Revised Scheme of CMPI Certification Examination

(Implemented with effect from January 2016)

The certification examination of the College of Medical Physics of India (CMPI) is conducted to certify the competency of the candidate in the specialty of Radiation Oncology Medical Physics (ROMP). The examination contains two parts, namely Part A: Written Examination, and Part B: Oral Evaluation. A candidate needs to successfully complete Part A of the examination to obtain eligibility for appearing in Part B of the examination. Specifically, a candidate scoring at least 50% marks in each of the papers of Part A of the examination will be declared eligible for appearing in Part B of the examination. However, it is required to score at least 60% marks in aggregate to be declared successful in CMPI certification examination. Successful candidates of CMPI certification examination are also enrolled as Member of the College. Following is the details of the examination scheme implemented with effect from January 2016:

Part A: The Written Examination (200 Marks)

The written examination consists of two papers:

Paper I: General Medical Physics (GMP) including Radiobiology & Radiation Protection - 100 marks

Paper II: Radiation Oncology Medical Physics (ROMP) – 100 marks

Paper I is designed to test the general knowledge and understanding of a qualified medical physicist in all specialties of the discipline including Radiation Oncology Medical Physics (ROMP), Diagnostic Radiology Medical Physics (DMRP), Nuclear Medicine Medical Physics (NMMP), Basic Radiation Biology and Radiation Protection pertaining to medical applications of radiation. The duration of this paper is two hours (2.0 hrs) and the maximum mark is 100. The question paper contains four sections as detailed below:

Section I: 50 Multiple Choice Questions (Qs) of one mark each (50x1=50 marks)
Section II: 5 Definitions/Very short answer type questions of two marks each (5x2=10 marks)
Section III: 4 Short answer type questions (out of 6 Qs) of 5 marks each (4x5=20 marks)
Section IV: 2 Descriptive answer type questions (out of 4 Qs) of 10 marks each (2x10=20 marks)

The syllabus and sample questions of this paper are given in Appendix-I.

Paper II is a specialty paper which is designed to test the competency of a candidate to work unsupervised as Radiation Oncology Medical Physicist. Complete knowledge of the science and practice of the specialty is required to answer the questions of this paper. The duration of examination for this paper will be two and half hours (2.5 hrs) and the maximum mark is 100. The question paper contains four sections as detailed below:

Section I: 25 Multiple Choice Questions (Qs) of one mark each (25x1= 25 marks)
Section II: 5 Definitions/Very short answer type questions of two marks each (5x2=10 marks)

Section III: 5 Short answer type questions (out of 7 Qs) of 5 marks each (5x5 = 25 marks)
Section IV: 4 Descriptive answer type questions (out of 6 Qs) of 10 marks each (4x10=40 marks)

The syllabus and sample questions of this paper are given in Appendix-II.

Part B: Oral Evaluation (100 Marks)

The oral evaluation consists of following two parts

Part I: Test of Presentation Skill (40 marks)

This part of the oral evaluation has been designed to test the presentation skill of a candidate. In this mode of examination, a candidate will be given about 10 minutes time to make a presentation on a topic of his/her choice. The topic of presentation could be a brief but complete report on a project work/ QA and commissioning of equipment or paper presented (or to be presented) in a conference, etc. The candidates are advised to bring the material of presentation in power point format to make the presentation before a panel of examiner and observers. The panel of examiner and observers will start testing the candidate at the end of the presentation by asking a few questions/clarifications which may last for about 15 minutes. The questions/ clarifications asked by the examiners/observers will be related to the topic of presentation of the candidate. The maximum mark for this part of oral evaluation is 40.

