The following pages contain references for use during the exam: tables containing the x86 instruction set (covered so far) and condition codes. You do not need to submit these pages when you finish your exam.

Remember that:

- Most instructions can have at most one memory operand.
- Brackets [ ] around a register name, immediate, or combination of the two indicates an effective address.
    - Example: MOV AX, [0x10] → contents of address 0x10 moved to AX
- Parentheses around an address mean "the contents of memory at this address".
    - Example: (0x10) → the contents of memory at address 0x10

Category	Instruction	Example	Meaning
Data transfer	Move	`MOV AX, BX`	`AX = BX`
	Move & sign-extend	`MOVSX EAX, DL`	`EAX = DL, sign-extended to 32 bits`
	Move and zero-extend	`MOVZX EAX, DL`	`EAX = DL, zero-extended to 32 bits`
	Exchange	`XCHG AX, BX`	`Swap contents of AX, BX`
	Load effective address	`LEA AX,[BX+SI+0x10]`	`AX = BX + SI + 0x10`
Arithmetic	Add	`ADD AX, BX`	`AX = AX + BX`
	Add with carry	`ADC AX, BX`	`AX = AX + BX + CF`
	Increment	`INC [EDI]`	`(EDI) = (EDI) + 1`
	Subtract	`SUB AX, [0x10]`	`AX = AX – (0x10)`
	Subtract with borrow	`SBB AX, [0x10]`	`AX = AX – (0x10) – CF`
	Decrement	`DEC CX`	`CX = CX – 1`
	Negate (2's complement)	`NEG CX`	`CX = -CX`

	Multiply
	Unsigned: `MUL`
	(all operands are non-negative)
	Signed: `IMUL`
	(all operands are signed integers in 2's complement form)
		`IMUL BH`
		`IMUL CX`
		`MUL DWORD PTR [0x10]`
			`AX = BH * AL`
			`(DX,AX) = CX * AX`
			`(EDX,EAX) = (0x10) * EAX`

	Divide
	Unsigned: `DIV`
	(all operands are non-negative)
	Signed: `IDIV`
	(all operands are signed integers in 2's complement form)
		`DIV BH`
		`IDIV CX`
		`DIV EBX`
			`AL = AX / BH (quotient)`
			`AH = AX % BH (remainder)`
			`AX = EAX / CX (quotient)`
			`DX = EAX % CX (remainder)`
			`EAX = (EDX,EAX) / EBX (Q)`
			`EDX = (EDX,EAX) % EBX (R)`

Category	Instruction	Example	Meaning
Logical	Logical AND	AND AX, BX	AX = AX & BX
	Logical inclusive OR	OR AX, BX	AX = AX | BX
	Logical exclusive OR	XOR AX, BX	AX = AX ^ BX
	Logical NOT (bit flip)	NOT AX	AX = ~AX

Shift/rotate (NOTE: for all instructions except RCL/RCR, CF = last bit shifted out)	Shift left	SHL AX, 7
		SAL AX, CX
			AX = AX << 7
			AX = AX << CX

	Logical shift right (treat value as unsigned, shift in 0s)	SHR AX, 7	AX = AX >> 7 (upper 7 bits = 0)
	Arithmetic shift right (treat value as signed; maintain sign)	SAR AX, 7	AX = AX >> 7 (upper 7 bits = MSB of original value)
	Rotate left	ROL AX, 7	AX = AX rotated left by 7 (lower 7 bits of AX = upper 7 bits of original value)
	Rotate right	ROR AX, 7	AX=AX rotated right by 7 (upper 7 bits of AX = lower 7 bits of original value)
	Rotate left through carry	RCL AX, 7	(CF,AX) rotated left by 7 (Treat CF & AX as 17-bit value with CF as MSB)
	Rotate right through carry	RCR AX, 7	(AX,CX) rotated right 7 (Treat CF & AX as 17-b8t value with CF as LSB)
Bit test/ scan	Bit test	BT AX, 7	CF = Value of bit 7 of AX
	Bit test and reset	BTR AX, 7	CF = Value of bit 7 of AX Bit 7 of AX = 0
	Bit test and set	BTS AX, 7	CF = Value of bit 7 of AX Bit 7 of AX = 1
	Bit test and complement	BTC AX, 7	CF = Value of bit 7 of AX Bit 7 of AX is flipped
	Bit scan forward	BSF DX, AX	DX = index of first non-zero bit of AX, starting with bit 0 ZF = 0 if AX = 0, 1 otherwise
	Bit scan reverse	BSR DX, AX	DX = index of first non-zero bit of AX, starting with MSB ZF = 0 if AX = 0, 1 otherwise

Category	Instruction	Example	Meaning
Conditional tests	Compare	CMP AX, BX	Subtract AX - BX Updates flags

	Byte set on condition	SETcc AH	AH = 1 if condition true
			AH = 0 if condition false

