Irradiator Welcome Packet

Masonic Cancer Center
University of Minnesota

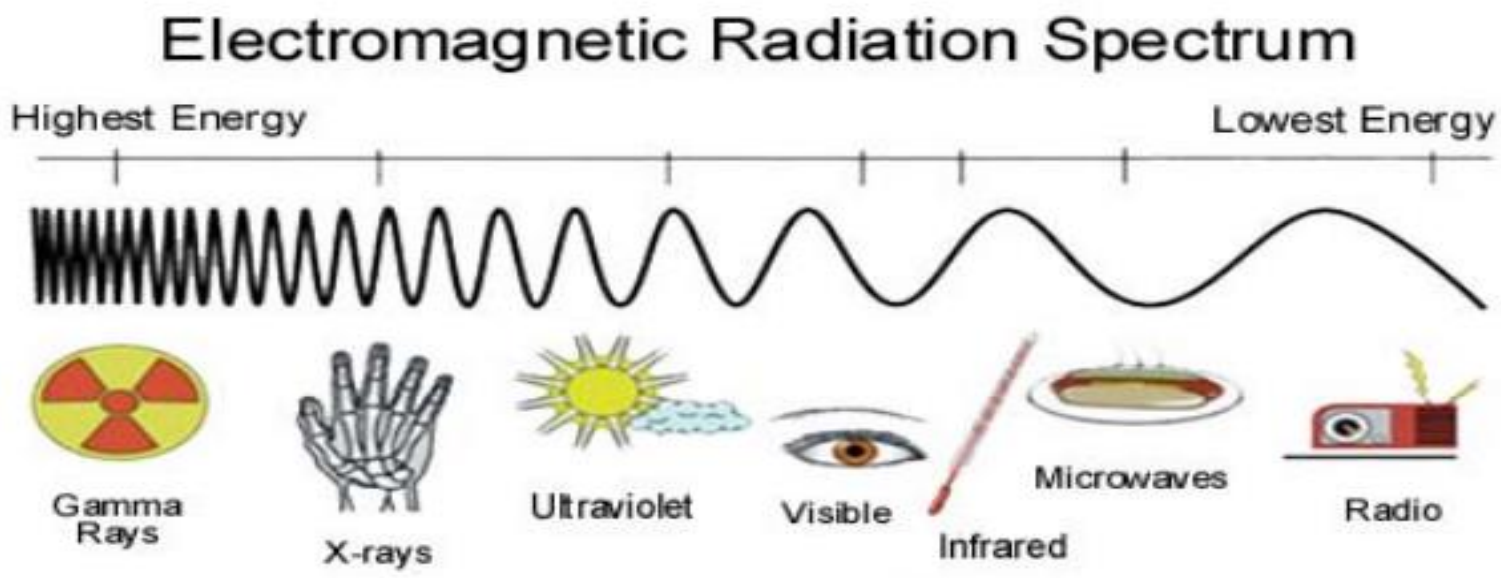
Comprehensive Cancer Center designated by the National Cancer Institute

Checklist

- ❑ Completed online Radiation Safety Training
  - ❑ Radiation Safety for Radioactive Material Users (takes roughly 1-2 hours)
- ❑ Completed in person machine operations training (Mayo first floor B185/186 sign up in iLabs)
  - ❑ Key code: 9989*
- ❑ Notify Coordinator of desired programs (new machine only)
- ❑ Please turn irradiator off after use

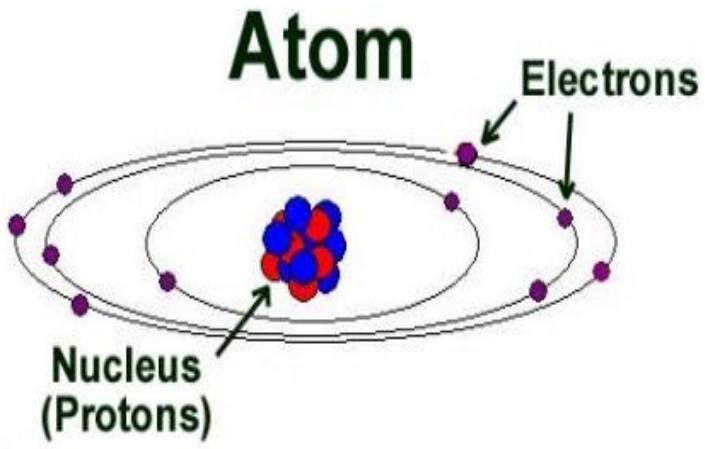
What are X-rays & Ionizing Radiation?

