



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 4, 2020

John Foster
Director of Reactor Operations
Nuclear Reactor Laboratory
Massachusetts Institute of Technology
138 Albany Drive, NW 12-116A
Cambridge, MA 02139

SUBJECT: EXAMINATION REPORT NO. 50-020/OL-20-01, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dear Mr. Foster:

During the week of February 03, 2020, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your Massachusetts Institute of Technology reactor. The examinations were conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. Examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with Title 10 of the *Code of Federal Regulations*, Section 2.390, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at <http://www.nrc.gov/reading-rm/adams.html>. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Ms. Michele DeSouza at (301) 415-0747 or via internet e-mail Michele.DeSouza@nrc.gov.

Sincerely,

Travis L. Tate, Chief
Non-Power Production and Utilization Facility
Oversight Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Docket No. 50-020

Enclosures:

1. Examination Report No. 50-020/
OL-20-01
2. Written Examination

cc: w/o enclosures: See next page

SUBJECT: EXAMINATION REPORT NO. 50-020/OL-20-01, MASSACHUSETTS INSTITUTE OF TECHNOLOGY DATED: JUNE 4, 2020

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NRR-079

OFFICE	NRR/DANU/UNPO/CE	NRR/DANU/UNPO/OLA	NRR/DANU/UNPO/BC
NAME	MDeSouza	ZTaru	TTate
DATE	02/06/2020	03/09/2019	06/04/2020

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Massachusetts Institute of Technology

Docket No. 50-020

cc:

City Manager
City Hall
Cambridge, MA 02139

Department of Environmental Protection
One Winter Street
Boston, MA 02108

Mr. Jack Priest, Director
Radiation Control Program
Department of Public Health
529 Main Street
Schrafft Center, Suite 1M2A
Charlestown, MA 02129

Ms. Samantha Phillips, Director
Massachusetts Emergency Management Agency
400 Worcester Road
Framingham, MA 01702-5399

Test, Research and Training
Reactor Newsletter
Attention: Ms. Amber Johnson
Dept of Materials Science and Engineering
University of Maryland
4418 Stadium Drive
College Park, MD 20742-2115

Ms. Sarah M. Don, Reactor Superintendent
Massachusetts Institute of Technology
Nuclear Reactor Laboratory
Research Reactor
138 Albany Street, MS NW12-116B
Cambridge, MA 02139

U. S. NUCLEAR REGULATORY COMMISSION
OPERATOR LICENSING INITIAL EXAMINATION REPORT

REPORT NO.: 50-020/OL-20-01
FACILITY DOCKET NO.: 50-020
FACILITY LICENSE NO.: R-37
FACILITY: Massachusetts Institute of Technology
EXAMINATION DATES: February 03, 2020
SUBMITTED BY: Michele DeSouza 02/06/2020
Michele DeSouza, Chief Examiner Date

SUMMARY:

During the week of February 03, 2020, the NRC administered an operator licensing examination to two Reactor Operator (RO) and one Senior Reactor Operator Upgrade (SRO-U). The candidates passed all applicable portions of the examinations.

REPORT DETAILS

1. Examiner: Michele DeSouza, Chief Examiner, NRC

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	2/0	0/0	2/0
Operating Tests	2/0	1/0	3/0
Overall	2/0	1/0	3/0

3. Exit Meeting:
Michele C. DeSouza, Chief Examiner, NRC
Marshall Wade, Training Supervisor, MIT
Sarah Don, Director of Reactor Operations, MIT
Susan Tucker, QA Supervisor, MIT
Edward Lau, Assistant Director of Operations, MIT

Prior to administration of the written examination, based on facility comments, adjustments were accepted. Upon completion of the examination, the NRC Examiner met with facility staff representative to discuss the results. Based on candidate responses, familiarization with the new Secondary Coolant system is needed. It is recommended to document and train prior to implementation of a new system. A facility issue was identified with Emergency Response Actions. It is recommended individuals familiarize with potential emergency situations and the facility support training and evaluation of emergency response situations. At the conclusion of the meeting, the NRC examiner thanked the facility for their support in the administration of the examination.



THE MASSACHUSETTS
INSTITUTE OF TECHNOLOGY

Operator Licensing Examination

Week of February 3, 2020

U. S. NUCLEAR REGULATORY COMMISSION
NON-POWER REACTOR LICENSE EXAMINATION

FACILITY: MIT
 REACTOR TYPE: Tank
 DATE ADMINISTERED: 02/04/2020
 CANDIDATE: _____

INSTRUCTIONS TO CANDIDATE:

Answers are to be written on the Answer sheet provided. Attach all Answer sheets to the examination. Point values are indicated in parentheses for each question. A 70% in each category is required to pass the examination. Examinations will be picked up three (3) hours after the examination starts.