Part II: Test of Practical Knowledge and Skill (60 marks)

This part of the oral evaluation has been designed to test the practical knowledge and skill of a candidate in the specialty of ROMP and associated radiation protection and safety. In this mode of examination, a candidate will be examined by six different examiners one-by-one through one-to-one interactions for about 15 minutes. The subject matter of the examination will be related to following topics of ROMP:

i) Radiotherapy Equipment - Commissioning and Quality Assurance
ii) Radiation Dosimetry - Dosimeters and Methods
iii) Radiotherapy Treatment Planning and Delivery - 3DCRT/IMRT/IGRT/VMAT
iv) Special Techniques in Radiotherapy - SRS/SRT, TBI, TSET
v) Brachytherapy - Sources, Dosimetry, Techniques
vi) Radiation Safety in Radiotherapy

Each examiner will ask a few questions from the candidate on the topic allotted to him/her in a randomized fashion from the question bank prepared by the examiner. Each examiner will have one candidate at time for about 15 minutes. On completion of about 15 minutes of interaction with a given examiner, the candidate will be asked to move to the next examiner. This process of evaluation of a candidate will continue till he/she finishes his/her evaluation by all the six examiners. The maximum mark for this part of oral evaluation is 60.

Appendix-I

Paper I: General Medical Physics (including Radiobiology and Radiation Protection)

SYLLABUS

(This syllabus is given only as a guideline and the students are expected to refer the standard books)

This paper includes the basics components of Diagnostic Radiology Medical Physics (DRMP), Radiation Oncology Medical Physics (ROMP), Nuclear Medicine Medical Physics NMMP), Radiation Biology (RB) and Radiation Protection (RP) pertaining to medical applications of radiation. It is expected that candidates will refer standard text books on these topics (e.g. IAEA handbooks on ROMP, DRMP, NMMP and RB). Following are the brief syllabi of RB and RP:

Biological modifiers and Cell Kinetics: Biological modifiers, Cell kinetics, Cell cycle control mechanisms.

Radiobiological Effects: Radiation effect at cellular level, Radiation effect on human tissue, Radiation effect on organs, Radiation effect on malignant cells and tissues.

Fundamentals of Radiobiology: Five R's of Radiobiology, Tissue structure and radiation effect, Radiation effect on the fetus, Fractionation and its effect, TCP / NTCP.

Radiobiological Concepts: Sensitizers, Protectors, Reduction of side effects, Linear energy transfer, (LET) Radiobiological effectiveness (RBE), Oxygen effect, Oxygen enhancement ratio (OER), Radiobiological models, TDF, LQ model, Alpha - Beta concepts.

Fundamentals of Radiation Protection: Radiation protection - Historical development, Principles of radiation protection and units, Equivalent dose, Effective dose, Radiation weighting factors, Tissue weighting factors, Rem, Sievert, Dose equivalent limits, Radiation effects –Somatic and genetic effects, Classification of radiation effects on dose - Stochastic and deterministic effects, justification, optimization, dose limits, Atomic Energy Regulatory Board (AERB) and prescribed Regulatory requirements.

Radiation Safety in Radiotherapy: Protective materials, Handling of brachytherapy sources, Basic safety standards (BSS) and ICRP 60 and 103. Facility design and shielding calculations - Teletherapy facility including and Neutron shielding in linear accelerator, Brachytherapy facility for LDR and HDR. Medical exposure and radiation accidents.

Radiation Protection Instruments: Ionization chamber, large volume chambers, Survey meters, Proportional counters, GM counters, Area zone monitors, Contamination monitors. Personal monitoring devices – Film badge, TLD and pocket dosimeters.

Transport of Radioactive Materials: Methods of transport, Classification of radioactive packages for transport, Procedures for preparing the radioactive package for transport, Regulatory requirements for transport of radioactive materials – National and international. IAEA safety standards, Emergency preparedness.

Regulatory Requirements: Physical protection of sources, Safety and security of sources during storage, Use, Transport and disposal of sources, Security provisions - Administrative

and technical, Security threat and Graded approach in security provision. National legislation – Regulatory framework, Atomic Energy Act, Radiation protection rules (RPR). Applicable Safety Codes, Standards, Guides and Manuals. Regulatory Control – Licensing, Inspection and Enforcement. Responsibilities of Employers, Licensees, Radiological safety officers and Radiation Workers. National inventories of radiation sources, Import and Export procedures.

