



**PE** 

**nuclear**  
practice exam

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**ISBN 978-1-947801-12-7**

Printed in the United States of America  
1st printing April 2020

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## About NCEES

NCEES is a nonprofit organization made up of the U.S. engineering and surveying licensing boards in all 50 states, the U.S. territories, and the District of Columbia. We develop and score the exams used for engineering and surveying licensure in the United States. NCEES also promotes professional mobility through its services for licensees and its member boards.

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## Exam Format

The PE Nuclear exam is computer-based. It contains 85 questions and is administered one day per year via computer at approved Pearson VUE test centers. A 9.5-hour appointment time includes a nondisclosure agreement, a tutorial, the exam, and a break. You have 8.5 hours to complete the actual exam.

In addition to traditional multiple-choice questions with one correct answer, the PE Nuclear exam uses common alternative item types such as

- Multiple correct options—allows multiple choices to be correct
- Point and click—requires examinees to click on part of a graphic to answer
- Drag and drop—requires examinees to click on and drag items to match, sort, rank, or label
- Fill in the blank—provides a space for examinees to enter a response to the question

To familiarize yourself with the format, style, and navigation of a computer-based exam, view the demo on [ncees.org/ExamPrep](http://ncees.org/ExamPrep).

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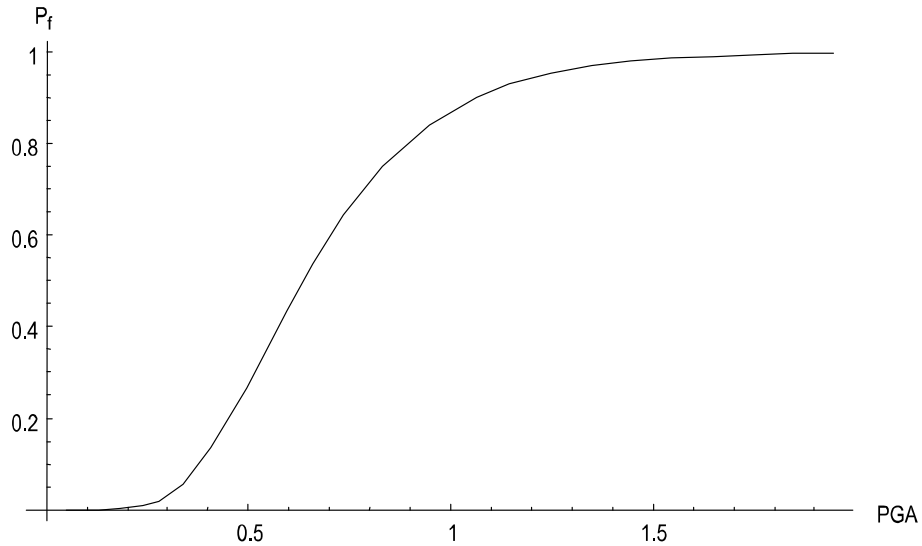


## **NUCLEAR PRACTICE EXAM**

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**PE NUCLEAR PRACTICE EXAM**

7. The safety analysis report (SAR) for a nuclear device handling facility is required to document analyses of seismic events. The following figure shows the fragility curve for the facility gross structure in the analyses.



FRAGILITY CURVE FOR STRUCTURE, PROBABILITY OF FAILURE VERSUS PGA

The fragility curve provides  $P_f(PGA)$ , defined as the probability of failure of the structure for a seismic event of magnitude equal to a particular Peak Ground Acceleration ( $PGA$ ) value, as a function of  $PGA$ . For example, from the figure, the probability that the structure fails given a seismic event with a  $PGA$  of 1.0 g is about 0.86.

$P_f(PGA)$  can be represented by the following equation:

$$P_f(PGA) = \ln(PGA/PGA_{\text{median}})/\beta$$

In general, the acceleration imposed on a structure, system, or component is different from the ground acceleration because of structural amplification and damping; this is accounted for in the specification for the median capacity,  $PGA_{\text{median}}$ , and  $\beta$  is a measure of the uncertainty of the capacity.