<u>CATEGORY</u>	<u>% OF</u>	<u>CANDIDATE'S</u>	<u>% OF</u>	<u>CATEGORY</u>
<u>VALUE</u>	<u>TOTAL</u>	<u>SCORE</u>	<u>VALUE</u>	<u>CATEGORY</u>
<u>20.00</u>	<u>33.3</u>	_____	_____	A. REACTOR THEORY, THERMODYNAMICS AND FACILITY OPERATING CHARACTERISTICS
<u>20.00</u>	<u>33.3</u>	_____	_____	B. NORMAL AND EMERGENCY OPERATING PROCEDURES AND RADIOLOGICAL CONTROLS
<u>20.00</u>	<u>33.3</u>	_____	_____	C. FACILITY AND RADIATION MONITORING SYSTEMS
<u>60.00</u>		_____	_____	% TOTALS
		<u>FINAL GRADE</u>		

All work done on this examination is my own. I have neither given nor received aid.

Candidate's Signature

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

ANSWER SHEET

Multiple Choice (Circle or X your choice)

If you change your answer, write your selection in the blank.

A01 a b c d ____

A02 a b c d ____

A03 a b c d ____

A04 a b c d ____

A05 a b c d ____

A06 a b c d ____

A07 a ____ b ____ c ____ d ____ (0.25 each)

A08 a b c d ____

A09 a ____ b ____ c ____ d ____ (0.25 each)

A10 a ____ b ____ c ____ d ____ (0.25 each)

A11 a b c d ____

A12 a b c d ____

A13 a b c d ____

A14 a b c d ____

A15 a b c d ____

A16 a b c d ____

A17 a b c d ____

A18 a b c d ____

A19 a b c d ____

A20 a b c d ____

(**** END OF CATEGORY A ****)

Category B – Normal/Emergency Operating Procedures and Radiological Controls

ANSWER SHEET

Multiple Choice (Circle or X your choice)

If you change your answer, write your selection in the blank.

B01 a _____ b _____ c _____ d _____ (0.50 each)

B02 a b c d _____

B03 a b c d _____

B04 a b c d _____

B05 a b c d _____

B06 a b c d _____

B07 a b c d _____

B08 a b c d _____

B09 a b c d _____

B10 a b c d _____

B11 a b c d _____

B12 a _____ b _____ c _____ d _____ (0.25 each)

B13 a b c d _____

B14 a b c d _____

B15 a ___ b ___ c ___ d ___ (0.25 each)

B16 a b c d _____

B17 a b c d _____

B18 a b c d _____

B19 a b c d _____

(***** END OF CATEGORY B *****)

Category C – Facility and Radiation Monitoring Systems

A N S W E R S H E E T

Multiple Choice (Circle or X your choice)

If you change your answer, write your selection in the blank.

C01 a b c d ____

C02 a b c d ____

C03 a b c d ____

C04 a b c d ____

C05 a b c d ____

C06 a b c d ____

C07 a b c d ____

C08 a b c d ____

C09 a b c d ____

C10 a b c d ____

C11 a b c d ____

C12 a b c d ____

C13 a b c d ____

C14 a b c d ____

C15 a b c d ____

C16 a b c d ____

C17 a b c d ____

C18 a b c d ____

C19 a ____ b ____ c ____ d ____ e ____ f ____ g ____ h ____ (0.25 each)

(**** END OF CATEGORY C ****)
(***** END OF EXAMINATION *****)

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. Cheating on the examination means an automatic denial of your application and could result in more severe penalties.
2. After the examination has been completed, you must sign the statement on the cover sheet indicating that the work is your own and you have neither received nor given assistance in completing the examination. This must be done after you complete the examination.
3. Restroom trips are to be limited and only one candidate at a time may leave. You must avoid all contacts with anyone outside the examination room to avoid even the appearance or possibility of cheating.
4. Use black ink or dark pencil only to facilitate legible reproductions.
5. Print your name in the blank provided in the upper right-hand corner of the examination cover sheet and each Answer sheet.
6. Mark your Answers on the Answer sheet provided. **USE ONLY THE PAPER PROVIDED AND DO NOT WRITE ON THE BACK SIDE OF THE PAGE.**
7. The point value for each question is indicated in [brackets] after the question.
8. If the intent of a question is unclear, ask questions of the examiner only.
9. When turning in your examination, assemble the completed examination with examination questions, examination aids and Answer sheets. In addition turn in all scrap paper.
10. Ensure all information you wish to have evaluated as part of your Answer is on your Answer sheet. Scrap paper will be disposed of immediately following the examination.
11. To pass the examination you must achieve a grade of 70 percent or greater in each category.
12. There is a time limit of three (3) hours for completion of the examination.

EQUATION SHEET

$$\dot{Q} = \dot{m} c_p \Delta T = \dot{m} \Delta H = UA \Delta T$$

$$P_{\max} = \frac{(\beta - \rho)^2}{(2\alpha \ell)}$$

$$\lambda_{\text{eff}} = 0.1 \text{ sec}^{-1}$$

$$P = P_0 e^{t/T}$$

$$SCR = \frac{S}{-\rho} \cong \frac{S}{1 - K_{\text{eff}}}$$

$$\ell^* = 1 \times 10^{-4} \text{ sec}$$

$$SUR = 26.06 \left[\frac{\lambda_{\text{eff}} \rho + \dot{\rho}}{\beta - \rho} \right]$$

