46th BCS Written Information and Communication Technology

Subject Code: 281
Time: 4 hours
Full Marks: 200
[N.B. Answer all the questions. Figures in the right margin indicate full marks.]

1.
(a) Explain the photoelectric effect and its significance in quantum theory.
(b) Derive the equation for the de Broglie wavelength of a particle.
(c) Convert the following sum of products canonical expression to product of sum canonical expression:

$f(A,B,C,D)=\sum(1,3,5,8,11)$

(d) Minimize the following function using the Karnaugh map method: $f(A,B,C,D)=\Pi(2,3,7,12,13,14,15)$

2.
(a) State and prove De Morgan's theorem using Boolean algebra.
(b) Design a 4-to-1 multiplexer circuit and explain its working principle.
(c) Explain the race-around condition in Flip-Flops and discuss how it can be resolved.
(d) Distinguish between Mealy and Moore machines.

3.
(a) Explain the concept of pipelining and its impact on CPU performance.
(b) Compare and contrast between RISC and CISC architectures.
(c) For the 8086 microprocessor, write the full name of the following registers: SP, BP, SI, DL, IP.
(d) Given a cache memory with a hit rate of 90% and main memory access time of 100 ns, calculate the average memory access time, if the cache access time is 10 ns.

4.
(a) Discuss the advantages and disadvantages of Time-Division Multiple Access (TDMA) and Code-Division Multiple Access (CDMA).
(b) For a noisy channel, if the signal to noise power ratio at the receiver is 0.1 and the bandwidth of the channel is 2.4 GHz, what is the channel capacity in Mbps?
(c) A monotone message signal of bandwidth 20 kHz and amplitude 10V is sampled at the rate of 150% higher than the Nyquist rate to obtain digital data with a uniform quantizer. The bit rate of the digital data signal is found to be 1.6 Mbps. Determine,
(i) the bits required per sample
(ii) the Signal-to-Quantization-Noise Ratio (SQNR)
(iii) the step size of the quantizer

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5.

(a) What is cryptography? Explain the working principle of RSA algorithm.

(b) Explain the concept of IPv6 addressing scheme and its advantages over IPv4.

(c) What is zero-day attack in cyber security? Draw a diagram to provide an illustration of the window of vulnerability for zero-day attacks.

(d) What is a one-way hash function? Briefly explain how they are used in a digital signature scheme in the area of computer security.

6.

(a) Illustrate the difference between 'Call-by-value' and 'Call-by-reference' in a function with examples.

(b) Write a program in C language or in Java to calculate the factorial of an integer number using recursion.

(c) Differentiate between function overloading and function overriding with examples.

(d) An integer number can be reversed by separating the digits and placing them into another variable in opposite order. For example, if the integer number is 4567, then the reversed value is 7654. Write a function in a structured programming language to reverse an integer using the following function prototype: `int reverse_int(int num);`

The variable 'num' contains the integer and the function returns the reverse value of 'num'.

7.

(a) Distinguish between White Box and Black Box testing.

(b) Explain the principles of low coupling and high cohesion in software design.

(c) The following task must be performed in a software project.

Task	Task Time (in Hours)			Other Tasks that must precede the task
	Earliest Time	Most likely time	Latest time	
A	35	50	60	–
B	30	40	50	–
C	15	20	25	A
D	35	45	55	C
E	15	20	30	C
F	15	25	30	D
G	05	11	15	E
H	25	35	45	B, F, G

Draw the precedence diagram and find the expected time of the software project completion using PERT method.

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8.

(a) Differentiate between stored procedure and trigger in Structural Query Language (SQL).

(b) What are the properties of a transaction? How are concurrent transactions managed? Explain any concurrency control mechanism.

(c) In a payroll management system, the salary of everyone working in a company is managed. The salary comprises several components, such as, basic, house rent (a certain percentage of basic), medical allowance, etc. and deductible components like PF contribution, insurance subscription etc. If an employee takes a loan, the repayment is adjusted at the beginning of the next month. Basic of all employees are incremented following a rule which defines the percentage of increment. However, each salary grade has a maximum bound. The increment will be applicable within this bound. Draw an Entity Relationship (ER) diagram of this payroll management system.

9.

(a) Discuss the causes and solutions of deadlock in operating systems.

(b) What is an expert system? Explain its components.

(c) Write down the algorithm for Breadth-First Search (BFS) in graph traversal.

(d) Discuss the significance of NP-Complete problems with examples.

10.

(a) Differentiate between supervised and unsupervised learning.

(b) Present the KNN algorithm. What is the significance of the value of K in KNN algorithm?

(c) What are the limitations of k-means clustering? How can you minimize these limitations?

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1) (a) Explain the photoelectric effect and its significance in quantum theory.

Answer:

What is the photoelectric effect?
When light shines on a metal surface, electrons are emitted if the light frequency is high enough.
Key experimental observations:

1. **Threshold frequency (f_0):** No electrons are emitted if light frequency is below a certain value, no matter how intense the light is.
2. **Instantaneous emission:** Electrons are ejected immediately when light hits the surface — no time delay.
3. **Kinetic energy of electrons:** Increases with increasing frequency of light, but does not depend on light intensity.
4. **Number of electrons:** Increases with light intensity.

Why classical physics failed to explain it:
Classical wave theory predicted:

- Higher intensity should give more energy to electrons (but it only increased *number*, not *energy*).
- There should be a time delay for electrons to absorb enough energy (but emission was immediate).
- No threshold frequency concept in wave theory.

Einstein's explanation (1905):
He proposed light is made of **photons** — discrete packets of energy:

$$E_{\text{photon}} = hf$$

where h is Planck's constant (), f is frequency.

When a photon hits an electron:

- Part of energy (W_0, called **work function**) is used to free electron from metal.
- Remaining energy becomes kinetic energy of electron:

$$\frac{1}{2}mv^2 = hf - W_0$$

Thus:

- If $hf < W_0$, no emission → explains threshold frequency $f_0 = W_0/h$.
- Higher intensity means more photons → more electrons, not more energy per electron.

Significance in quantum theory:

1. **Particle nature of light:** Light behaves as particles (photons), not just waves.
2. **Wave-particle duality:** This was a key step toward de Broglie's idea that matter also has wave nature.
3. **Foundation of quantum mechanics:** Showed energy is quantized, leading to development of quantum theory.

1) (b) Derive the equation for the de Broglie wavelength of a particle.

Answer:

Louis de Broglie's hypothesis (1924):
If light (a wave) can behave as particles (photons), then particles (like electrons) should behave as waves.

Step-by-step derivation:

1. **For a photon:**
   From Einstein's relativity:

$$E = pc$$

   From Planck's quantum theory:

$$E = hf = \frac{hc}{\lambda}$$

   Equating the two:

$$pc = \frac{hc}{\lambda} \implies p = \frac{h}{\lambda}$$