Use the graph provided and a  $PGA$  of 1.0 g. The value of  $\beta$  is most nearly:

- A. 0.23
- B. 0.46
- C. 0.54
- D. 1.87

## PE NUCLEAR PRACTICE EXAM

8. Assume that a particular PWR and a particular BWR both output 950 MWe net. The average temperature of the coolant in the PWR core is 580°F, and the average temperature of the coolant in the BWR core is 545°F. The PWR pressure is 2,200 psig. The temperature of the fluid in the pressurizer is \_\_\_\_\_ °F.

Enter your response in the blank.

9. A PWR has  $17 \times 17$  square fuel assemblies. The fuel pins are 12 ft long. The power ( $Q$ ) profile of a fuel pin is a cosine between  $z = -L/2$  and  $z = L/2$  (with  $Q = 0$  at each end).

Assume that the equivalent diameter of a central subchannel is 0.510 in. The system pressure is 2,250 psia. The average coolant temperature in the subchannel is 565°F, and the average velocity is 22 ft/sec. The Reynolds number is 675,000. If the Blasius form of the Fanning friction factor ( $f = 0.0791 \text{ Re}^{-0.25}$ ) is used, the frictional pressure drop (psid) over the length of the subchannel is most nearly:

- A. 0.63
- B. 1.9
- C. 7.6
- D. 244

10. A PWR has  $17 \times 17$  square fuel assemblies. The fuel pins are 12 ft long. Assume that the fuel pin O.D. is 0.374 in., and the pitch-to-diameter ratio ( $P/D$ ) is 1.326. The equivalent diameter (in.) of a coolant-centered central subchannel in this assembly is most nearly:

- A. 0.116
- B. 0.374
- C. 0.465
- D. 0.841

## PE NUCLEAR PRACTICE EXAM

25. Match each material to the definition to which it belongs. Some options are used more than once.

		Material
Iron that has undergone activation in a nuclear reactor	<input type="text"/>	High-level waste
Plutonium-contaminated metal filings	<input type="text"/>	Transuranic waste
Spent nuclear fuel	<input type="text"/>	Low-level waste
Contaminated rags	<input type="text"/>	By-product material
Cobalt sources produced by irradiation in a reactor	<input type="text"/>	

26. The reason that the direct thermal fission yield of  $^{99}\text{Tc}$  is so much smaller than its cumulative thermal fission yield is best represented by the statement that:
- A.  $^{99}\text{Tc}$  is technically not a fission product
  - B.  $^{99}\text{Tc}$  has a long half-life
  - C.  $^{99}\text{Tc}$  is only one decay away from stability
  - D.  $^{99}\text{Tc}$  can also exist in a metastable state



**PE NUCLEAR PRACTICE EXAM**

75. Which of the following detectors does **not** provide information about the energy of the radiation that is detected?

- A. Geiger-Müller counter
- B. Ionization chamber
- C. Proportional counter
- D. NaI(Tl) detector

76. Phosphorus-32 is valued for cancer therapy because phosphorus is part of many nucleotides, the P-32 isotope has a "Goldilocks" half-life of 14 days (not too short, not too long), and the P-32's beta deposits energy locally in the tumor. P-32 is produced by an activation process. What is its source? Choose the square for the correct source nuclide.