$$CR_1 (1 - K_{\text{eff}_1}) = CR_2 (1 - K_{\text{eff}_2})$$

$$CR_1 (-\rho_1) = CR_2 (-\rho_2)$$

$$P = \frac{\beta(1 - \rho)}{\beta - \rho} P_0$$

$$M = \frac{1}{1 - K_{\text{eff}}} = \frac{CR_2}{CR_1}$$

$$P = P_0 10^{SUR(t)}$$

$$M = \frac{1 - K_{\text{eff}_1}}{1 - K_{\text{eff}_2}}$$

$$SDM = \frac{1 - K_{\text{eff}}}{K_{\text{eff}}}$$

$$T = \frac{\ell^*}{\rho - \beta}$$

$$T = \frac{\ell^*}{\rho} + \left[\frac{\bar{\beta} - \rho}{\lambda_{\text{eff}} \rho + \dot{\rho}} \right]$$

$$T_{\frac{1}{2}} = \frac{0.693}{\lambda}$$

$$\Delta \rho = \frac{K_{\text{eff}_2} - K_{\text{eff}_1}}{K_{\text{eff}_1} K_{\text{eff}_2}}$$

$$\rho = \frac{K_{\text{eff}} - 1}{K_{\text{eff}}}$$

$$DR = DR_0 e^{-\lambda t}$$

$$DR_1 d_1^2 = DR_2 d_2^2$$

$$DR = \frac{6 Ci E(n)}{R^2}$$

$$\frac{(\rho_2 - \beta)^2}{Peak_2} = \frac{(\rho_1 - \beta)^2}{Peak_1}$$

DR – Rem, Ci – curies, E – Mev, R – feet

1 Curie = 3.7 x 10¹⁰ dis/sec

1 kg = 2.21 lb

1 Horsepower = 2.54 x 10³ BTU/hr

1 Mw = 3.41 x 10⁶ BTU/hr

1 BTU = 778 ft-lb

°F = 9/5 °C + 32

1 gal (H₂O) ≈ 8 lb

°C = 5/9 (°F - 32)

c_p = 1.0 BTU/hr/lb/°F

c_p = 1 cal/sec/gm/°C

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

QUESTION A.01 [1.0 point]

What effect does moderator temperature have on neutron population?

- a. As the density of the moderator decreases, less moderation occurs and more neutrons leak from the core.
- b. As the density of the moderator increases, less moderation occurs and more neutrons leak from the core.
- c. As the density of the moderator decreases, more moderation occurs and less neutrons leak from the core.
- d. As the density of the moderator increases, less moderation occurs and less neutrons leak from the core.

QUESTION A.02 [1.0 point]

Which ONE of the following is the major source of energy released during fission?

- a. Absorption of prompt gamma rays
- b. Fission fragments
- c. Fission neutron scattering
- d. Neutrino interactions

QUESTION A.03 [1.0 point]

Five minutes after shutting down the reactor, reactor power is 3×10^6 counts per minute (cpm). Which ONE of the following is the count rate you would expect two minutes later?

- a. 1×10^6 cpm
- b. 7×10^5 cpm
- c. 5×10^5 cpm
- d. 3×10^5 cpm

QUESTION A.04 [1.0 point]

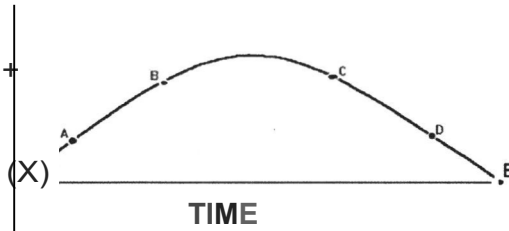
What is β ?

- a. The fractional change in neutron population per generation
- b. The fraction of all fission neutrons that are born as delayed neutrons
- c. The time required for the reactor to change by power by a factor of e
- d. The fraction of all delayed neutrons that reach thermal energy

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

QUESTION A.05 [1.0 point]

Shown below is a trace of reactor period as a function of time. From point B to point D reactor power is:



- a. constant.
- b. continually increasing.
- c. increasing, then constant.
- d. increasing, decreasing, then constant.

QUESTION A.06 [1.0 point]

Which ONE of the following conditions will DECREASE the core excess reactivity?

- a. Fuel depletion
- b. Burnable poison burnout
- c. Insertion of a positive reactivity worth experiment
- d. Lowering moderator temperature (assume negative temperature coefficient)

QUESTION A.07 [1.0 point, 0.25 each]

The listed isotopes are potential daughter products due to the radioactive decay of ${}_{35}\text{Br}^{87}$. Identify the type of decay to produce each of the isotopes: Alpha, Beta+, Beta-, Gamma or Neutron emission (Answers may be used once, more than once or not at all)

- a. ${}_{33}\text{As}^{83}$
- b. ${}_{35}\text{Br}^{86}$
- c. ${}_{35}\text{Br}^{87}$
- d. ${}_{36}\text{Kr}^{87}$

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

QUESTION A.08 [1.0 point]

Which ONE of the following is the direct result of using heavy water for a reflector and light water as a moderator?

