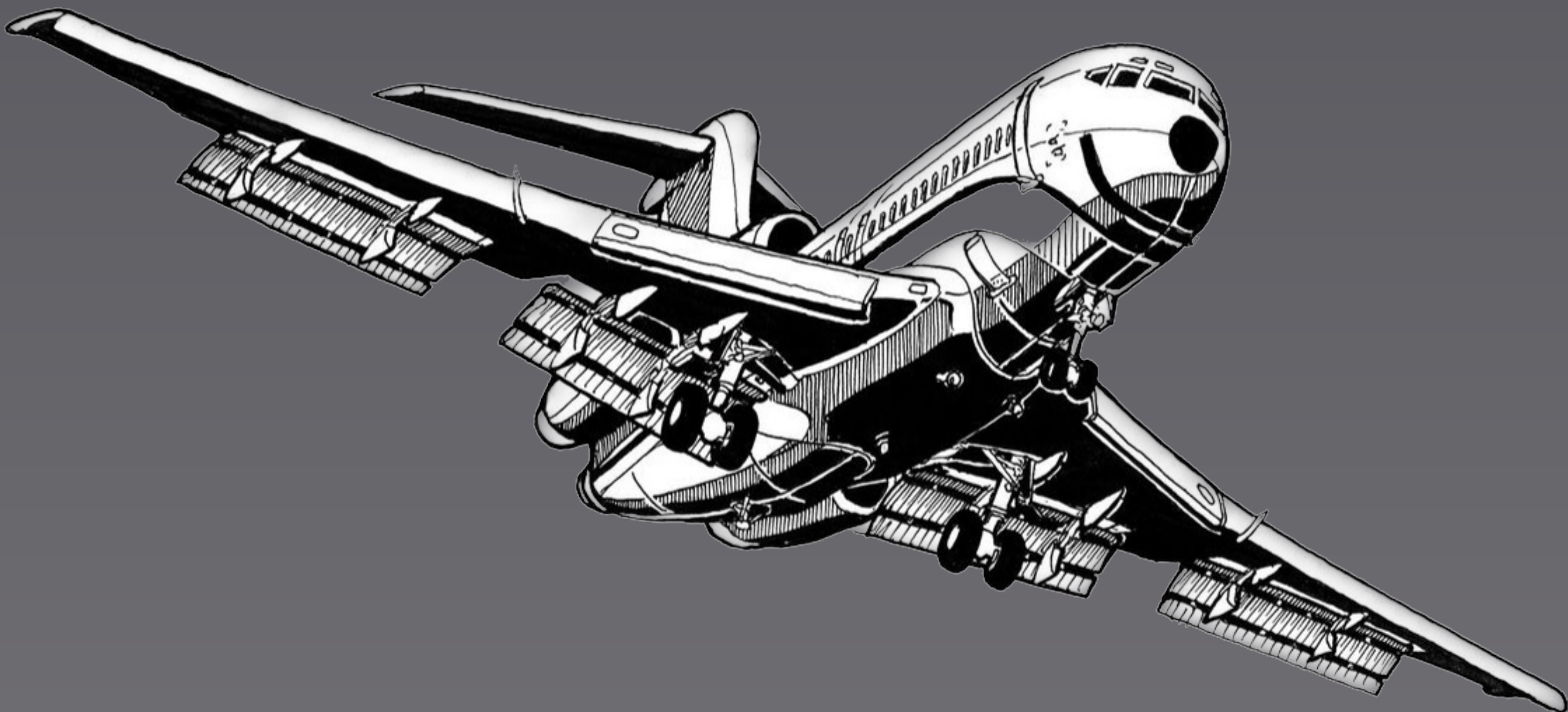
ATPLQ

PERFORMANCE

EASA 2021 All questions



ANDRES FRANCISCO HIDALGO CRUZ

GENERAL

Performance class A

- All multi-engined JET aircraft.
- Multi- engined TURBOPROPS with an MOPS of more than 9 or MTOM exceeding5700Kg.