SAMPLE QUESTION PAPER

Section I: Answer ALL questions. Encircle the most appropriate answer. 50x1 = 50

(There will be 50 MCQs in this Question Paper. However, 20 MCQs are given here as sample questions of this section of the paper)

1. The factors which determine x-ray production efficiency of a diagnostic x-ray machine

   a) Tube voltage (kVp) and the atomic number (Z) of the target
   b) Tube voltage (kVp) and tube current (mA)
   c) Tube voltage (kVp) and atomic mass (A) of the target
   d) Only Tube voltage (kVp)

2. The amount of scatter dose received by a conventional radiograph does not depend on

   a) kV_p b) Focal spot size c) Collimation d) Patient size

3. Entrance skin exposure (ESE) for a single 10 mm CT slice of the head is about 4R. The ESE for 15 contiguous slices will be approximately

   a) 4R b) 5R c) 16R d) 40R

4. The modulation transfer function (MTF) is a tool for describing the

   a) Properties of the H&D curve of an imaging system
   b) Noise content of an imaging system
   c) Latitude of an imaging system
   d) Effect on sharpness of combined imaging system

5. Where do MRI signals come from?

   a) Hydrogen atoms (H) b) Water molecules (H_2O).
   c) The hydrogen nucleus (^1H) d) None of these

6. Changing from a 2 MHz to a 5 MHz ultrasound transducer would generally produce

   a) Faster imaging b) Deeper penetration
   c) Shorter wavelengths d) None of these

7. The principal disadvantage in using a high resolution collimator on a gamma camera is its

a) Limited field of view
b) More distortion
c) Less scatter rejection
d) Lower sensitivity

8. In Positron Emission Tomography (PET) the image is created by detection of

a) Positions
b) Augur electrons
c) Characteristic x-rays
d) Annihilation photons

9. An alternative to the emission of a characteristic x-ray is

a) Internal conversion
b) K-capture
c) Auger electron
c) Isomeric transition

10. The binding energy per nucleon in a nucleus

a) Is proportional to the Coulomb interaction between nucleons
b) Is the same for light and heavy nuclei
c) Is affected by the structure of electron shells in the atom
d) Determines the stability of the nucleus

11. In a t-test looking for a statistically significant difference between two experimental results claims of such a difference with a p-value of 0.01

a) Means there is unquestionably a difference between the two results
b) Allows the experimenter a wider latitude of error than would a p-value of 0.05
c) Means there is a 99% chance that the claim is true
d) Means there is a 99% chance that the claim is incorrect

12. The Use factor (U) taken for calculating thickness of primary wall of a standard LINAC facility is

a) 1 b) ½ c) ¼ d) 1/16

13. The Radiation protection quantity which is used to estimate the cancer risk from x-ray irradiation of occupational worker is

a) Exposure (X)
b) Equivalent Dose (H)
c) Effective Dose (E)
d) Absorbed Dose (D)

14. The dose to a resident's hands from a brachytherapy procedure is 25 mSv. The number of procedures that the resident can perform per year without exceeding the recommended dose limit is

a) 1 b) 2 c) 10 d) 20

15. A 0.5 mm lead equivalent protective apron is an effective protection device when working with

a) A patient with ^{192}Ir implant b) Diagnostic x-rays
c) With ^{131}I therapy administration d) Positrons

16. The term CHART stands for

a) Continues Hyper-fractionated Accelerated Radiotherapy
b) Conformal Hyper-fractionated Accelerated Radiotherapy
c) Conformal Hyper-fractionated Altered Radiotherapy
d) Continues Hyper-fractionated Altered Radiotherapy

17. The average latent period for cataract to appear in patients who had received 2.5 to 6.5 Gy

a) 2 years b) 8 years c) 16 years d) 20 years

18. OER approaches unity for LET value of about

a) 10 keV/µm b) 100 keV/µm c) 160 keV/µm d) 180 keV/µm

19. The use of BED is to determine

a) Equivalent fractionation schemes b) Over all treatment time
c) Both a and b d) None of these

20. The cell survival data are represented by the linear quadratic relationship by

a) $S= e^{(\alpha D - \beta D2)}$ b) $S= e^{-(\alpha D + \beta D2)}$ c) $S= e^{(\alpha D2 - \beta D)}$ d) $S= e^{(\alpha D2 - \beta D2)}$

Section II: Answer ALL the questions **5 x 2 = 10**

1. What do you mean by a double strand break?
2. What is a pulse height analyser?
3. Who is a classified Radiation worker as per RPR 2004?
4. What is SNR in MR imaging?
5. What is DICOM and what is its advantage?