- a. Less xenon accumulation.
- b. Less neutron leakage.
- c. Longer prompt neutron lifecycle.
- d. Tangential distributed thermal neutron flux

QUESTION A.09 [1.0 point, 0.25 each]

Identify whether each of the following conditions will INCREASE or DECREASE the shutdown margin of a reactor.

- a. Burnout of a burnable poison.
- b. Insertion of boron graphite to the reactor core.
- c. Moving one fuel element from reactor core to fuel storage.
- d. Insertion of a fueled ICSCA (in-core sample assembly).

QUESTION A.10 [1.0 point, 0.25 each]

Match the term listed in Column A with its corresponding unit listed in column B (use only once in column B).

Column A	Column B
a. 1 barn	1. cm^{-1}
b. Macroscopic Cross Section	2. 10^{-24} cm^2
c. Neutron Flux	3. Neutrons / cm^2 /sec
d. Reaction Rate	4. Fissions / cm^3 sec

QUESTION A.11 [1.0 point]

During a fuel loading of the core, as the reactor approaches criticality, the value of $1/M$:

- a. Increases toward one.
- b. Decreases toward one.
- c. Increases toward infinity.
- d. Decreases toward zero.

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

QUESTION A.12 [1.0 point]

If the multiplication factor, k , is increased from 0.800 to 0.950, the amount of reactivity added is:

- a. 0.532 k/k
- b. 0.150 k/k
- c. 0.166 k/k
- d. 0.197 k/k

QUESTION A.13 [1.0 point]

Which factors of the six-factor formula are affected by an INCREASE in core moderator temperature and how are they affected? L_f - Fast non-leakage probability L_t - Thermal non-leakage probability ϵ - Fast fission factor p - Resonance escape probability η - Reproduction factor f - Thermal utilization factor

- a. $\downarrow L_f, \downarrow L_t, \downarrow p, \uparrow f$
- b. $\uparrow \epsilon, \uparrow L_f, \downarrow L_t, \uparrow p$
- c. $\uparrow \epsilon, \downarrow L_f, \downarrow L_t, \downarrow p, \uparrow \eta, \uparrow f$
- d. $\uparrow \epsilon, \uparrow L_f, \downarrow L_t, \downarrow p, \uparrow \eta, \uparrow f$

QUESTION A.14 [1.0 point]

Which ONE of the following isotopes will readily absorb neutrons when it interacts with neutrons?

- a. Hydrogen-1
- b. Boron-10
- c. Oxygen-16
- d. Iodine-131

QUESTION A.15 [1.0 point]

Which ONE of the following parameters is MOST significant in determining the differential rod worth of a control rod?

- a. Rod speed
- b. Flux shape
- c. Reactor power
- d. Fuel temperature

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

QUESTION A.16 [1.0 point]

Which type of neutron interaction (light nuclei) is most effective in moderating fast neutrons to thermal neutrons?

- a. Neutron capture
- b. Elastic scattering
- c. Inelastic scattering
- d. Charged particle reactions

QUESTION A.17 [1.0 point]

A reactor with $k_{\text{eff}} = 0.8$ contributes 1000 neutrons in the first generation. Changing from first generation to third generation, what is the total number of neutrons produced in all three generations?

- a. 2040 neutrons
- b. 1940 neutrons
- c. 3640 neutrons
- d. 2440 neutrons

QUESTION A.18 [1.0 point]

Reactor is critical. What would be the corresponding k_{eff} when removing $0.03 \Delta k/k$ from its criticality?

- a. 0.9244
- b. 0.9434
- c. 0.9708
- d. 1.0521

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

QUESTION A.19 [1.0 point]

The reactor is on a CONSTANT positive period. Which ONE of the following power changes will take the LONGEST time to complete?

- a. From 100 kW to 150 kW
- b. From 10 kW to 20 kW
- c. From 10 W to 30 W
- d. From 1 W to 5 W

QUESTION A.20 [1.0 point]

Which ONE of the following is the definition of Differential Control Rod Worth? Reactivity:

- a. Due to the control rod position (k/k)
- b. Change per unit of rod motion (k/k/in)
- c. Due to the difference in rod speed (k/k/in/min)
- d. Available for shutdown after control rod withdrawal

(***** END OF CATEGORY A *****)

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.01 [2.0 points, 0.50 each]

Match the change/modification listed in Column A with its corresponding classifications listed in Column B. Answers can be used once, more than once or not at all.

<u>Column A</u>	<u>Column B</u>
a. Modification of Administrative Procedure, PM 1.4	1. Class A
b. Replace Shim blade with identical one	2. Class B
c. Basis change in TS 3.2.2, Reactivity Insertion Rate and Automatic Control	3. Class C
d. Modification to reflector piping system (Change requires an amendment)	

QUESTION B.02 [1.0 point]

60% of the decay of a 2 Curie source results in emission of 150 keV gamma. What is the dose rate at 1 foot?

- a. 90 mRem
- b. 180 mRem
- c. 1080 mRem
- d. 2160 mRem

QUESTION B.03 [1.0 point]

Which ONE of the following is NOT required to be evaluated at least annually?