Everyone knows that x-rays are a type of radiation, but what exactly is radiation? Radiation is simply energy in motion. As you look at the figure below, there are many types of radiation that you are already familiar with:

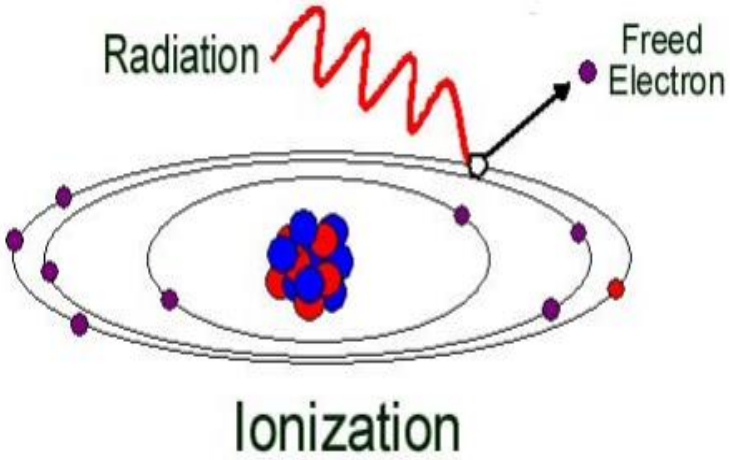


While all these types of radiation have many traits in common (e.g., all travel at the speed of light) only x-rays and gamma rays have enough energy to cause **ionization** when they interact with the body. So our next question is "What is ionization and why is it a concern?"

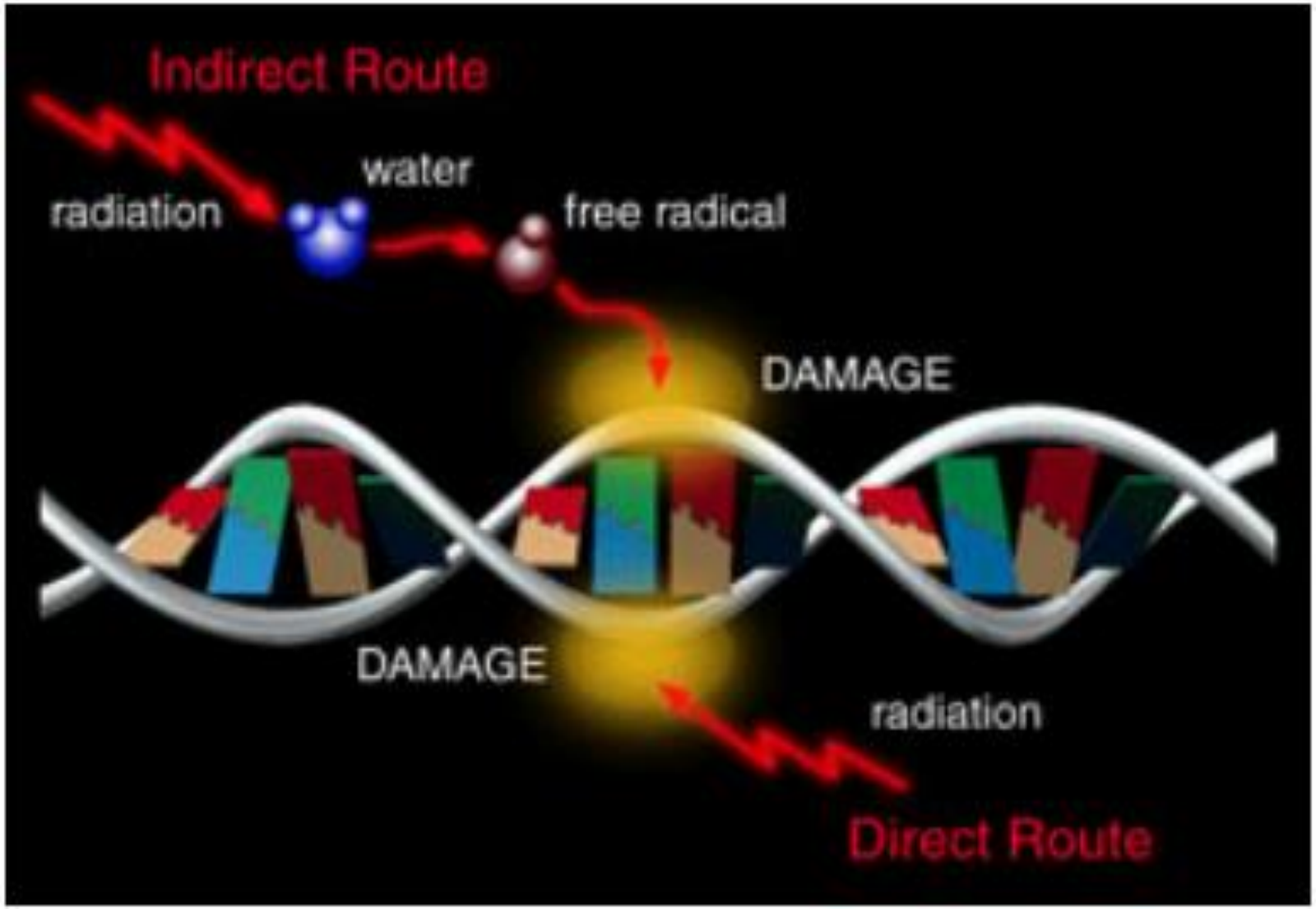
All matter is made up of atoms. Atoms contain a small central nucleus containing protons, which have electrically positive charges. Orbiting the nucleus are electrons which are small particles with electrically negative charges. In a neutral atom the number of positive (+) and negative (-) charges are equal (see the figure below).