Section III: Answer ANY FOUR questions **4 x 5 = 20**

1. Sketch the cell survival curves for single and fractionated regimen and compare?
2. Write a short note on internal amplification in gas filled detectors?
3. Outline AERB guidelines for providing Air Conditioning in a Teletherapy facility?
4. What is Digital Radiography and how is it different from Computed Radiography?
5. Explain different types of collimators used in gamma camera?
6. What is a Helical CT?

Section IV: Answer ANY TWO questions **2 x 10 = 20**

1. (a) Write a note on radiation weighting factors W_R giving the values for various types of radiation and the basics on which the ICRP has arrived at these values. What are the major changes in Radiation weighting factor as per ICRP 103?

   (b) Calculate the equivalent dose (H) for a person exposed to 20 mGy of 1 MeV Neutron, 10 mGy of α rays and 5 mGy of 6 MV x-rays?

2. (a) Derive the equation for Biologically Equivalent Dose?

   (b) Calculate the BED for early and late effects for hyper fractionation schedule of 70 fractions of 1.15 Gy given twice daily, 6 hours apart, 5 days per week, an overall treatment time of 7 weeks. What do you infer from the BED values arrived at?

3. Explain with the help of a block diagram the working of a Gamma Camera?

4. What is a Multi Detector CT? Explain its advantages?

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Appendix-II

Paper II: Radiation Oncology Medical Physics

SYLLABUS

(This syllabus is given only as a guideline and the candidates are expected to refer standard text books and current literature)

Radioactivity: Natural and artificial radioactivity, Modes of radioactive decay, Exponential decay, Physical, biological and effective half-lives, mean life, decay constant, Types of nuclear reactions and Principles of radionuclide production.

Production of X-rays for Clinical Use: Production of bremsstrahlung and characteristic radiation by electron bombardment. Efficiency of x-ray production and its dependence on electron energy and target atomic number. X-ray tubes used for therapy – Quantity and Quality of x-ray beams.

Photon Absorption and Scattering Processes and Electron Interactions: Attenuation, Energy transfer, absorption and their coefficients. Interaction of Photons with matter – types, properties and their relative importance, mass, electronic and Atomic attenuation coefficient – Total attenuation coefficient, Total transfer and absorption coefficient - Interaction of heavy charged particle with matter – Electron interaction with matter - Energy loss mechanisms: Collisional losses, Radiation losses, Stopping power - Mass collisional and radiative stopping power, LET, Ionization, Excitation, Scattering.

Radiation Quantities, Units and Measurement: Concept, definition, units of kerma, absorbed dose, dose equivalent, equivalent dose, effective dose, air kerma rate constant, reference air kerma rate, activity and apparent activity – Energy Transfer – Electronic Equilibrium – Bragg Gray Cavity theory – measurement of absorbed dose.

Radiation Measuring Instruments: Things to consider in Radiation Dosimetry – Dosimetric environment: patients and phantoms; Detectors: Ionization chambers, Semi-conductor detectors, Luminescence Dosimetry, Film Dosimetry, Chemical dosimetry, Gel dosimetry, Calorimetric, MOSFETS, Diamond detectors, Scintillation Detectors, Detector arrays, Special Dosimetric Measurements: Brachytherapy dosimetry, Neutron dosimetry and Radiation Protection dosimetry

Measurement of Radiation: Phantoms, Measurement of radiation quality - Output and dose distribution for photon and electron beams. Dosimetry protocols – IAEA TRS 398 and AAPM TG 51. Dosimetry in brachytherapy – AAPM TG 43 - Measurement of reference air kerma rate (RAKR)/ air kerma strength (AKS) for sealed brachytherapy sources and activity and dose rates for unsealed radionuclides.

External Beam Radiation Sources: kV x-ray: History, current scenario, Design and operation of Orthovoltage and Superficial therapy units, Teleisotope units: Cesium teletherapy unit, Cobalt-60 teletherapy unit, Vaults design, Specification and acceptance testing, commissioning, quality control. Medical Accelerators: Linear accelerator, Medical Microtron, Betatron, - facility design, Photon & Electron beam properties, Specification for Linear accelerator, Installation and acceptance testing, commissioning, Quality assurance, Safety considerations. Beam Shaping: Alloy Blocks, Multileaf collimators (MLCs). Intensity Modulation: wedges, compensating filters, inverse planning, different methods of Intensity modulation.