- a. Neutron Flux Level
- b. Fuel in Storage
- c. Core Tank Level
- d. Shield Coolant Flow

QUESTION B.04 [1.0 point]

Which ONE of the following is the radiation dose limit for the public from licensed operation?

- a. No limit
- b. 2 mrem in a year
- c. 50 mrem in a year
- d. 100 mrem in a year

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.05 [1.0 point]

What is the maximum exposure guideline in accordance with MITR emergency plan exposure guidelines, the emergency task “protection of major equipment not vital for the nuclear safety of the reactor”?

- a. Low, 5 Rem
- b. Low, 10 Rem
- c. High, 25 Rem
- d. High, >25 Rem

QUESTION B.06 [1.0 point]

Which ONE of the following is the 10CFR20 occupational Total Effective Dose Equivalent (TEDE) limit?

- a. 100 mrem
- b. 0.5 rem
- c. 5.0 rem
- d. 50 mrem

QUESTION B.07 [1.0 point]

Which individual is authorized to “downgrade and initiate recovery operations” in accordance with MITR emergency plan?

- a. Director of Reactor Operations
- b. MITR Radiation Protection Officer
- c. Off-site Emergency Coordinator
- d. SRO with the most years of experience licensed at MITR

QUESTION B.08 [1.0 point]

Which ONE of the following changes must be submitted to the NRC for approval prior to implementation?

- a. Replace a primary coolant pump with an identical pump
- b. Add a new member to the Reactor Safety Committee
- c. Delete Section 5.1, Site and Facility Description from the MITR Technical Specifications
- d. Add responsibilities to the Radiation Protection Officer within the operational procedures

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.9 [1.0 point]

The dose rate from a mixed beta-gamma point source is 100mrem/hour at one foot and is 0.1 mrem/hour at ten feet. What percentage of the source consists of beta radiation?

- a. 30%
- b. 50%
- c. 70%
- d. 90%

QUESTION B.10 [1.0 point]

Which ONE of the following is NOT a duty for the Shift Supervisor in accordance with Administration Procedure, PM 1.3?

- a. Verifying the completeness and accuracy of the log book entries on the shift.
- b. Informing the Operations Superintendent of unusual occurrences on the shift.
- c. Present at the reactor room whenever the Console Relief/Turnover is conducted.
- d. Authorizing and witnessing both Startups and increases in reactor power of greater than 10%.

QUESTION B.11 [1.0 point]

As a licensed reactor operator at MITR, who is allowed to manipulate the controls of the reactor under your direction?

- a. A local college newspaper reporter who wants to write a story on the safety of the nuclear reactor.
- b. A student participating in the reactor operator training program.
- c. A health physicist who is trying to gain a certified health physicist (CHP) license.
- d. An NRC examiner trying to make sure that all set points of the reactor are the same as listed in the MITR Technical Specifications.

QUESTION B.12 [1.0 point, 0.25 each]

Identify the PRIMARY source (irradiation of AIR, irradiation of WATER, irradiation of reactor STRUCTURE, or FISSION product) for EACH of the following radioisotopes.

- a. Al-28
- b. Ar-41
- c. N-16
- d. Br-87

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.13 [1.0 point]

10 CFR 20 limits the annual occupational exposure to the EYE of an individual to:

- a. 5 rem
- b. 15 rem
- c. 50 rem
- d. 100 rem

QUESTION B.14 [1.0 point]

A radiation field is 123 mR/hr at 4 feet. What is your dose rate at 2 feet away from the source?

- a. 235 mR/hr
- b. 371 mR/hr
- c. 492 mR/hr
- d. 984 mR/hr

QUESTION B.15 [1.0 point, 0.25 each]

Match the appropriate radiation reading in Column A with the radiation classification in Column B. Answers may be used once, more than once or not at all.

Column A

Column B

- | | |
|---------------------------|-----------------------------|
| a. 2 mrem/hr at 1 meter | 1. Public Area |
| b. 20 mrem/hr at 1 meter | 2. Radiation Area |
| c. 120 mrem/hr at 1 meter | 3. High Radiation Area |
| d. 450 rad/hr at 1 meter | 4. Very High Radiation Area |

QUESTION B.16 [1.0 point]

What is the reason a normal reactor startup requires reactor power to be maintained at 1MW for 5 minutes?

- a. Allows for cooling tower flow to be switched to spray
- b. Prevents buckling of the voltage potentiometers
- c. Excess reactivity must be measured prior to achieving full power
- d. Thermal equilibrium between the core and coolant reduces stress on fuel cladding, core structures and thermal shield

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.17 [1.0 point]

Calculate an individual's total whole body dose given the individual received the following doses: 15 mrad of alpha, 20 mrad of gamma, and 20 mrad of neutron (unknown energy)

- a. 55 mrem
- b. 308 mrem
- c. 435 mrem
- d. 520 mrem

QUESTION B.18 [1.0 point]

What emergency classification is an abnormal loss of coolant where core tank level cannot be maintained above scram setpoint but is above the anti-siphon valves?

- a. Alert
- b. Unusual event
- c. Site Area emergency
- d. General emergency

QUESTION B.19 [1.0 point]

Which ONE of the following is the criteria for the Emergency Core Cooling System?