<p><b>S31</b> 1/+ <b>2.56 s</b> <math>\beta^+</math> 4.39, ... <math>\gamma</math> 1266.2, ...  E 5.396</p>	<p><b>S32</b> <b>94.99</b>  <math>\sigma_\gamma</math> 0.53, 0.26 <math>\sigma_\alpha \leq 0.5</math> mb  31.9720710</p>	<p><b>S33</b> 3/+ <b>0.75</b>  <math>\sigma_\gamma</math> 0.45, 0.23 <math>\sigma_\alpha</math> 0.14 <math>\sigma_p</math> 2 mb  32.9714588</p>	<p><b>S34</b> <b>4.25</b>  <math>\sigma_\gamma</math> 0.25, 0.13  33.9678669</p>	<p><b>S35</b> 3/+ <b>87.2 d</b>  <math>\beta^-</math> 0.1674 no <math>\gamma</math>  E 0.1672</p>
<p><b>P30</b> 1+ <b>2.50 m</b>  <math>\beta^+</math> 3.24, ... <math>\epsilon</math> <math>\gamma</math> 2235.2 (<math>\omega</math>), ...  E 4.2324</p>	<p><b>P31</b> 1/+ <b>100</b>  <math>\sigma_\gamma</math> 0.17, 0.08  30.9737616</p>	<p><b>P32</b> 1+ <b>14.28 d</b>  <math>\beta^-</math> 1.709 no <math>\gamma</math>  E 1.7105</p>	<p><b>P33</b> 1/+ <b>25.3 d</b>  <math>\beta^-</math> 0.249 no <math>\gamma</math>  E 0.249</p>	<p><b>P34</b> 1+ <b>12.4 s</b>  <math>\beta^-</math> 5.1, 3.2, ... <math>\gamma</math> 2127.7, ...  E 5.37</p>
<p><b>Si29</b> 1/+ <b>4.685</b>  <math>\sigma_\gamma</math> 0.120, 0.08  28.97649470</p>	<p><b>Si30</b> <b>3.092</b>  <math>\sigma_\gamma</math> 0.107, 0.7  29.97377017</p>	<p><b>Si31</b> 3/+ <b>2.62 h</b>  <math>\beta^-</math> 1.48, ... <math>\gamma</math> 1,266.2 <math>\omega</math> <math>\sigma_\gamma</math> 0.07  E 1.4919</p>	<p><b>Si32</b> <b>1.6E2 a</b>  <math>\beta^-</math> 0.221 no <math>\gamma</math>  E 0.2243</p>	<p><b>Si33</b> (3/+) <b>6.1 s</b>  <math>\beta^-</math> 3.92, ... <math>\gamma</math> 1847.6, ...  E 5.84</p>

## **NUCLEAR SOLUTIONS**

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## PE NUCLEAR SOLUTIONS

7. **Step 1:** Write the equation:  $P_f(PGA) = \ln(PGA/PGA_{\text{median}})/\beta$

**Step 2:** Solve the equation for  $\beta$ :  $\beta = \ln(PGA/PGA_{\text{median}})/P_f(PGA)$

**Step 3:** Determine  $PGA_{\text{median}}$ .

a) The median is the 50th percentile value.

b) Thus,  $PGA_{\text{median}}$  is the  $PGA$  value for which  $P_f(PGA) = 0.5$ .

c) Take 0.5 on the  $y$ -axis of the included graph to the curve and read the  $x$ -axis value for  $PGA_{\text{median}}$ , which is about 0.63.

**Step 4:** Plug in the values to estimate  $\beta$ :

$$\beta = \ln(PGA/PGA_{\text{median}})/P_f(PGA) = [\ln(1.0/0.63)]/0.86 = 0.54$$

**THE CORRECT ANSWER IS: C**

8. The pressurizer is the reactor component that maintains the pressure in the primary loop of the PWR reactor. The pressure in the PWR core and the pressurizer are assumed equal. The coolant in the PWR core is subcooled liquid, whereas the fluid in the pressurizer exists as a mixture of saturated water and steam at 2,214.7 psia (= 2,200 psig + 14.7 psia). The temperature of the fluid in the pressurizer is obtained from the steam tables for the saturated liquid at 2,214.7 psia. Therefore, the temperature of the saturated steam/water mixture at 2,215 psia is 650.4°F.

**THE CORRECT ANSWER IS: 645–655°F**

**PE NUCLEAR SOLUTIONS**

9. The problem statement gives the Reynolds number of 675,000 such that the flow through the subchannel is completely turbulent. Remember that  $Re < 2,000$  for laminar flow in an enclosed channel and the transition to completely turbulent flow occurs when  $Re < 4,000$ .