When an x-ray or gamma ray is traveling through the human body, it will sometimes interact with an orbital electron of an atom. During the interaction the radiation can impart enough energy to the electron to "free" it from the atom. The atom now has one less electron, which results in the atom having more positive than negative charges. An atom that does not have the same number of positive & negative charges is called an **ion**. The process of ionization is illustrated below;

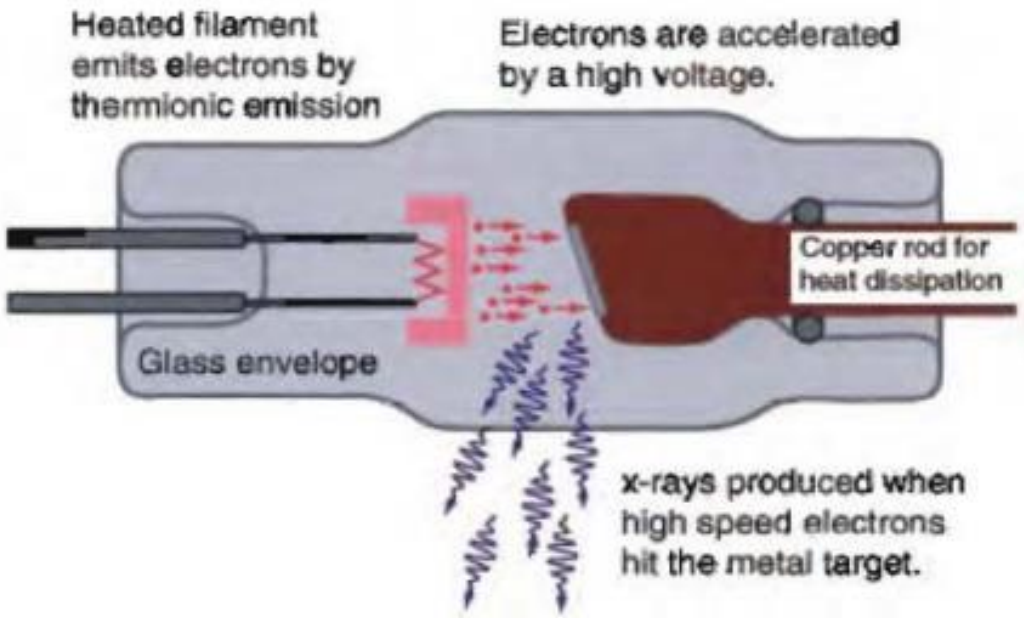


This "freed" electron can potentially cause damage to living cells or DNA. The damage can be repaired from small amounts of radiation, however if enough radiation is imparted, biological damage can occur. The biological damage can include the death of the cell, mutation of the DNA, or preventing the cell from reproducing.


Indirect Route
radiation
water
free radical
DAMAGE
DAMAGE
radiation
Direct Route

How are X-rays Produced?

- Most irradiators traditionally use a radioactive substance which continuously gives off gamma radiation. The RS-2000 uses an x-ray tube to produce x-rays as its ionizing radiation source. It should be noted that the only thing that differs between an x-ray and gamma ray is where they were originated (x-rays are produced outside the nucleus, gamma rays originate inside the nucleus), otherwise you can't tell the difference between either.
- Like the x-ray machine used to take x-rays on patients, the X-RAD 320 irradiator uses an x-ray tube to generate x-rays (see picture below). Basically, what happens is that a metal filament is heated up to a very high temperature allowing electrons from the metal to essentially "boil" off. Electrons, the small negatively charged particles orbiting the nucleus, are then accelerated across the glass tube to a positively charged anode. While the majority of the electrons collide with the metal anode and generate heat, some of the electrons lose their energy in the form of x-rays.
- An important distinction that should be made between traditional irradiators that use a radioactive source and the X-RAD 320 unit which uses an x-ray tube is that no radiation is produced in the x-ray tube when the power is off (while the radioactive source continuously gives off radiation).