- a. Close heat exchanger valves to ensure it does not overheat
- b. Ensure at least 20gpm within 10 mins
- c. Each element receives at least 20% of the average spray to all elements
- d. Prevent overheating of the secondary coolant system

(***** End of Category B *****)

Category C – Facility and Radiation Monitoring Systems

QUESTION C.01 [1.0 point]

The Emergency Power Distribution System batteries have the capacity to supply power to selected instruments and pumps for a MAXIMUM period of _____ under a nominal battery load of 72 amps.

- a. 1 hour
- b. 4 hours
- c. 8 hours
- d. 12 hours

QUESTION C.02 [1.0 point]

The weekend surveillance system is activated. All of the following conditions will cause this alarm to sound, EXCEPT:

- a. High Temperature Reactor Outlet
- b. Low Level Core Tank
- c. High Level Radiation Monitor
- d. Seismic scram

QUESTION C.03 [1.0 point]

Which ONE of the following of interlocks associated with the Rod Control System (RCS) will cause a shim blade to be inserted if xenon were to be burned out as the result of a startup following a brief shutdown?

- a. Startup Interlocks
- b. Subcritical Interlock
- c. Automatic Control
- d. Automatic Rundown

QUESTION C.04 [1.0 point]

What instrumentation region is associated with “the voltage is such that every primary ion produces an avalanche of secondary ions”? This region also cannot differentiate between types of radiation.

- a. Region I, Recombination
- b. Region II, Ionization
- c. Region III, Proportional
- d. Region IV, Geiger-Mueller

Category C – Facility and Radiation Monitoring Systems

QUESTION C.05 [1.0 point]

Which ONE of the following describes the function of Channel 7?

- a. Provides a linear indication of the flux level
- b. Provides a flux indication if electrical power is lost
- c. Provides a level signal to the nuclear safety system
- d. Provides a signal based on system flows and temperatures

QUESTION C.06 [1.0 point]

Which ONE of the following coolant systems has a nominal flow rate of 150 gpm?

- a. Shield
- b. Reflector
- c. Primary
- d. Secondary

QUESTION C.07 [1.0 point]

Which ONE of the following, observed on the LED display of the radiation area monitor control unit, is indicated by the display of all “9’s”?

- a. Detector saturation
- b. Control unit test is in progress
- c. Over-range of count rate
- d. Source check is remotely activated

QUESTION C.08 [1.0 point]

In accordance with MITR Technical Specifications which ONE of the following defines REACTOR SECURED?

- a. There are no experiments in any reactor experiment facility
- b. No work is in progress involving core fuel, core structure, installed control devices, or control device drives unless they are physically decoupled from the control devices.
- c. Reactor is in the natural convection cooling mode and a Senior Reactor Operator is in charge of the operation.
- d. All fuel elements and core components must be secured in position to prevent mechanical damage of the components.

Category C – Facility and Radiation Monitoring Systems

QUESTION C.09 [1.0 point]

Which ONE of the following will initiate a reactor SCRAM? (Assume the reactor is operating at full power)

- a. 9 second period
- b. D₂O flow rate is 100 gpm
- c. Main intake damper oil pressure is 650 psig
- d. Reg rod drives into 1.5" (Auto Mode, no op. action)

QUESTION C.10 [1.0 point]

The temperature of the recombiner is discovered to be 40°C for fifteen minutes during a 3 MW reactor operation. Which ONE of the following is the MAXIMUM reactor power you must reduce to, to ensure you do not violate the Technical Specifications?

- a. 129 kW
- b. 119 kW
- c. 109 kW
- d. 99 kW

QUESTION C.11 [1.0 point]

Which ONE of the following is the MOST correct reason why the reactor takes a long period of time to attain thermal equilibrium?

- a. Primary Coolant has a large volume of water, so it creates a negative temperature feedback before attaining thermal equilibrium
- b. Primary coolant pumps require a long period of time to reach a constant speed; therefore it takes more time for distributing heat capacity
- c. Heavy water has a large heat capacity; therefore, it is slow to attain an equilibrium distribution
- d. Graphite reflector has a large heat capacity; therefore, it is slow to attain an equilibrium distribution

Category C – Facility and Radiation Monitoring Systems

QUESTION C.12 [1.0 point]

When the off-gas system is isolated and H₂ concentration exceeds 1% in the air space above the primary water pool system, the reactor power level shall be reduced to less than _____ and samples must be taken every_____.

- a. 500 kW / 0.5 hr
- b. 300 kW / 1.0 hr
- c. 200 kW / 1.5 hrs
- d. 100 kW / 2.0 hrs

QUESTION C.13 [1.0 point]

MIT Technical Specification requires the worth of all single movable experiments not to exceed _____ and the worth of non-secured single experiments not to exceed _____.