The frictional pressure drop across the subchannel for turbulent flow is calculated using the Fanning equation:

$$\Delta p_f = 4f_{\text{Fanning}} \frac{L}{D_h} \frac{\rho \bar{V}^2}{2g_c} = 4(0.0791 Re^{-0.25}) \frac{L}{D_h} \frac{\rho \bar{V}^2}{2g_c}$$

where:

$L$  = the length of the fuel pin

$D_h$  = the equivalent (i.e., hydraulic) diameter of the subchannel

$\rho$  = the coolant density

$\bar{V}$  = the average coolant velocity

$g_c$  = the gravitation conversion constant (i.e., 32.2 lbf-ft/lbf-sec<sup>2</sup>), which is required for dimensional consistency

Note that the Fanning equation can be derived from the Darcy-Weisbach equation:

$$h_f = f \frac{L}{D_h} \frac{\bar{V}^2}{2g_c}$$

Also note that the leading factor of 4 in the Fanning equation is required to convert the Fanning friction factor to the more familiar Darcy friction factor that appears in the Darcy-Weisbach equation and the Moody chart; otherwise, your answer will correspond to one of the distractors.

The density of the water at 2,250 psia and 565°F is obtained from steam tables for subcooled water. The coolant density should be around 45.86 lbf/ft<sup>3</sup>, depending on the version of steam tables used.

Inserting numerical values and calculating the result gives the frictional pressure loss as:

$$\begin{aligned} \Delta p_f &= 4 \left[ 0.0791 (675,000)^{-0.25} \right] \left( \frac{12 \text{ ft}}{\frac{0.510 \text{ in.}}{12 \text{ in./ft}}} \right) \frac{(45.86 \text{ lbf/ft}^3)(22 \text{ ft/sec})^2}{2(32.2 \text{ lbf-ft/lbf-sec}^2)} \\ &= \frac{1,074 \text{ lbf/ft}^2}{144 \text{ in}^2/\text{ft}^2} \\ &= 7.46 \text{ psid} \end{aligned}$$

**THE CORRECT ANSWER IS: C**

## PE NUCLEAR SOLUTIONS

10. The equivalent diameter of the coolant-centered central subchannel in the PWR  $17 \times 17$  square assembly is equal to the hydraulic diameter of the subchannel,  $D_h = 4A/p$ , where  $A$  is the flow area and  $p$  is the wetted perimeter of the subchannel.

From the problem statement, the pitch  $P$  of the fuel pins is  $1.326D$ , where  $D$  is the outer diameter of the fuel pin. Therefore,

$$\begin{aligned} P &= 1.326D \\ &= 1.326(0.374 \text{ in.}) \\ &= 0.496 \text{ in.} \end{aligned}$$

The flow area of the subchannel is given by:

$$\begin{aligned} A &= P^2 - A_{\text{pin}} = (1.326D)^2 - \frac{\pi}{4}D^2 \\ &= \left(1.326^2 - \frac{\pi}{4}\right)(0.374 \text{ in.})^2 \\ &= 0.136 \text{ in}^2 \end{aligned}$$

The wetted perimeter  $p$  is the circumference of the fuel pin, which is calculated as:

$$\begin{aligned} p &= \pi D \\ &= \pi(0.374 \text{ in.}) \\ &= 1.175 \text{ in.} \end{aligned}$$

Therefore, the equivalent diameter of the subchannel is:

$$\begin{aligned} D_h &= \frac{4A}{p} = \frac{4(0.136 \text{ in.}^2)}{1.175 \text{ in.}} \\ &= 0.463 \text{ in.} \end{aligned}$$

**THE CORRECT ANSWER IS: C**

## PE NUCLEAR SOLUTIONS

24. The solution to this problem requires knowing what type of information is contained in each part of the Code of Federal Regulations (CFRs) and which organization is primarily responsible for those regulations. The EPA is responsible for waste handling. Protection of Environment, 40CFR, is the EPA portion of the CFRs.

