EASTERN UNIVERSITY, SRI LANKA

FACULTY OF SCIENCE

Second Year First Semester Examination in Science – 2021/2022

(Mar./Apr., 2024)

CS 2022 - Introduction to Database Management Systems

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nswer all questions **Time: One hour**

1. Databases play a critical role in modern computing and information management.

(a) Define clearly the term *Database Management System* (DBMS) and explain its role in modern information systems. [15 marks]

(b) Discuss the advantages of using a DBMS over traditional file-based systems using *three* valid points. [15 marks]

(c) Compare and contrast *Data Definition Language* (DDL) and *Data Manipulation Language* (DML). Provide examples of each. [20 marks]

(d) Define the term *Data Model* and explain its role in representing data in a database. [15 marks]

(e) Explain the concepts of *normalisation*, emphasising the goals and benefits of normalisation in database design. [10 marks]

(f) Consider the following three Functional Dependencies (FDs):

Employee → Department

Employee → Manager

Department → Manager

i. One of the three FDs above is a *transitive* FD. Which is the transitive FD and what is meant by the term *transitive*? [10 marks]

ii. Explain why does *Third Normal Form* disallow relation schemas which have transitive FDs. [05 marks]

iii. Given the above three FDs over the set of attributes Employee, Department, Manager, produce a *Third Normal Form* design. [10 marks]

2. An Entity Relationship (ER) model describes a database in an abstract way, primarily in t of entities, relationships and attributes.

(a) Define each of the following with suitable examples:

i. Primary Key;

ii. Composite Attribute;

iii. Strong Entity;

iv. Unary Relationship. [40 m

(b) Consider the following scenario:

The Library Management System database keeps track of readers with the following con

- The system keeps track of the staff with a single point authentication system comp login Id and password.
- Staff maintains the book catalog with its ISBN, Book title, price, category(r general, story), edition, author number and details.
- A publisher has publisher_Id, year when the book was published, and name o book.
- Readers are registered with their user_id, email, name (first name, last name), p no (multiple entries allowed), communication address. The staff keeps track of rea
- Readers can return/reserve books that stamps with issue date and return date. I returned within the prescribed time period, it may have a due date too.
- Staff also generate reports that has readers_id, registration number of report, number and return/issue information.

Draw an ER diagram for the data set described above. The ER diagram shoul contain redundant entity sets, relationships, or attributes. Also, use relationships whe appropriate. If you need to make any assumptions, include them in your answer.

[60 m

(d) If $\hat{L}_x, \hat{L}_y$ and Y_1^1 are given by $\hat{L}_x = i\hbar\left(\sin\phi\frac{\partial}{\partial\theta} + \cot\theta\cos\phi\frac{\partial}{\partial\phi}\right)$, $\hat{L}_y = i\hbar\left(-\cos\phi\frac{\partial}{\partial\theta} + \cot\theta\sin\phi\frac{\partial}{\partial\phi}\right)$ and $Y_1^1 = -\sqrt{\frac{3}{8\pi}}\sin\theta\, e^{i\phi}$, determine Y_1^0.

[40 marks]

You may assume the commutator relations,

(i) $[\hat{L}_x, \hat{L}_y] = i\hbar\hat{L}_z, [\hat{L}_y, \hat{L}_z] = i\hbar\hat{L}_x, [\hat{L}_z, \hat{L}_x] = i\hbar\hat{L}_y$

(ii) $[\hat{L}^2, \hat{L}_x] = [\hat{L}^2, \hat{L}_y] = [\hat{L}^2, \hat{L}_z] = 0$,

(iii) $[\hat{L}_+, \hat{L}_-] = 2\hbar\hat{L}_z$

(iv) $[\hat{L}_z, \hat{L}_\pm] = \pm\hbar\hat{L}_\pm$

(v) $[\hat{L}^2, \hat{L}_\pm] = 0$

3. Two particles of equal masses with coordinates x_1 and x_2 moves in one dimension under the influence of an external potential $V_1 = \frac{1}{2}m\alpha x^2$ and they have a mutual interaction potential $V_2 = \frac{1}{4}m\beta(x_1 - x_2)^2$

(a) Write down the stationary Schrodinger equation. [20 marks]

(b) By changing these $X = \frac{1}{2}(x_1 + x_2)$ and $Y = (x_1 - x_2)$ and assuming that the two-particle wavefunction $\psi(x_1, x_2)$ may be written in the form $U(X)V(Y)$, show that Schrodinger equation separates into two.

