Name: _____Solution_____   **Roll No.:** _____

Time allowed: 15 minutes   **Maximum Marks:** 15

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1. How does a buddy allocator merge free blocks?   [2]

To merge, a buddy allocator checks if the addresses of the two free blocks differ only by one bit and if they are of the same size.

2. What would the following free list look like after an allocation request of size 12 is completed in case of (a) best fit and (b) worst fit?   [3]

head ⟶ 10 ⟶ 30 ⟶ 20 ⟶ NULL

   (a) head → 10 → 30 → 8
   (b) head → 10 → 18 → 20

3. Assume the following:
   - Page size: 32 bytes
   - Address space: 32KB
   - Physical memory size: 4KB
   - Size of Page Directory Entry (PDE) and Page Table Entry (PTE): 1 byte
   - Both PDE and PTE only have a valid bit in addition to the PFN, so have this bit format: VALID | PFN bits (x … 0)

   Answer the following questions:

   i. How many bits would be there in the virtual address?   [1]

$32KB = 2^5 \times 2^{10} = 2^{15}$ bytes, so 15 bits.

   ii. How many bits would the offset have in the virtual address? And how many would be there for the virtual page number?   [1]

As page size is 32 (2^5) bytes, the offset will be 5-bit wide. The bits for the VPN will then be: $15 – 5 = 10$

   iii. How many page frames are there in the physical memory?   [1]

Physical memory size / Page frame size = $4KB/32B = 2^7$ page frames.

   iv. Considering two level paging, and the page directory to be 1 page long, how many bits of the VA will be used to index into the page directory? How many bits would be required to index into the page table?   [1]

5 bits to index into the page directory
5 bits to index into the page table

v. Given that the value of page directory base register (PDBR) is `30`, which tells you that the page directory is located at page number 30, and a complete dump of each page of memory (remember, each page has 32 bytes), find the physical address translation (if valid, you would need to check the valid bit) and the value stored at this physical address for the following two virtual addresses: [6]

VA1: `0x4ea6` (0 100 1110 1010 0110) (PDEIndex: 19, PTEIndex: 21, offset: 6)
VA2: `0x21b0` (0 010 0001 1011 0000) (PDEIndex: 8, PTEIndex: 13, offset: 16)

Page dump:

