☐ **C.** The mass of nuclear fuel required to achieve a self-sustaining chain reaction.
☐ **D.** The mass of fuel that is too large to fit in a standard reactor core.

Part II: Answer the following question **(25 Marks)**

Q1. Explain the synchronization principle in a synchrotron. How do the magnetic and electric fields work together to keep particles on a fixed-radius path as their energy increases?

Q2. Explain why the Large Hadron Collider (LHC) is a synchrotron and not a cyclotron. What specific operational features of a synchrotron allow it to achieve the extremely high energies required for modern particle physics?

Q3. Why is a medical linear accelerator (linac) the preferred technology for external beam radiation therapy, while a cyclotron is often used to produce radioisotopes for PET scans? Explain the design principles of each that make them suitable for these distinct medical applications.

Q4. Describe the sequence of accelerators used in a typical modern high-energy physics facility, such as the LHC at CERN. Why is it necessary to use a chain of different accelerators rather than just one large machine?

Q5. What are the advantages and disadvantages of Linear Accelerator (Linac) and Synchrotron?

********** **Good Luck** **********

Prof. Dr. A. A. Ebrahim

☐ **B.** A static magnetic field to bend the particles' path.
☐ **C.** A combination of electric and gravitational fields.
☐ **D.** A series of drift tubes with a constant voltage.

Q18. What is the role of control rods in a nuclear reactor?
☐ **A.** They absorb neutrons to control the rate of the chain reaction.
☐ **B.** They slow down neutrons to increase fission probability.
☐ **C.** They cool the reactor core.
☐ **D.** They reflect neutrons back into the core.

Q19. The first artificial nuclear transmutation, splitting a lithium nucleus with a proton, was achieved by:
☐ **A.** John Cockcroft and Ernest Walton
☐ **B.** Albert Einstein
☐ **C.** Ernest Rutherford
☐ **D.** Marie and Pierre Curie

Q20. The main purpose of the core of a nuclear reactor is to:
☐ **A.** Generate electricity directly.
☐ **B.** Shield the surrounding environment from radiation.
☐ **C.** Produce a controlled chain reaction of nuclear fission.
☐ **D.** Contain the control rods.

Q21. A cyclotron is a type of particle accelerator that is most effective for:
☐ **A.** Creating beams of neutral particles.
☐ **B.** Accelerating particles to energies close to the speed of light.
☐ **C.** Accelerating protons and heavier ions to non-relativistic speeds.
☐ **D.** Accelerating electrons to very high energies.

Q22. In a synchrotron, particles are accelerated in a fixed circular path by:
☐ **A.** Varying both the magnetic field and the electric field in sync with the particles' motion.
☐ **B.** A series of static magnets and no electric fields.
☐ **C.** A constant magnetic field and a constant electric field.
☐ **D.** A constant electric field that pushes the particles along the circular path.

Q23. What is the primary reason why high-energy electrons are not typically accelerated in circular accelerators like protons?
☐ **A.** They lose a significant amount of energy through synchrotron radiation.
☐ **B.** Their charge is too small to be affected by the magnetic fields.
☐ **C.** They are too massive for the available magnet strength.
☐ **D.** Their wave-like properties interfere with the acceleration process.

Q24. Which particle is the carrier of the electromagnetic force?
☐ **A.** Neutrino
☐ **B.** W boson
☐ **C.** Photon
☐ **D.** Gluon

Q25. The term 'critical mass' in reactor physics refers to:
☐ **A.** The maximum mass of fuel that can be safely used in a reactor.
☐ **B.** The mass of the moderator needed to slow down neutrons.

☐ **C.** A synchrotron.
☐ **D.** A linear accelerator (linac).

Q11. Which accelerator type is most suitable for a national laboratory that needs to accelerate protons and heavy ions to the highest possible energies for fundamental particle physics research, and why?
☐ **A.** A cyclotron, because its continuous beam is perfect for a high collision rate.
☐ **B.** A linear accelerator, because it produces a straight beam with the highest precision.
☐ **C.** A synchrotron, because its ability to synchronize the magnetic and electric fields allows particles to reach the highest energies in a fixed, manageable-sized ring.
☐ **D.** A Van de Graaff generator, because it can produce a stable, high-voltage beam.

Q12. In a linear accelerator (linac), the particles are accelerated through a series of drift tubes. What is the purpose of the drift tubes?
☐ **A.** To focus the particle beam using strong magnetic fields.
☐ **B.** To contain the particles and prevent them from escaping the vacuum chamber.
☐ **C.** To shield the particles from the decelerating phase of the oscillating electric field.
☐ **D.** To increase the particle's kinetic energy as they pass through them.

Q13. As a particle accelerates in a linear accelerator (linac), it passes through tubes that get progressively longer.
Which of the following statements is the correct reason for making the tubes longer?
☐ **A** The particles gain more energy within each tube.
☐ **B** The frequency of the accelerating voltage increases.
☐ **C** The accelerating particles spend the same time in each tube.
☐ **D** The accelerating particles gain mass.

Q14. The tubes of a linear accelerator (linac) get progressively longer down its length because:
☐ **A** the accelerating particles become relativistic.
☐ **B** the frequency of the applied potential difference changes.
☐ **C** the accelerating particles must spend the same time in each tube.
☐ **D** the accelerating particles gain mass.

Q15. The Large Hadron Collider is designed to accelerate protons to very high energies for particle physics experiments.
Very high energies are required to
☐ **A** annihilate protons and antiprotons.
☐ **B** allow protons to collide with other protons.
☐ **C** create particles with large mass.
☐ **D** to produce individual quarks.