- a. 0.2% $\Delta k/k$ and 0.5% $\Delta k/k$
- b. 0.3% $\Delta k/k$ and 0.5% $\Delta k/k$
- c. 0.4% $\Delta k/k$ and 0.6% $\Delta k/k$
- d. 0.5% $\Delta k/k$ and 0.8% $\Delta k/k$

QUESTION C.14 [1.0 point]

On a startup within 16 hours of shutdown, you are required to check all of the listed below for Channel #1 operation, EXCEPT:

- a. Amplifier ON
- b. Count Rate OK
- c. Source is in place
- d. Gain and discrimination settings

QUESTION C.15 [1.0 point]

Sampling of the secondary system occurs once every 24 hours during normal operation to detect which ONE of the following isotopes?

- a. H-3
- b. B-10
- c. Ar-41
- d. I-131

Category C – Facility and Radiation Monitoring Systems

QUESTION C.16 [1.0 point]

The reactor is operating at 5.9 MW with an experiment in the pneumatic system. What will the temperature be about 6 minutes after receiving a 'vacuum off pneumatic system' alarm?

- a. 50°C
- b. 100°C
- c. 250 °C
- d. 500°C

QUESTION C.17 [1.0 point]

To minimize radiation streaming from a reactor core to top shield lid, the sleeve and plug are:

- a. Made of Lead and a beam port is blanketed by helium
- b. Made of Aluminum and a gasket cover is bolted over the beam port's opening
- c. Stepped and gas seals are made by bolting a ring against the aluminum flange
- d. Made of Polyethylene and a gasket cover is bolted over the beam port's opening

QUESTION C.18 [1.0 point]

In the event of a loss of building power, where will the emergency battery DIRECTLY provide a 120 volt to DC power to?

- a. No systems directly receive power from the emergency battery
- b. Entire building can be powered by the emergency battery
- c. Radiation area, continuous air, and stack gas monitors
- d. Emergency lighting panel

Category C – Facility and Radiation Monitoring Systems

QUESTION C.19 [2.0 points, 0.25 each]

Match each monitor and instrument (channel) listed in Column A with a specific purpose in Column B. (Answers used only once)

Column A

Column B

- | | |
|---------------------------------------|---|
| a. Stack Gas Monitor | 1. Monitor radiation level in the reactor top |
| b. Plenum Particulate Monitor | 2. Detect radioisotopes release due to fuel failure |
| c. High Level Emergency Power Channel | 3. Determine the effluent of Ar-41 |
| d. Portable Monitor | 4. Survey of Laboratory |
| e. Log Count Rate Meter
startup | 5. Monitor Neutron level during the reactor |
| f. Area Radiation Monitor | 6. Provide a period scram |
| g. Channel 3 Safety Amplifier | 7. Provide a High Power level scram |
| h. Power Level (Channel 4) | 8. Provide indication of the reactor power level when all off-site electrical power has been lost |

(***** END OF CATEGORY C *****)
((***** END OF EXAM *****))

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

A.01

Answer: a
Reference: Burn, Section 6.5, pg. 6-14

A.02

Answer: b
Reference: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory

A.03

Answer: b
Reference: Burn, R., Introduction of Nuclear Reactor Operations, © 1988, Sec 4.6; For *S/D* reactor, $T = -80$ seconds. Time = 120 seconds.
 $P = POe^{1r1} = 3x 10^6 e^{-120/80} = 6.69 x 10^5$

A.04

Answer: b
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 4

A.05

Answer: b
Reference: Reactor power increasing, positive period

A.06

Answer: a
Reference: NRC previous exam, October, 2014; decreasing core reactivity worth will decrease the core excess

A.07

Answer: a. Alpha b. Neutron c. Gamma d. Beta-
Reference: Chart of the Nuclides

A.08

Answer: b
Reference: MIT SAR 1.2.3 (c), pg. 1-4
DOE Fundamentals of Reactor Theory, Volume 2, NP-04, pg.25

A.09

Answer: a. Decrease; b. Increase; c. Increase; d. Decrease
Reference: DOE Fundamentals of Reactor Theory, Volume 2, NP-04, pg.28

A.10

Answer: a. 2, b. 1, c. 3, d. 4
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 1, Module 1, Page 43-46

A.11

Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations*

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

A.12

Answer: d
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1982, Sec 3.3.3, page 3-21. $\rho = \frac{k_{eff1} - k_{eff2}}{k_{eff1} \times k_{eff2}} = \frac{0.95 - 0.8}{(0.8 \times 0.95)} = 0.197 \text{ k/k}$

A.13

Answer: a
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 1

A.14

Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 2.5.1, Pages 2-38-43

A.15

Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 7.2

A.16

Answer: b
Reference: Lamarsh 3rd ed., Section 3.6, pg. 68-71
Basic Nuclear Engineering 4th ed., Slowing Down of Neutrons

A.17

Answer: d
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1982, § 5.3, p. 5.6
For third generation $n = n + K^*n + K^2 *n = 1000 + 800 + 640 = 2440$ neutrons

A.18

Answer: c
Reference: $\rho = \frac{k-1}{k-0.03} \rightarrow 1 = \frac{k-(-0.03k)}{k(1+0.03)} \rightarrow k = 1/1.03 = 0.9708$

A.19

Answer: d
Reference: $P = P_0 e^{t/T} \rightarrow t = T \ln(P/P_0)$ assume constant period = 1
The largest ratio of P/P_0 is the longest time to complete