Dose Distribution and Treatment Planning: Functions used in dose calculation – Derivation and their properties – Treatment planning – Isodose charts – Measurements of dosimetry parameters - Treatment planning techniques, methods and combination of beams - Calculation methods – inhomogeneity corrections. Specification of Tumor dose – ICRU Reports – ICRU 50 & ICRU 62 terminology – Patient data acquisition techniques - Determination of body contour and location of internal structures, target volume and critical tissues. Imaging for radiotherapy planning Plain film, fluoroscopy, Simulator – CT Simulator - CT, MRI, Ultrasonography, nuclear medicine imaging – SPECT, PET, Hybrid imaging.

Beam Modification Techniques for Photon Beams: Effects on dose distribution - Methods of compensation for patient contour variation and/or tissue inhomogeneity. Shielding of dose-limiting tissues. Wedge filters and their use. Dynamic wedges, bolus, build-up material, compensating filters, multileaf collimators (MLC) – different designs of MLCs – Acceptance testing and QA for MLCs.

Treatment Planning and Advances in Radiotherapy Delivery: Patient positioning and Immobilization methods – lasers - Computerized Treatment planning systems – 2D and 3D treatments planning – commissioning – data acquisition – quality assurance – networking in Radiotherapy – DICOM Format – DICOM RT – Radiation Oncology information management system. Advanced Treatment techniques & calculations: 3D Conformal Radiotherapy (3D CRT) – dose calculation algorithms – Model-Based Algorithms - Dose Calculation in Homogeneous Media - Superposition and Convolution Algorithms -Pencil Beam and Path Length Scaling - Collapsed Cone and Kernel Tilting – Monte Carlo calculations – IMRT optimization techniques – Plan Evaluation techniques and parameters for plan evaluation. Treatment verification Methods: Portal films – portal imaging – Electronic portal imaging devices (EPID) – type of EPIDs, IGRT - 2D Image guided radiotherapy, 3D image guided radiotherapy, kV cone beam CT, MV Cone beam CT and other IGRT techniques.

Electron Beam Therapy: Energy spectra, Energy specification, Variation of mean energy with depth, Suitability of measuring instruments for electron beam dosimetry, Characteristics of electron beams, Surface dose, percentage depth dose, beam profiles, isodose curves and charts, Flatness and symmetry, Beam collimation, Variation of percentage depth dose and output with field size and SSD, Photon contamination, Treatment planning - energy and field size choice, air gaps and obliquity. Tissue inhomogeneity - lung, bone, and air filled cavities. Bolus, Field junctions (with either electron or photon beams), Internal shielding and Arc therapy.

Radioactive Sources for Brachytherapy: Gamma sources - Caesium-137, Iridium-192, Gold-198, Cobalt-60, Iodine-125, and Palladium 103. Beta sources - Strontium-90, Yttrium-90 and Ruthenium-106. Production of these radioactive sources, Source construction including filtration. Physical Properties - Spectra of radiation emitted, half-life and specific activity. Comparative advantages of these radio nuclides.

Brachytherapy: Basic principles - Surface, interstitial, intracavitary, intravascular and intraluminal techniques. Low, medium, high and pulsed dose rate brachytherapy. Remote afterloading machines and manual afterloading, Brachytherapy dosimetry, Dosage systems – Manchester system, Paris system, Methods of reconstruction – optimization in Brachytherapy and dosage calculation using radiography, CT and MRI, ICRU dose specification system, Stereotactic technique, X-ray brachytherapy, Beta-particle brachytherapy - methods of use and dose distribution. Handling, calibration, cleaning, inspection, storage and transport of brachytherapy sources.