Performance class B

- Propeller- driven aircraft, either PISTON or TURBOPROP with a MOPS of 9 or less and a MTOM of 5700Kg or less.

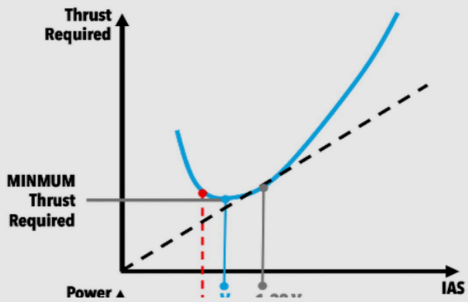
Drag/Thrust Required Curve

Lowest point of curve-VMD= best L/D ratio and best glide

- For JET: V_X = Maximum Endurance Speed
- For PROP: Maximum Range Speed

Tangent-1,32 VMD

- For JET: Best Range Speed, V_Y



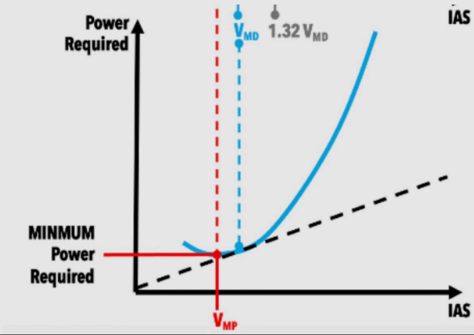
Power Required Curve

Lowest point of the curve -VMP

- For PROP: Best Endurance Speed

Tangent- VMD, best L/D ratio

- For PROP: Maximum Range
- For JET: VX= Maximum Endurance



JET AIRCRAFT ENDURANCE

Maximum endurance will occurs at minimum fuel flow. In a JET, this means minimum thrust and Therefore minimum Drag, VMD which occurs at the LOWEST POINT OF THE DRAG CURVE.

PROPELLER AIRCRAFT ENDURANCE

Minimum fuel flow for a PROPELLER occurs when power required is minimum, so the speed to fly for ENDURANCE is VMP.

VMP is minimum power to maintain straight and level flight, always less than VMD therefore the speed is UNSTABLE.

EFFECT OF WEIGTH ON TOTAL DRAG

At given IAS, when the aircraft's weight is INCREASED or TURNING, the LIFT must be INCREASED and this results in a greater Induced Drag.

Parasite Drag curve and the Induced Drag curve will be displaced to the RIGHT = VMD is INCREASED.

Now we know that VMD INCREASES with an INCREASE the aircraft's weight, so we can say that for a JET, the MAXIMUM ENDURANCE SPEED IS PROPORTIONAL TO AEROPLANE WEIGHT.

Decreasing air density

Vx (IAS)=CONSTANT
Vx (TAS)=INCREASE
VY (IAS)=DECREASE
Vy (TAS)=INCREASE

REMEMBER

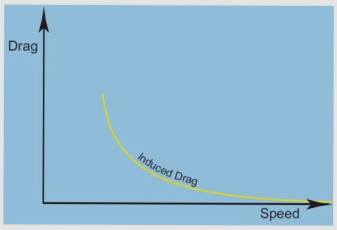
Increasing altitude, PERFORMANCE DECREASE. To maintain IAS we have to put down the nose, then reduce PITCH and CLIMB.

CONTINUOUS DESCENT ARRIVAL (CDA)

The meaning of CDA is to avoid having to level off in stages, during the descend phase and to plan an approach/descent at idle thrust as far as possible. The purpose of this is to reduce NOISE and SAVE FUEL, NOT TIME, by keeping the aircraft as high as possible for as long as possible.