Jumps and loops	Unconditional jump	JMP label	Jump to label
	Conditional jump	Jcc label	Jump to label if condition true
	Loop	LOOP label	Decrement CX; jump to label if CX != 0
	Loop if equal/zero	LOOPE label LOOPZ label	Decrement CX; jump to label if (CX != 0) && (ZF == 1)
	Loop if not equal/zero	LOOPNE label LOOPNZ label	Decrement CX; jump to label if (CX != 0) && (ZF == 0)
Subroutine-related instructions	Call subroutine	CALL label	Jump to label; save address of instruction after CALL
	Return from subroutine	RET label	Return from subroutine (jump to saved address from CALL)

	Push	PUSH AX
		PUSH EAX
			SP = SP - 2
			(SP) = AX
			SP = SP - 4
			(SP) = EAX

	Pop	POP AX
		POP EAX
			AX = (SP)
			SP = SP + 2
			EAX = (SP)
			SP = SP + 4

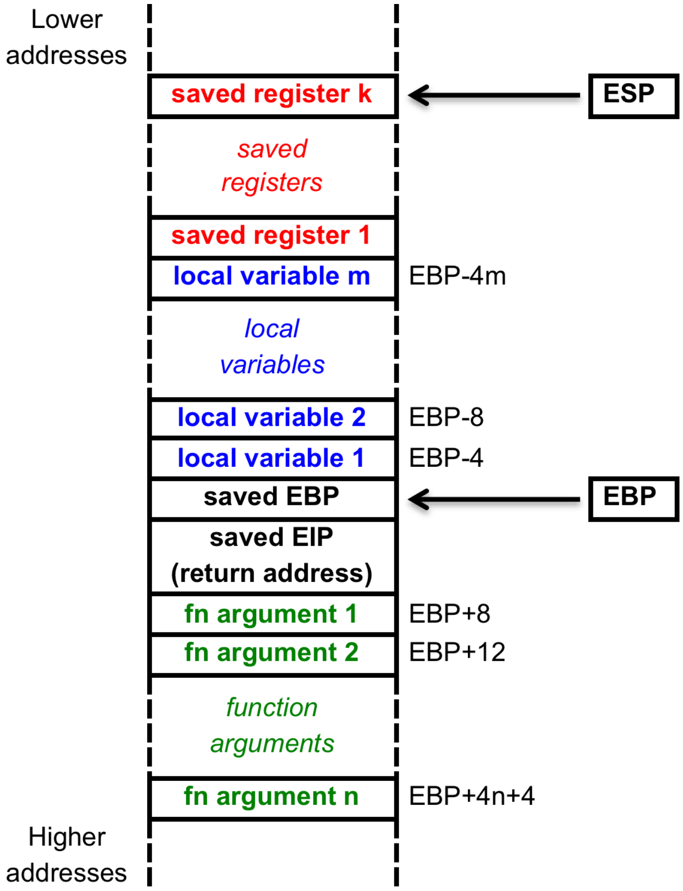
	Push flags	PUSHF	Store flags on stack
	Pop flags	POPF	Remove flags from stack
	Push all registers	PUSHA	Store all general purpose registers on stack
	Pop all registers	POPA	Remove general purpose registers from stack

Condition code	Meaning	Flags
O	Overflow	OF = 1
NO	No overflow	OF = 0
B NAE C	Below Not above or equal Carry	CF = 1
NB AE NC	Not below Above or equal No carry	CF = 0
S	Sign set	SF = 1
NS	Sign not set	SF = 0
P PE	Parity Parity even	PF = 1
NP PO	No parity Parity odd	PF = 0
E Z	Equal Zero	ZF = 1
NE NZ	Not equal Not zero	ZF = 0
BE NA	Below or equal Not above	CF OR ZF = 1
NBE A	Not below or equal Above	CF OR ZF = 0
L NGE	Less than Not greater than or equal	SF XOR OF = 1
NL GE	Not less than Greater than or equal	SF XOR OF = 0
LE NG	Less than or equal Not greater than	(SF XOR OF) OR ZF = 1
NLE G	Not less than or equal Greater than	(SF XOR OF) OR ZF = 0

x86 subroutine details:

- Subroutine arguments are passed on the stack, and can be accessed within the body of the subroutine starting at address EBP+8.
- At the start of each subroutine:
  - Save EBP on the stack
  - Copy the current value of the stack pointer (ESP) to EBP
  - Create space within the stack for each local variable by subtracting the appropriate value from ESP. For example, if your function uses four integer local variables, each of which contains four bytes, subtract 16 from ESP. Local variables can then be accessed starting at the address EBP-4.
  - Save any registers the function uses other than EAX, ECX, and EDX.
- A subroutine's return value is typically stored in EAX.

Typical x86 stack frame (covered in HLL → assembly lectures)


Lower addresses
saved register k
ESP
saved registers
saved register 1
local variable m
EBP-4m
local variables
local variable 2
EBP-8
local variable 1
EBP-4
saved EBP
EBP
saved EIP (return address)
fn argument 1
EBP+8
fn argument 2
EBP+12
function arguments
fn argument n
EBP+4n+4
Higher addresses