Special Procedures: Total Body Irradiation- patient positioning, dosimetry for commissioning, in-vivo dosimetry protocol, Total skin electron irradiation- patient positioning and dosimetry, Stereotactic Radiotherapy and Radiosurgery – Methods, dosimetry, treatment planning and quality assurance. Other Radiosurgery systems - CyberKnife Radiosurgery, Novalis. Tomotherapy, Helical Tomotherapy and Rapid arc, Proton therapy - rationale, techniques, Boron Neutron Capture therapy, Photodynamic therapy – Monoclonal antibodies.

Quality Assurance (QA): Periodic QA of Telecobalt unit - Linear accelerator – MLC – EPID – OBI – Treatment planning system – Stereotactic Radiosurgery – Stereotactic Radiotherapy – IMRT – patient specific QA of IMRT – QA of special procedures – Rapid Arc – Cyberknife – Tomotherapy.

SAMPLE QUESTIONS

Section I: Answer ALL questions. ENCIRCLE most appropriate option. 25 x 1 = 25

(There will be 25 MCQs in this Question Paper. However, 20 MCQs are given here as sample questions of this section of the paper)

1. Which of the following is not an accelerator component?

a) Waveguide b) Transducer c) Modulator d) Thyratron

2. The advantages of Flattening Filter Free Beam are

i) Higher dose Rate
ii) Lesser scatter radiation
iii) Higher Percentage Depth Dose

a) i) alone is correct
b) ii) & iii) are correct
c) i) & ii) are correct
d) i) & iii) are correct

3. The side of the equivalent square of a 8 x 30 cm^2 field is

a) Approximately equal to $\sqrt{(8x30)}$
b) Closer to 30 than 8
c) The square field which has the same PDD as the rectangle
d) Approximated by the area / perimeter of the rectangle

4. As photon energy increases from 6MV to 15 MV all the following occur except

a. The depth of d_{max} increases
b. The linear attenuation increases
c. The neutron dose increases
d. The PDD and TMR at 10cm depth increases

5. The dose under a 1.5 cm width cord block (5 HVL thickness) in a 15 x 15 cm^2 6 MV photon beam at 5 cm depth due to transmission plus scatter is approximately _____ & of the dose in the open beam

a) 3 b) 7 c) 15 d) 30

6. Achromatic bending of electron beam in Linear accelerator is at

a) 45^o b) 90^o c) 270^o d) 180^o

7. It has been recommended that the dose to the pacemaker be kept below 2.0 Gy. In a lung treatment of 40Gy with 6 MV photons, the fields should be no closer than _____ to the pacemaker

a) 0.5 cm b) 2.0 cm c) 7.0 cm d) 15.0 cm

8. Soft tissue contrast is better in a spiral CT than in a kV cone beam scan because

a) Spiral CT uses a lower energy beam
b) There is more scatter radiation in a cone beam scan
c) Spiral CT scans give higher patient doses
d) Slice thickness is less on Spiral CT

9. The correct ordering of imaging modalities from poorest to best resolution is

a) PET, CT, Film b) Film, PET, CT c) Film MRI, CT d) MRI PET, Film

10. The total dose from a permanent seed implant is 1600cGy. The half-life is 17 days. The total dose delivered in the first 34 days is ___cGy

a) 1400 b) 1200 c) 800 d) 400

11. When a linac calibration is performed with an ion chamber, temperature and pressure corrections are applied to account for expansion or contraction of

a. The chamber wall material
b. The gas in the ion chamber
c. The phantom
d. Changes in the cables between the chamber and electrometer

12. Radiochromic films offer the following advantages as dosimeter, ***except***

a) High resolution b) Tissue equivalence
c) Small dependence on photon energy d) High sensitivity

13. A physicist is checking the MU for a computer-generated plan of breast tangents, using a reference point in the centre of the breast. The hand calculation gives a lower MU setting by 3%. Possible reason for this is

a) Lack of scatter to the reference point from the part of the tangent in air is accounted for in the plan, but not in the hand calculation
b) The plan is calculated using a rectangular field, while the hand calculation uses an equivalent square field.
c) Beam hardening in tissue is not accounted for in the hand calculation
d) The hand calculation does not correct for increased scatter from the lung /chest wall interface

14. It is difficult to visualize small bony structures on an 8-MV portal film because

    a. The Compton process predominates at this energy
    b. Equal masses of bone and soft tissue will absorb equal numbers of photons
    c. Most of the interactions will be independent of Z
    d. All of the above