INDUCED DRAG

Induced Drag is caused by the production of lift.
The diagram shows that Induced Drag is INVERSELY proportional to IAS. The Induced Drag is greatest at the stalling speed. (decreases with increased speed)



MINIMUM DRAG SPEED (VMD)

Is the speed at which INDUCED DRAG and profile drag values are equal. It is also the speed that has the lowest total drag penalty. This speed also represents the best lift-drag ratio (best aerodynamic efficiency).
Minimum aircraft drag requires minimum thrust (thrust=drag), that thrust is a product of engine power and fuel consumption is a function of engine power used, aircraft has its lowest fuel consumption in terms of fuel used per hour.
To minimize fuel consumption, the pilots should maintain altitude, keep the aircraft clean and reduce the speed to VMD.

REGION OF REVERSE COMMAND

Has 3 alternative names:
BACK-SIDE OF THE DRAG CURVE
SPEED UNSTABLE REGION
REGION OF REVERSE COMMAND

To maintain unaccelerated flight at an IAS slower than VMD,thrust available must be increased, at speeds below VMD, Thrust required (DRAG) INCREASES.

SPECIFIC RANGE

There are 2 types of SPECIFIC RANGE
(SAR) Specific Air Range in terms of Nautical Air Miles (NAM) per unit of fuel
(SRG) Specific Ground Range in terms of Nautical Ground Miles (NGM) per unit of fuel
The difference is due to wind strength and direction.
SPECIFIC RANGE is the distance flown per unit of fuel (distance that an aircraft travels per unit of fuel consumed). SR= TRUE AIRSPEED / TOTAL FUEL FLOW

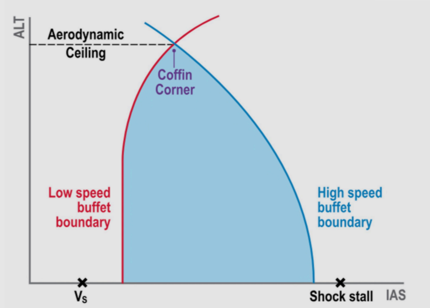
FLIGHT PATH ANGLE: Angle between the flight path vector and the horizon. Assumed to be GROUND-RELATED, therefore WIND DEPENDENT.

CLIMB/DESCENT ANGLE: Angle between the local horizon and TAS vector. Assumed to be AIR-RELATED, therefore NO WIND DEPENDENT.

THE BUFFET BOUNDARY

The buffet boundary has both LOW and HIGH speed limits.
LOW SPEED BUFFET BOUNDARY describes the IAS at which we find the onset of the pre-stall buffet at a margin above Vs.

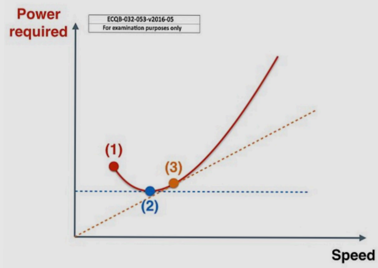
HIGH SPEED BUFFET BOUNDARY describes the IAS at which we find the onset of Mach related buffet, normally MMO but sometimes slightly below that.



The right-hand limit on the graph shows the maximum indicated airspeed VMO and the at high altitudes the maximum Mach number, MMO.
The left-hand limit is based on the stall speed, 1.1 Vs
Therefore, with INCREASING ALTITUDE, LOW SPEED BUFFET WILL INCREASE AND THE HIGH SPEED BUFFET WILL DECREASE.

CORRECT LABELS FOR THE POINTS ON THE POWER CURVE

Single-engined piston Performance class B
(1)= Take-off/Climb
(2)= Max. Endurance (cruise)
(3)= Max. Range (cruise)



VARIATION OF THRUST WITH RPM

Mass flow is directly affected by the engine RPM. High RPM increase mass flow which consequently increases fuel flow and thrust.
NORMALLY OPERATE
Piston= 40% to 70% of available RPM
Jet= 85% to 90% (most efficiency), with a flight idle RPM of 50% to 60%

GROSS AND NET PERFORMANCE

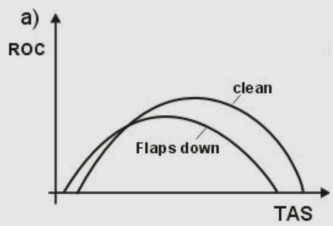
GROSS Performance: The average Performance that a fleet of aeroplanes should achieve if satisfactorily maintained and flow in accordance with the techniques described in the manual.