[50 marks]

(c) Hence obtain the energy eigenvalues of the particles.

[10 marks]

(d) What conditions must be satisfied by U(X) and V(Y) if the particles are;

(i) Bosons

(ii) Fermions

[20 marks]

You may assume that the energy eigenvalues of a linear simple harmonic oscillator with angular frequency ω are given by $E_n = \left(n + \frac{1}{2}\right)\hbar\omega$, where n is a positive integer.

4. (a) Obtain an expression for the first order correction to the n^{th} energy eigenvalue $E_n^{(0)}$ of a quantum system with unperturbed Hamiltonian H^0 and subjected to a time-independent perturbation H'. You may take the unperturbed wave function as n^0.

[45 marks]

(b) A particle of mass m moves in a one-dimensional infinite well with the potential $V(x)$ defined as follows:

$$V(x) = 0, \text{ if } 0 \leq x \leq a$$
$$= \infty, \text{ otherwise.}$$

Suppose a perturbation is introduced to this particle by adding constant potential V_0 inside the well, then

(i) find the first-order correction to the allowed energies of the particle in the potential well; [20 marks]

(ii) comment on your result. [05 marks]

(c) Suppose a delta-function shape perturbation represented by $H' = \alpha\,\delta(x - \frac{a}{2})$ at $x = \frac{a}{2}$ is introduced inside the infinite potential well, where α is a constant, then

(i) find the first-order correction to the allowed energies;

[20 marks]

(ii) explain why energies are not perturbed for even n.

[10 marks]

You may find the following information useful:

The eigenfunctions of a particle of mass m confined to a one-dimensional potential well defined by

$$V(x) = 0, \text{ if } 0 \leq x \leq a$$
$$= \infty, \text{ otherwise.}$$

are given by $U_n(x) = \sqrt{\frac{2}{a}} \sin\frac{n\pi x}{a}$, $\quad n = 1,2,3, \ldots.$

The corresponding eigenvalues are $E_n = \frac{\hbar^2\pi^2}{2ma^2} n^2$

5. (a) Explain what you understand by 'fine structure' and 'hyperfine structure' in atomic spectra. [20 marks]

(b) (i) Stating the selection rules, indicate in an energy level diagram with fine structure levels the spectral transitions that form the main line of the Balmer series (transitions in which the final level is the $n = 2$ level) of hydrogen-like spectra. Assign appropriate quantum numbers to the energy levels. [30 marks]

(ii) What is the maximum number of fine structure components of th[e] main line of the Balmer series that could be observed if a[n] instrument of sufficiently high resolving power is available?

[05 marks]

(iii) What must be the resolving power of a spectroscopic instrume[nt] capable of resolving the two fine structure component[s] corresponding to the transitions $3d_{3/2} \rightarrow 2p_{3/2}$ and $3d_{5/2} \rightarrow 2p_{3/2}$ when the atom is

(A) Hydrogen [35 marks]

(B) He⁺ ion? [10 marks]

You may find the following information useful:

The fine structure correction to the energy of the n[th] level of an H-lik[e] atom is given by,

$\Delta E_{l,\frac{1}{2},j,m_j} = -\frac{\alpha^2 Z^4 R_H}{n^3}\left(\frac{1}{j+\frac{1}{2}} - \frac{3}{4n}\right)$, where symbols have their usua[l] meaning.

The fine structure constant $\approx \frac{1}{137}$.