page 0:001b0319181b111b06140a1b170e100001120f1a12040b171000191902100b18
page 1:100d021314130f1115010d0403170a0a08120313021d0417100d090b17101007
page 2:04041a1907110e1605191e151c1d0b1a191203131c09141b120113071a14091b
page 3:08030e16171b09141b0c1c031c1b1e19160d161b11131c080a011b131407050e
page 4:0000000000000000000000000000000000000000000000000000000000000000
page 5:7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7fa77f7f7f7f7f7f7f7f7f7f
page 6:0c0611160d1609051911060b0b011a031b1003080c12181a061117051907120f
page 7:0000000000000000000000000000000000000000000000000000000000000000
page 8:0000000000000000000000000000000000000000000000000000000000000000
page 9:7fe37f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7ffe7f
page 10:7f7f7f7f7f7ffef7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 11:0000000000000000000000000000000000000000000000000000000000000000
page 12:0000000000000000000000000000000000000000000000000000000000000000
page 13:0000000000000000000000000000000000000000000000000000000000000000
page 14:0000000000000000000000000000000000000000000000000000000000000000
page 15:1b07080c16060902071713121b0008130b1e061d16141d0d0a0d161913181418
page 16:17021e0502061c141b0f030a0e1e05071a031e0911141c021a05160017050601
page 17:0c1818111c191b130816161c05000a070b01120d080311031a081b030c18100d
page 18:1b1719090c12010c1e171a091518150d05001b1c08170c131a0913070f000808
page 19:7f7ffee7f7f7f7f7fb27f7f7f7f7f7f7f7f7fe27f7f7f7f7f7f7f
page 20:7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f c3 7f 7f 7f 7f7f7f7f7f7f7f7f7f7f7f7f
page 21:04010f071e0310170c1e0e070c010d071b190f00070706071a04011c111e0c1b
page 22:01151b1d161d00081d180c1d131909050d040b1d0a000105180b09031e0d0601
page 23:1705121e0c1e070b04040c18140602020a110003140701190217011a0e0a0619
page 24:0000000000000000000000000000000000000000000000000000000000000000
page 25:0000000000000000000000000000000000000000000000000000000000000000
page 26:090f1a101a0e031b0d04110d0009030c091d0109000b0a090509191c1011071d
page 27:7f7f7f7f7f7fd97f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 28:fc7f7f7f7f7f7f7f7f7f7f7f7f7f7fa37f7f7f7f7f7f7f7f7f
page 29:1d0203131b0f0d1a18021b0609190d18051b05040f0a101c160009100f160f02
page 30:fa d6 89 93 d0 85 f6 ad `94` be ba f8 e8 a0 9b ae cf f3 9c `dc` dfd5af7fe47f8acab5f07fa5
page 31:0000000000000000000000000000000000000000000000000000000000000000
page 32:7f7f7f7f7f7f7f7f7f7ffa97f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 33:11191a1d020c0e081a0c1c020d13180e1b090b05050f16050f0d1e0f19071b00
page 34:0000000000000000000000000000000000000000000000000000000000000000
page 35:11141d19051103150d14020f0d01141e171d0213120e180c02131a0b13041e1e
page 36:0000000000000000000000000000000000000000000000000000000000000000
page 37:7f7f7f7f7f7f7f7f7f7f917f7f7f7f7f7f7f7f7f7f7f7fe17f817f
page 38:00001d1918191d04120f111d171e031414171319091c0c121b1509070a131e1b
page 39:1917041919110801010d16130618011305000618060000e0a1111151c0a130307
page 40:051a09141c070911020f110d161412190405080051b1a1b0c1a171a15000a08
page 41:161918090a1d0e1101180d060e060a0b0d0a0519100b1303090b0e1a0d0c1217
page 42:1e120b1e05061d1d151e011c15141a0306040e10100b17191701040607110613
page 43:191b1b1b141512101e0a02160f1012070602181c15031e190f001a1313001601
page 44:0000000000000000000000000000000000000000000000000000000000000000
page 45:7f7f7f7f7f7f7f7f7f7fb47f7f7f7f7f7f7f7f7fec7f7f7f7f
page 46:7f7f7f7f7f7f7f7f927f7f7f7f7f7fbbfb7f7f7f7f7f7f7f7f7f
page 47:7f7f7f7f7f7f7f7f7fbf7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 48:0000000000000000000000000000000000000000000000000000000000000000
page 49:0000000000000000000000000000000000000000000000000000000000000000
page 50:020c1c18170610080503061c191918050913161a1b0212140f050e021c1a1009
page 51:080c00051015130b1d1304021e1e1c12090207061c1b180407091d051815101d
page 52:0102100c0109061a1c1b1b0e0613061c06121303160e15018030615020c1604
page 53:7f7fb67f7f7fc17f7f7f7f7fc67f7f7f7f7f7fcd7f7f7f7f7f7f7f7f
page 54:1a031a0015170e1608040b081611141e17181e1c160a0f17181b171407130514
page 55:0000000000000000000000000000000000000000000000000000000000000000
page 56:0000000000000000000000000000000000000000000000000000000000000000
page 57:0000000000000000000000000000000000000000000000000000000000000000
page 58:7f7f7f7f7f7f867f7f7f7faa7fa67f7f7f7f967f7f7f7f7f7fff777f7f7f7f
page 59:111c1211010f1114091d15161e1d041b10120002180b1e1d10121210191e0a0c
page 60:0000000000000000000000000000000000000000000000000000000000000000
page 61:14101111061d15161d0e0a09090909060f090b14091a180a1905021e01001a00
page 62:7f7f7f7f7f7f7f7f7f7f7f7f7f7fff7f7f7f7f7f7f7f7f7f7f7f7f7f9d7f
page 63:00190f1a0a1b19071801131816090a051b12180f0d1d1d17141b0a0918141716