NET Performance: is the GROSS Performance diminished to allow for various contingencies that can't be accounted for operations.

GROSS PERFORMANCE= Calculated, No Factor
NET PERFORMANCE= Actual with Safety Factor

RATE OF CLIMB (ROC vs TAS)

"Flaps down" compared to "Clean" configuration
With Flaps Down, RATE OF CLIMB should be lower compared to clean configuration.

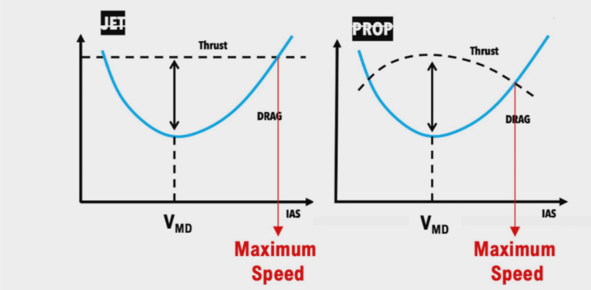


ABSOLUTE CEILING: Is the highest altitude to which the aircraft can climb, where THRUST=DRAG, so with no excess of thrust the rate (and gradient) of climb is ZERO.
SERVICE CEILING: The pressure altitude at which the rate of climb is reduced to a specified minimum value of 100 ft/min for PROP and 500 ft/min for JET.

MAXIMUM SPEED

If the thrust available exceeds the thrust required in level flight, the aeroplane will climb, unless the throttles/thrust levers are adjusted to maintain level flight. If the pilot use the control column and trimmers without adjusting the throttles/thrust, the aeroplane accelerate.
Consequently the drag starts to decrease until VMD. Thereafter, it starts to increase again until it reaches a point where drag (thrust required) equals thrust available.
At this point the aircraft is unable to accelerate and will maintain the speed. THE MAXIMUM SPEED HAS BEEN REACHED.

Thrust (Thrust Available) and Drag (Thrust Required)



TAS VALUE CHANGE, INCREASES IN ALTITUDE (TROPOSPHERE-TROPOPAUSE)

TAS decreases in troposphere and stays the same in the tropopause

V_{SR1}: Reference stall speed in a SPECIFIC CONFIGURATION
V_{SR0}: Reference stall speed in the LANDING CONFIGURATION
V_{S1g}: 1-g stall speed or minimum speed at which the aeroplane can develop a lift force equal to its weight
V_{S1}: Stall speed or minimum steady flight speed obtained in a SPECIFIED CONFIGURATION

ENGINE TYPE (BEST ENDURANCE)

-PISTON (PROP) ENGINE: LOW altitudes
-TURBO PROP ENGINE: MEDIUM altitudes
-JET ENGINE: HIGH altitudes

SPECIFIC FUEL CONSUMPTION (SFC)

We have 2 types of SFC, for JET and for PROPELLER
In a JET is the fuel flow per unit of thrust-In a PROP is the fuel flow per unit of power
It is a measurement of efficiency, LOWER SFC means LESS fuel used, so is better. Keep in mind that is a engine measurement, noting to do with the aircraft's aerodynamics.
In a JET, SFC is lowest (which is the best) when the air temperature is LOW and also when the engine is running at its design RPM of approx 90% to 95%, this means that SFC is proportional to temperature, most efficient at high altitude.
HIGHER ALTITUDE = COLDER TEMPERATURE = LOWER SFC

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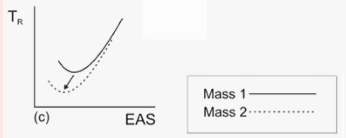
IMPORTANT

High Mass = High lift requirement

High lift induced drag=drag curve shifts to the right=increase speed



POWER REQUIRED= DRAG x TAS

If we compare the shape of the POWER REQUIRED CURVE and TRHUST REQUIRED, we notice that these are very similar.