15. When treating a small lung lesion which moves with respiration, which of the following techniques can be used without a gating system or spirometer?

    a. Deep inspiration breath hold for CT and treatment
    b. Binning the CT into segments of breathing cycle & planning with selected segments
    c. PTV created by leaving margin around maximum tumour excursion observed under fluoroscopy
    d. All of the above

16. Which of the following has the highest skin dose for a 10 x 10 cm^2 field at 100 cm SSD?

    a) 6 MV photons b) 18 MV photons c) 6 MeV electrons d) 20 MeV electrons

17. For Total Skin Electron Beam (TSEB) Therapy, a large 1 cm thick Lucite screen is often placed in front of the patient to

    i. Protect the patient from scattered radiation
    ii. Energy degrader
    iii. Decreases depth dose
    iv. Increases dose uniformity

    a) i) & ii) are correct
    b) i), ii) and iii) are correct
    c) ii), iii) and iv) are correct
    d) All are correct

18. Historically, ^{137}Cs activity has been expressed in terms of mg-Raeq because

    a) The activity in millicuries is difficult to determine
    b) The gamma ray energy is the same
    c) Patterson Parker tables designed for radium could be used
    d) Shielding requirements are the same for 1mg radium and 1 mgRaeq of ^{137}Cs

19. A physicist measures the output of a linac and finds it to be 2.2% low. The usual action taken by the physicist is

    a. To change the tables of output factors to the new measured values
    b. Nothing is changed as it is within 5%
    c. All patients treated since the last monthly calibration spot check must be notified
    d. A potentiometer is adjusted so that one monitor chamber unit is equal to 1cGy measured at the reference point

20. The rapid dose fall-off with distance around a ^{137}Cs source in tissue is mainly due to

    a) Tissue attenuation
    b) Inverse square effect
    c) Short range of the betas
    d) The Attenuation in the source encapsulation

Section II: Answer ALL the questions **5 x 2 = 10**

1. Define stopping power of a medium
2. The source in a cobalt-60 unit is 2 cm in diameter, the SSD is 80 cm and the SDD is 50 cm. What is the size of the penumbra at the surface of the patient?
3. Where X-band Linacs are used and why?
4. Define practical range of a clinical electron beam. What is the practical range of a 12 MeV electron beam?
5. Define Clinical Target Volume (CTV)

Section III: Answer ANY FIVE questions **5 x 5 = 25**

1. What is radioactive equilibrium and what are their types? Mention one isotope used in Brachytherapy that benefits from this concept?
2. How is ^{60}Co isotope produced? Draw the decay scheme of the ^{60}Co isotope.
3. Compare standing and traveling waveguide LINACs?
4. Explain why thick target is used in linear accelerator?
5. With a diagram explain extra-focal radiation?
6. Draw the diagram of a rounded edge MLC leaf and explain with diagram how it helps to reduce the penumbra?
7. State and explain reference condition for electron beam dosimetry?

Section IV: Answer ANY FOUR questions **4 x 10 = 40**

1. a) Describe the shutter timer error associated the timer of telecobalt machines?
   b) Explain the method of measurement of the timer error?
   c) How is it applied in practice when setting treatment times on a Cobalt machine?

2. a) How does x-ray contamination of clinical electron beams happen and which component contributes maximum to this?
   b) What are the techniques to produce clinical (broad) electron beam from pencil electron beam in a linear accelerator? Compare both the techniques?

3. Draw the graph for total mass attenuation coefficient for water and lead and explain relative importance of Photoelectric, coherent, Compton and pair production

4. Draw a neat cross sectional diagram of a parallel plate chamber. What is the electrode spacing in a Parallel plate chamber? (c) Explain the advantages of using the parallel plate chamber for electron beams (d) what are its applications?

5. Where are the MLCs placed in the linacs of Varian and Elekta machines? Discuss the issues related to the position of the MLC in linac? Compare the advantages and disadvantages of these designs.

6. What is Tomotherapy? Compare Fan beam Tomotherapy and Helical Tomotherapy. Draw a table comparing Standard Radiotherapy and Tomotherapy

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