**THE CORRECT ANSWER IS: 40**

25.	Iron that has undergone activation in a nuclear reactor	By-product material
	Plutonium-contaminated metal filings	Transuranic waste
	Spent nuclear fuel	High-level waste
	Contaminated rags	Low-level waste
	Cobalt sources produced by irradiation in a reactor	By-product material

High-level waste is spent fuel or waste resulting from reprocessing spent fuel. Transuranic waste (TRU) is any waste containing elements that have a higher atomic number than uranium; therefore, plutonium-contaminated filings are considered TRU. By-product material is radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to producing or using special nuclear material. Activated iron and cobalt fit the category of by-product material. Low-level waste is waste other than the previously described categories and includes items that have become contaminated with radioactive material.

**THE CORRECT ANSWER IS SHOWN ABOVE.**

26. Cumulative fission yield is the yield of the product itself (i.e., direct yield) plus the yields of all of its short-lived precursors. Technetium-99 ( $^{99}\text{Tc}$ ) is near the end of a beta decay chain and beta-decays into stable ruthenium-99. Each of the precursors of  $^{99}\text{Tc}$  has a larger direct fission yield than  $^{99}\text{Tc}$ . Therefore, the cumulative fission yield of  $^{99}\text{Tc}$  is greater than the direct fission yield because it is generated predominantly from beta decay of its precursors.

**THE CORRECT ANSWER IS: C**

## PE NUCLEAR SOLUTIONS

### 74. (Continued)

In order for the alpha particles to be detected by the alpha probe, the alpha particles must penetrate the thin mylar window to enter the sensitive detector volume. For this problem, however, the alpha contamination is 5 cm from the detector's window, and the air between the surface contamination and the detector window will absorb a portion of the alpha particles' energy, so the alpha particles must have sufficient energy to both travel to and penetrate the mylar window to be detected. Therefore, before attempting potentially unnecessary calculations such as the disintegration rate of the Am-241, first check the range of alpha particles in air. If the range is less than the distance to the detector window, the detector will not detect any alpha particles.

From the *PE Nuclear Reference Handbook*, the range of alpha particles in air is calculated as

$$R = 0.325E_{\alpha}^{3/2}$$

where  $R$  is the range (cm) and  $E_{\alpha}$  is the energy of the alpha particle (MeV). The range of the most energetic alpha particle from Am-241 is

$$\begin{aligned} R &= 0.325E_{\alpha}^{3/2} \\ &= 0.325(5.486 \text{ MeV})^{3/2} \\ &= 4.19 \text{ cm} \end{aligned}$$

which is less than the distance between the source and the detector window. Note that alpha particles have a mean range in air and a maximum range due to energy straggling. However, the calculated range is sufficiently less than the distance between the source and the detector window to allow any alpha particles from entering the active detector volume. Therefore, the detector will not count any alpha particles emitted by the Am-241 contamination.

**THE CORRECT ANSWER IS: A**

### 75. Properties of all of these detectors can be found in the *PE Nuclear Reference Handbook*.

For both the ionization chamber and proportional counter, the output signal is proportional to the energy of the incident radiation whether averaged (ion chamber) or for discrete events (proportional counter). NaI(Tl) is an inorganic scintillator wherein the intensity of light given off is proportional to the incident radiation energy. A Geiger-Müller counter is operated at a high voltage such that any ionization event, regardless of the energy of radiation that caused it, results in a large signal pulse.

**THE CORRECT ANSWER IS: A**

**PE NUCLEAR SOLUTIONS**

76. The source nuclide is sulfur-32. Neutrons are by far the most common activation projectile, since protons have a much higher Coulomb barrier and electrons don't carry enough energy to activate. For a reliable supply, the source has to be a stable nuclide. Stable S-32 has a reasonable neutron absorption cross section, and with some extra neutron energy it can kick out a proton, producing  $^{32}\text{S} (n, p) ^{32}\text{P}$ .

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**THE CORRECT ANSWER IS SHOWN ABOVE.**