The difference being that in the POWER REQUIRED CURVE is displaced to the left, which results in the Minimum Power Required Speed VMP being slower than the Minimum Thrust Required VMD.

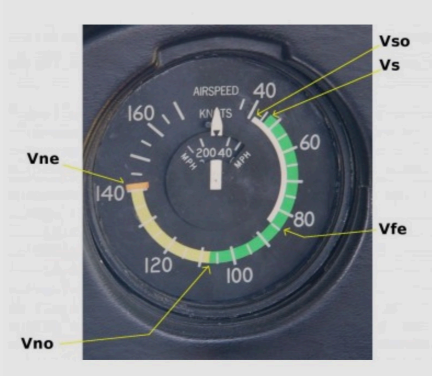
VNE

The red line at the top of the yellow arc, is the Velocity (V) that you Never (N) Exceed (E).

Is the maximum speed the aircraft should ever be operated. Exceeding this Velocity can cause uncontrollable and destructive flutter and may cause serious or catastrophic failure of structural components on the aircraft and is:

-Aerodynamic limitation

-Structural limitation



CERTIFIED THRUST RATINGS

There are 2 principal Certified Thrust Rating and these define the safe limits of operation of the engine.

MAXIMUM TAKE-OFF/GO AROUND THRUST (TOGA)

Is the highest amount of thrust an aircraft is allowed to deliver in the first 5 min of take-off and flight. We use TOGA when the aircraft is heavy and the runway is small for take-off. TOGA cause a lot of engine wear and this is why most of the time the pilot has to calculate the minimum thrust needed for an efficient take-off.

MAXIMUM CONTINUOUS THRUST (MCT)

Is the most thrust that an engine can produce over a long period of time. The engine can produce more thrust than the maximum continuous level, but only for a few minutes.

SCREEN HEIGHT

Is the height of imaginary screen which the aeroplane would just clear when taking off or landing in an unbanked attitude with landing gear extended. (Cross at the end of take-off distance)

GLIDE: The best glide occurs at VMD. Glide angle (glide range) itself is independent of the aircraft mass. Faster or slower speeds than VMD will lead to steeper glide angles.

GLIDE ANGLE= CD/CL

GLIDING DISTANCE: Wind speed is an important practical influence on gliding distance over the surface.

GLIDING TIME: The aircraft's mass varies the time that the aircraft will glide for.

Glide Distance (varies with wind)	Glide duration (varies with mass)
TAILWIND= increase glide distance	LOW MASS= increases glide duration
HEADWIND= decreases glide distance	HIGH MASS= decreases glide duration

CLIMB GRADIENT AND ANGLE OF CLIMB

Climb gradient: Is the ratio between distance travelled over the ground and altitude gained, is expressed as a percentage.
Angle of climb: Is the angle between a horizontal plane representing the Earth's surface and the actual flight path followed by the aircraft during its ascends.

The climb gradient numerical value is ALWAYS LARGER than the ANGLE OF CLIMB.
3 degrees angle of climb = approx 5% gradient

REMEBER

In a turn at a constant angle of bank, the rate of turn is
INVERSELY PROPORTIONAL TO THE AIRCRAFT TAS
HIGHER TAS MEANS A LOWER RATE OF TURN