page 64:100f1c12030312000b180e1e0e0a020d0d16121a0e0d0317090e14100514041c
page 65:080a08130d10141a150914151c0b10170a0a130b1a0a0612121e1d0d0d140f12
page 66:0c081a0a16081e060d0b1b160807170d0503161418020e041107071105180508
page 67:02000903011e081b1516141d1b16111516110f041a0f02051b070c151a0a0b0d
page 68:0000000000000000000000000000000000000000000000000000000000000000
page 69:1914111c071e0d1304000410071804141b151c191a010f090d16160605021619
page 70:07051511020309110d090712180b0e150b1700081103011311141a091c1a1d09
page 71:06071d0c070d160902180201001e0d16111e0a0a15000b17110f1d0d160c020c
page 72:1b081c1904181c1d150c101413051b100209020e0210081917051912081c000c
page 73:1a0f0c120d0509190101130810ae0a1e060c0613080b1709111c030107171307
page 74:7f7ffc27f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 75:0000000000000000000000000000000000000000000000000000000000000000
page 76:00 0d 18 04 01 05 `08` 0d 0913050a14101d1d070a10100b1a060e031b121e04161201
page 77:0408190310021913031b14130219150b02170618120b0d080f1b110c151e0511
page 78:0000000000000000000000000000000000000000000000000000000000000000
page 79:7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7ff57f
page 80:7f7f7fea7f7f7fc57f7f8f7f7f7f7f7f7f7f7f7f7f7f7fd17f7f7f7f
page 81:1010130a140c12160917191e010d05050e1803181a1d1706161108180a1a1b0c
page 82:1c0f02160f0a0106190e10130b17160013000f1c19091c0515170108101e050e
page 83:0000000000000000000000000000000000000000000000000000000000000000
page 84:0000000000000000000000000000000000000000000000000000000000000000
page 85:7f7f7f7f7f7f7f7f7fe67f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 86:7f7f7f7f7f7f7f7f7f7f7f7f7fdd7f7f7f957f7f7f7f7f7f7f7f
page 87:0000000000000000000000000000000000000000000000000000000000000000
page 88:0000000000000000000000000000000000000000000000000000000000000000
page 89:0c0b171d08030b1a1e010a0e1b110d1e161b191e15180f151d1d1b140f0c0c1d
page 90:050a1e06000519161d0f0109160c040b0e0b0d040018160c0309111b0e1e1005
page 91:0000000000000000000000000000000000000000000000000000000000000000
page 92:7f 7f 7f 7f 7f f1 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f `cc` 7f7f7f7f7f7f7ffbd
page 93:0c0b0a0b110c030e1e17161c0d0b18031704130f17011419011508171e000c0f
page 94:0000000000000000000000000000000000000000000000000000000000000000
page 95:ab7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7ffe5c77f
page 96:0000000000000000000000000000000000000000000000000000000000000000
page 97:06130a0b02160a11101a16161c1a041a1b0508171b01171b0d0707071a170817
page 98:1a10091a0505110e17001c080f000b0f1d05031a1c0f101b0e0d0d07080b020e
page 99:0501161514031607d0f140a0b1914190118050a1418130f1012060b0d030d1500
page 100:7f7f7f7f7fa17f7f7f7f7f7f7f7f7f7f7f7f7fff47f7f7f7f7fa87f
page 101:0f02061b1b1c0a14181319101415081c1d021e1d14011b031e1401051311171c
page 102:030d0a1e150b0f1b10150b0d1706141a1e10131e181a10041902160919130f0e
page 103:0000000000000000000000000000000000000000000000000000000000000000
page 104:7f7f7f7f7f7f7f7f7f7f7f7f7f977f7f7fc87fb3f27f9a7f7f7f
page 105:0000000000000000000000000000000000000000000000000000000000000000
page 106:100a0412060b100607020a190708041216051900030218021606090319 0b1c15
page 107:0000000000000000000000000000000000000000000000000000000000000000
page 108:171e131412091c0e1c091a18130d04170b140402041905 1b0b110a13020c1d05
page 109:070912180f020d171b020c1c1613030f0c0f0f02190d05130a0312001c11081d
page 110:0a161b0b06070f0c021a131b1a1619150d191c0304050e1a101a0b1107130800
page 111:1d18121008010e1a060e08151d1b080c00101a1a020d020d1c081a1d19061c1c
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page 113:0a15051e1d05170a0006160e1003050b0f190d0a1c1517180f080314171b1c0f
page 114:18171b071d06030f040712040c0b1d020f0e050a0b0b11110e0d120f03140c1a
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page 116:0c040a001c04001d09130b0a1c160a19171a0d0d1b0e0b131510021e05120a01
page 117:01111408021208050711 0e0b0306130c0519100a1e10040e081a180204140f09
page 118:7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f837f7f7f7f7f7f80
page 119:1c031c1c13060e0411030c04150a1a19041616 0819010915181d11161d1c0a0d
page 120:da7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f7f
page 121:0000000000000000000000000000000000000000000000000000000000000000
page 122:7f7f7f7f7f7f7f7f7f7f7fd27f7f7f7fc07f7f7f7f827f7f7f
page 123:020b10121204 0f050b0509130c050e1409080d150114011b0519010f07181703
page 124:051e15130e00061808120f05010216070f1117040d17140e13181b1003041415
page 125:0000000000000000000000000000000000000000000000000000000000000000
page 126:111b05150a130e041b0f1e121d1401001e1418190b151401101c1118020c0f11
page 127:111d030005091e03101a0909 0601121106110f1507071b15170a120b151d0f0e