Q16. In a nuclear reactor, the primary purpose of the moderator is to:
☐ **A** Slow down fast neutrons to increase the probability of fission.
☐ **B** Absorb excess neutrons to stop the chain reaction.
☐ **C** Accelerate the fission products to higher energies.
☐ **D** Absorb heat from the reactor core.

Q17. A linear accelerator (linac) accelerates charged particles using:
☐ **A.** An alternating electric field in a straight line.

☐ **D.** The particles' mass increases with speed, causing them to fall out of phase with the constant frequency of the accelerating voltage.

Q5. A synchrotron overcomes the limitations of a classic cyclotron by synchronizing which two parameters with the increasing particle energy?

☐ **A.** The vacuum chamber pressure and the particle injection rate.
☐ **B.** The particle's charge and its mass-to-charge ratio.
☐ **C.** The frequency of the electric field and the length of the accelerator's path.
☐ **D.** The strength of the magnetic field and the frequency of the accelerating electric field.

Q6. What is the primary application of a synchrotron 'light source' facility, and why is this accelerator type ideal for it?

☐ **A.** Medical imaging, because the intense X-rays can be used for high-resolution CT scans.
☐ **B.** Scientific research in materials and biology, because the intense synchrotron radiation provides a powerful tool for studying atomic and molecular structures.
☐ **C.** Industrial manufacturing, because the accelerated beams can be used for cutting and welding materials.
☐ **D.** High-energy particle collisions, because synchrotrons can reach the highest energies to create new particles.

Q7. What is the main advantage of a linear accelerator (linac) over a circular accelerator like a cyclotron for applications requiring a perfectly straight, high-energy particle beam?

☐ **A.** Linacs can accelerate both positive and negative ions simultaneously.
☐ **B.** Linacs are cheaper and easier to build than cyclotrons.
☐ **C.** Linacs require less space for a given final energy, making them more compact.
☐ **D.** Linacs do not require magnetic fields to bend the particle path, eliminating a source of beam distortion.

Q8. A cyclotron is often used to produce medical isotopes. How does its design facilitate this application?

☐ **A.** It can be installed directly in a hospital, providing a high-energy proton beam to irradiate a target and create short-lived radioisotopes on-site.
☐ **B.** It uses a pulsed beam, which is necessary for precise control of the isotope production reaction.
☐ **C.** Its large size allows for the simultaneous production of many different isotopes.
☐ **D.** The continuous, low-energy electron beam is ideal for bombarding target materials.

Q9. The Betatron accelerator, a type of circular induction accelerator, is unique because it uses a changing magnetic field for both accelerating and bending the electrons. What is a common application for this type of accelerator?

☐ **A.** Colliding protons to discover new fundamental particles.
☐ **B.** Creating high-intensity electron beams for food sterilization.
☐ **C.** Producing high-energy X-rays for industrial radiography and material testing.
☐ **D.** Accelerating heavy ions for nuclear physics experiments.

Q10. A particle beam from an accelerator is used to modify the properties of materials, such as hardening polymers or implanting ions into semiconductors. What type of accelerator is most likely used for this industrial application?

☐ **A.** A cyclotron.
☐ **B.** A Betatron.

كلية العلوم
جامعة أسيوط

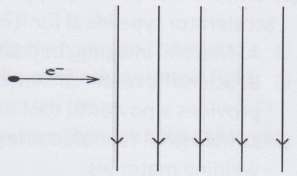
جامعة أسيوط

Assiut University
Department of Physics
Selected Topics 2 in Physics P492
Final Exam (50 pts.)

Sep 07, 2025 **Time: 3 hours**

Part I: Circle the correct answer for the following questions: **(25 Marks)**

Q1. An electron travelling horizontally enters a uniform electric field which acts vertically downwards as shown in the diagram.



Which of the following statements is **incorrect**?

- ☐ **A** The electron follows a parabolic path.
- ☐ **B** The electron accelerates while in the field.
- ☐ **C** The electric force on the electron acts downwards.
- ☐ **D** The speed of the electron increases.

Q2. A cyclotron is a type of particle accelerator. It consists of two metal Dees which are connected to a high frequency voltage supply and are in a strong magnetic field. The particles change their speed because

- ☐ **A** of the magnetic field they are in.
- ☐ **B** the voltage supply is alternating.
- ☐ **C** there is a potential difference between the two Dees.
- ☐ **D** the magnetic field is at right angles to the Dees.

Q3. Which of the following accelerators is most commonly used for external beam radiation therapy in cancer treatment, and why is its design particularly suitable for this application?

- ☐ **A.** linear accelerator (linac), because its straight path allows for highly precise beam targeting while minimizing damage to surrounding healthy tissue.
- ☐ **B.** A synchrotron, because its high-energy particles can penetrate deep into the body to reach tumors.
- ☐ **C.** A betatron, because it can accelerate electrons to very high energies for deep-tissue treatment.
- ☐ **D.** A cyclotron, because its strong magnetic fields allow for precise beam focusing on the tumor.

Q4. What is the primary reason that classic cyclotrons are not suitable for accelerating particles to relativistic speeds?

- ☐ **A.** The particles lose too much energy to synchrotron radiation at high speeds.
- ☐ **B.** The magnetic field strength cannot be increased sufficiently to keep the particles on a circular path.
- ☐ **C.** The accelerating electric field becomes too weak at high particle energies.