Thrust Required Curve

(Lowest Point)
JET: Minimum Drag
PROP: Maximum Specific Range

ENDURANCE

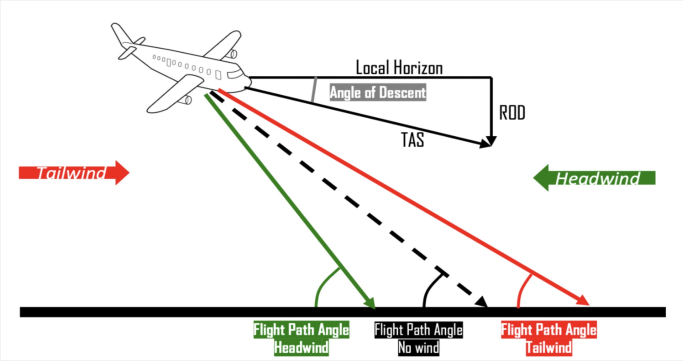
Endurance is the TIME that an aircraft can remain airborne with the fuel available. It will be greatest when the fuel is used at the LOWEST POSSIBLE RATE, the fuel flow is minimum.
Increasing altitude (decreasing air density) increases the endurance due to increase jet engine efficiency. INVERSELY PROPORTIONAL to the fuel flow
Endurance is MAXIMUM at high level, low OAT and design RPM
Specific endurance is defined as 1/fuel flow

IMPORTANT

Tailwind: Flight Path Angle ➡️ DECREASE
Descent Angle: CONSTANT

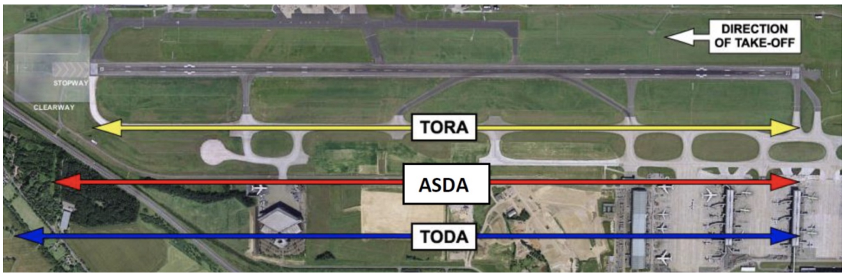
Headwind: Flight Path Angle ➡️ INCREASE
Descent Angle: CONSTANT

The diagram shows that descent angle will be same although we have a tailwind when landing.
Only ground speed will be higher.
With tailwind when approach phase flight path angle will decrease gradually



DECLARED DISTANCES

TORA= Takeoff run available
TODA= TORA + CLEARWAY
ASDA= TORA + STOPWAY
LDA= TORA - Displaced threshold



EFFECT OF FLAPS

If we use HIGHER flaps, the profile of the wing is changed and the wing's capability to provide lift at low speed INCREASE. The actual generated lift through remains the same, considering the lower speed, for the same amount of lift.

With the change of wing shape, the parasite drag INCREASES and Total Drag Curve moves right and upwards. This reduces V_{MD},V_X,V_Y and RATE OF CLIMB ACHIEVED.

INCREASING	ROC	Vy-Vx PROP	Vy-Vx JET
ALTITUDE	REDUCES	SAME	LOWER
TEMPERATURE	REDUCES	SAME	LOWER
MASS	REDUCES	HIGHER	HIGHER
FLAP ANGLE	REDUCES	LOWER	HIGHER

SPEED OF BEST ANGLE OF CLIMB Vx

The speed to gain more altitude with the least horizontal distance. It is almost the same as the minimum drag speed (V_{MD}) so all factors affecting the drag, affects the V_X

SPEED OF BEST RATE OF CLIMB Vy

The speed to gain more altitude with the least time. It is the same speed for maximum excess of power, so all factors affecting the require power, affects the V_Y

IMPORTANT

There is 2 important performance parameters in the cruise RANGE and ENDURANCE.
For an airliner RANGE is more important than ENDURANCE.
ENDURANCE= is about the airborne time.
RANGE= is more concerned with the distance covered.

CALCULATION

Range is not only about to reduce fuel flow, it also maximize speed.
Maximum range can be defined being the maximum distance that an airplane can fly for a given quantity of fuel.