A.20

Answer: b
Reference: DOE Fundamentals of Reactor Theory, Volume 2, NP-03, pg. 52
The reactivity change per unit movement of a rod and is normally expressed as ρ/inch , k/k per inch, or pcm/inch

Category B – Normal/Emergency Operating Procedures and Radiological Controls

B.1

Answer: a. 2 (Class B) b. 3 (Class C) c. 1 (Class A) d. 1 (Class A)
Reference: MITR PM 1.4

B.2

Answer: c
Reference: $I=6CE_n=R/hr@ft. \rightarrow 6 \times 2Ci \times 0.6 \text{ MeV} \times 0.6 = 1.08 \text{ Rem or } 1080 \text{ mRem}$

B.3

Answer: b
Reference: MITR TS 4.1.5.c.

B.4

Answer: d
Reference: 10CFR20.1301(a)(1)

B.5

Answer: b
Reference: MITR, EP Table 4.7.5.1-1

B.6

Answer: c
Reference: 10CFR20.1201(a)(1)(i)

B.7

Answer: a
Reference: MITR EP 4.3.3.1

B.8

Answer: c
Reference: 10CFR50.59, changes to Technical Specifications require an amendment

B.9

Answer: d
Reference: 10CFR20 – at 10 feet, there is no beta radiation; calculate gamma at 1 foot;
 $DR_1D_1^2 = DR_2D_2^2$; $0.1 \times (10)^2 = DR_2(1)^2$; Gamma at 1 foot = 10 mrem/hour
Therefore, beta at 1 foot = 90mrem/hour or 90%

B.10

Answer: c
Reference: MITR TS 6.1.3

B.11

Answer: b
Reference: 10CFR55.13

B.12

Answer: a. Structure, b. Air c. Water, d. Fission
Reference: Standard NRC Question

B.13

Answer: b
Reference: 10 CFR 20.1201

Category B – Normal/Emergency Operating Procedures and Radiological Controls

B.14

Answer: c

Reference: $I_1 D_1^2 = I_2 D_2^2 \rightarrow 123 \text{ mR/hr} @ (4\text{ft})^2 = I_2 @ (2\text{ft})^2 \rightarrow 492 \text{ mR/hr}$

B.15

Answer: a (2), b. (3), c. (3), d. (3)

Reference: 22.2 mrem/hr at 30cm = radiation area; 222 mrem/hr at 30cm = high radiation area; 1332 mrem/hr at 30cm = high radiation area; 4.5 gray = 450 rad/hr at 1 meter = high radiation area; 10CFR20.1003 definition: Radiation Area = 5 mrem/hr at 30cm, High Radiation Area = 100 mrem/hr at 30cm, Very High Radiation Area = 500 rad/hr at 1 meter

B.16

Answer: d

Reference: MITR PM 2.3.1 (21)

B.17

Answer: d

Reference: $15\text{mrad Alpha} \times 20 = 300\text{mrem}$, $20\text{mrad Gamma} \times 1 = 20\text{mrem}$, $20\text{mrad neutron} \times 10 = 200\text{mrem} \rightarrow 300\text{mrem} + 20\text{mrem} + 200\text{mrem} = 520\text{mrem}$

B.18

Answer: b

Reference: MITR EP, Table 4.5.3-1

B.19

Answer: c

Reference: MITR SAR 3.1.2.3

Category C: Facility and Radiation Monitoring Systems

C.01

Answer: c
Reference: MITR RSM 8.8.2

C.02

Answer: d
Reference: MITR RSM 9.5

C.03

Answer: d
Reference: MITR SAR 7.2.2.1, pg. 7-7 and 7.3.1.5, pg. 7-16

C.04

Answer: d
Reference: MITR RSM Figure 5.9, NRC standard question

C.05

Answer: a
Reference: MITR SAR 7.4.1, pg. 7-19 and 7.6.1, pg. 7-26

C.06

Answer: b
Reference: MITR SAR Table 5-4, pg. 5-25

C.07

Answer: c
Reference: MITR RSM 7.2.1

C.08

Answer: b
Reference: MITR TS 1.3.28, pg. 1-7

C.09

Answer: a
Reference: MITR TS Table 3.2.3-1, RSM 4.5, 9.3.1, 9.4.1 and 9.4.3

C.10

Answer: d
Reference: MITR TS 3.3.3

C.11

Answer: d
Reference: MITR RSM 6.3.4

C.12

Answer: d
Reference: MITR RSM 3.2.5

C.13

Answer: a
Reference: MITR TS 6.1.1

Category C: Facility and Radiation Monitoring Systems

C.14

Answer: c
Reference: MITR PM 3.1.1.2

C.15

Answer: a
Reference: MITR RSM 7.4.1

C.16

Answer: b
Reference: MITR PM 5.5.1

C.17

Answer: c
Reference: MITR RSM 1.1.8

C.18

Answer: d
Reference: MITR RSM Figure 8.11

C.19

Answer: a. (3), b. (2), c. (8), d. (4), e. (5), f. (1), g. (6), h. (7)
Reference: MITR TS 4.3 and RSM 5-3