RANGE=DISTANCE (NM) ÷ FUEL (Kg)

The formula above needs to be adjusted in order to be practical and give us useful information.

The SPECIFIC RANGE can be determined with speed of the airplane and fuel flow.

SPECIFIC RANGE (SR)=TAS ÷ FUEL FLOW

SPECIFIC RANGE

Is the distance that an aircraft can travel per unit of mass of fuel.

Determine the SPECIFIC RANGE (SR), given:
Fuel flow: 28 Imp Gal/hr
Specific gravity: 0.72
TAS: 154 MPH

1)Convert Imp Gal to Kg =1 Imp Gal = 4,546L
28 Imp Gal= 28 x 4,546= 127,3L x 0,72= 91,7kg

2)Convert MPH (Statue Miles Per Hour) into Kg (Nautical Miles Per Hour)
1 MPH= 0.8689 NM
154 MPH= 154 x 0.8689= 133,8 kt

3)Calculate the distance covered per 1Kg of fuel
To cover 133,8 NM the aircraft burns 91,7 Kg of fuel
On 1Kg of fuel the aircraft covers: (SR=TAS÷FUEL FLOW)
133,8 ÷ 91,7= 1,46NM/Kg

RATE OF CLIMB (ROC)

The RATE OF CLIMB is the aircraft's vertical speed, the height gained per unit of time, usually expressed in feet per minutes. Considering an aircraft in a steady climb, the ROC is affected by TAS and the climb angle. IS APPROXIMATELY CLIMB GRADIENT x TAS ÷ 100

RoC= (CLIMB GRADIENT x TAS)

REMEMBER
Sometimes the questions about ROC, talk about "obstacle clearance" and we have to remember that "obstacle clearance" is related to the Ground Flight Path, therefore WE HAVE TO USE GROUNDSPEED, not TAS.

RoC (FT/MIN)= GROUNDSPEED x CLIMB GRADIENT

If a departure procedure requires 4,6% climb gradient to 1300ft, to clear an obstacle, what is the minimum ROC give the following?
TAS: 125 kts
Headwind Component: 25 kts

Rate of climb(ft/min)= GS x Climb Gradient
= (125-25) x 4,6= 460ft/min

FORCES ACTING ON THE AEROPLANE

Given:
T= Thrust — D= Drag — W=Weight
D=T+W Sin 3

RATE OF DESCENT (ROD)

Now we have an example of ROD and for your information this kind of questions was seen in PERFORMANCE exam but there is no matching to the subject at all.

ROD(FT/MIN)=GRADIENT x GROUNDSPEED

If you want to follow a 3,25 degrees glide slope (ILS), when TAS is 130kts and wind component is 15kts tailwind, your ROD must be?

1)We have to know our gradient and our GS

Tan 3,25= 0,0568 x 100= 5,68 Gradient

GS= 130 + 15 (tailwind)= 145kts

2)Now we can use the formula

ROD=5,68 x 145= 823,6ft/min

CLOSEST ANSWER 832ft/min

CLIMB GRADIENT

The ratio in the same units of measurement, expressed as a %, as obtained from this formula

GRADIENT%= CHANGE IN HEIGHT ÷ HORIZONTAL DISTANCE x 100%

CLIMB GRADIENT=((THRUST-DRAG) ÷ WEIGHT) x 100

On a segment of the take-off flight path, an obstacle requires a minimum gradient of climb of 2,6% in order to provide an adequate margin of safe clearance. At a mass of 110000Kg, the gradient of the climb is 2,95%

For the same power and assuming that the sine of the angle of climb varies inversely with mass, at what maximum mass will the aeroplane be able to achieve the minimum gradient?

1)A percentage gradient of 2,6% equates to a gradient expressed as decimal

2,6 ÷ 100= 0,026

2)A percentage gradient of 2,95% equates to a gradient expressed as decimal

2,95 ÷ 100= 0,0295

(0,0295 ÷ 0,026) x 110 000 Kg= 124808 Kg

AND WE CAN DO IT MORE SIMPLE AS A RULE OF 3

110 000 — 2,6%

X — 2,95%

X= 2,95 x 110000= 324500 ÷ 2,6= 124808 Kg

WIND SPEED AND WIND INTENSITY

HEADWIND or TAILWIND = Cos } X wind intensity = wind speed

CROSSWIND =Sin } ÷ wind speed = wind intensity

Calculated the one-engine-failed climb gradient of a four-engine-aeroplane, given the following information:
Aeroplane Mass: 358000 Kg
Thrust per Engine: 245000 N
Drag: 455000 N (assume the acceleration due to gravity is 10m/s^2)

1) Thrust (T)= Number of Engines (4-1 inop) x Thrust per Engine
T= 3 x 245000 N= 735000 N
2) Weight (W)= Aeroplane Mass x 10m/s^2
W= 358000 Kg x 10m/s^2= 3580000 N
3) Climb Gradient=[(thrust-drag) ÷ weight] x 100%
Climb Gradient= [(735000-455000) ÷ 3580000] x 100% = 7,8%

Sometimes, the question give us "Lift to Drag ratio". Here is an example:
Thrust per engine: 33000 lbs
Mass: 89500 Kg
Lift to Drag ratio: 7,8:1
G= 10m/s^2
Is the same process but first we have to know or Weight "weight=massXg" and then make our Weight divided by our Lift to Drag ratio this case "7,8"
Weight= 89500 x 10= 895000 N
895000 ÷ 7,8= 114743,6 N
Be carefully with the units.
33000 lbs ÷ 2.205 = 15000 Kg then the Total Thrust produced by both engines will be:
15000 kg X 10m/s^2 X 2= 300000 N
Finally use the formula Climb Gradient=[(thrust-drag) ÷ weight] x 100%
(300000-114743,6) ÷ 895000 x 100%= 20,7%

MACH NUMBER CALCULATION

Mach Number can be calculated using this formula

M=TAS ÷ LSS

Local Speed of Sound (LSS)

The Local Speed of Sound is only dependent on absolute temperature and can be calculated with this formula

LSS= 38,95 x √k

K= °C +273

An aircraft is cruising at a TAS of 480 kts and the OAT is -55°C. Calculate the Mach Number.
1) Convert °C into K:
K=-55°C + 273= 218 K
2) Calculate LSS:
LSS= 38,95 √218= 575 kts
3) Determine Mach Number:
TAS: 480 kts
LSS= 575 kts M=480÷575= 0,83

Following a take-off, limited by the 50ft screen height, a light twin-engine climbs on a gradient of 9%. It will clear a 800ft obstacle in relation to the runway at sea level (horizontally) situated at 2NM from the 50ft point with an obstacle clearance margin of:

1) Solving for Change in height we get:

Change in height= gradient X distance travelled

= 0,09 x 2NM x 6080= 1094ft

2) we assume that the required climb gradient of 9% will be achieved at the screen height of 50% and 2NM after the screen height the gained altitude will be:

1094ft + 50ft= 1144ft

3) the aircraft will clear the obstacle by:

1144ft- 800ft = 344 ft

Note: 1NM= 6080FT

Other important formulas:

Climb angle (°) = Arctg (Altitude difference (ft) / Ground distance (ft))

Time to Climb = (Height Difference (ft) / Rate of Climb (fpm)) x 60 seconds

Distance to Climb (NM) = (Height Difference (ft) / Rate of Climb (fpm)) x (Groundspeed (kt) / 60)

Still Air Gradient of Climb = (Rate of Climb (fpm)/ TAS (kt)) x (6000 / 6080) %

Rate of Climb = Gradient (%) x Groundspeed (kt)

Rate of Climb = Groundspeed (kt) x Gradient (ft/NM) / 60