Radiation Dose

When x-rays interact with the specimen being irradiated, the radiation interacts with orbital electrons of the atoms and radiation (energy) is deposited. The amount of radiation deposited is called the **radiation dose** (or simply "**dose**") and is measured in either **rad** or **Gray (Gy)**. A Gray is 100 times greater than a rad. For the specimens being irradiated in the RS-2000 the dose typically ranges from a few Gray to tens of Gray.

The rate at which the radiation is delivered is the **dose rate** and is in either in units of **rad/hr** or **Gray/hr** (**Gy/hr**). A Gray/hr is 100 times greater than a rad/hr. In the RS-2000 the dose rate used is highly dependent upon how close the specimen is to the x-ray tube, but will vary from around 1.2 to almost 9 Gy/minute.

The next question you might ask is "How much radiation will I receive from handling irradiated specimens and from using this irradiator?". As for handling irradiated specimens, they do **NOT** become radioactive after an irradiation and you will not receive any radiation from handling irradiated these specimens.

As for using (or being near) the irradiator, the unit is heavily shielded and minimal radiation is given off outside the unit. In addition, an interlock system will shut off the x-ray tube if the door to the RS-2000 is opened. Therefore, you should expect virtually NO radiation exposure from using the RS-2000 and therefore, individuals using the unit are NOT required to wear radiation badges to monitor exposure (**NOTE: If the interlock system is somehow defeated or if the shielding is removed, individuals could receive DANGEROUS radiation doses**).

Radiation Dose ("Dose") measured in rad or Gray (Gy)

100 rad = 1 Gy

Dose Rate measured in rad/hr or Gy/hr

100 rad/hr = 1 Gy/hr

Irradiated specimens **do NOT** give off radiation

Radiation levels outside the RS-2000 are minimal

Warnings, Precautions Using the X-RAD 320

Radiation Exposure

- As previously discussed, radiation exposure should be minimal unless the unit itself is compromised. Examples of unsafe conditions which could result in potentially dangerous radiation levels include;
  - Door interlock to the X-RAD 320 does not work
  - Shielding has been damaged
  - Evidence of machine tampering

IF UNSAFE CONDITIONS ARISE WITH THE X-RAD 320:

1. STOP WORK!
2. TURN POWER OFF
3. NOTIFY EMILY TARAS (TARA0068@UMN.EDU) AND RADIATION SAFETY IMMEDIATELY (ext. 6-6002)

Other Precautions

- - Another serious hazard from an x-ray device is electrical shock. The x-ray generator is a highly regulated DC power supply that applies a voltage of 160 kilovolts.
- - No unauthorized personnel may defeat or override any safety features on the x-ray generator, collimator, or shielding, without permission of the manufacturer (Rad Source). The RS-2000 is to be serviced by trained personnel only.
- - Please keep unit dry. When cleaning do not allow cleaners or water to drip into panels or chamber. Use only a damp cloth with mild soaps for cleaning.
- - Do not use the top of the unit as a storage area. Do not place any heavy items or items containing liquids or materials that may harm the unit if they leaked or spilled on top or inside.
- - The x-ray tube can be damaged if power is shut off immediately following an irradiation. After the irradiation is completed, wait 5 minutes before turning the unit off.

X-RAD 320

- Dose Output
  3 Gy/min at 320KV, 12.5mA, 50cm SSD, (HVL≈1mm Cu)
  1 Gy/min at 320KV, 12.5mA, 50cm SSD, (HVL≈4mm Cu)
  >15 Gy/min at 320KV, 12.5mA, 50cm SSD, (No Beam Hardening))

Old Irradiator Protocol B186

1. Enter room and turn key to the right to “Standby” position
2. Sign in to the log book on the counter
3. Software will boot and initialize various parameters, Dose Management screen will change to “Null offset”, then “Ready”
4. When screen reads ”Ready”, turn key to ON
5. Set the test voltage to 12.5mA and 320 kV. Set your time for 99.9 minutes to allow the machine enough time to warm up. You will use the touch screen attached to the cabinet to set your program. Press enter using the arrow key as you set your parameters.
6. If you are the first user of the day, the irradiator will need to warm up for approximately 8-10 minutes. You will be prompted by message on the touchscreen. The green button will start the X-Ray to warm up the machine, and the lightning bolt on the white button will flash while the machine is running.
7. When the warm-up is complete: the screen will read ”Warm-up Program Completed”
8. You will need to set your program for your specific dose:
9. Use the Dosimeter Box next to the X-Ray machine to set your specific dose for your experiment
10. Press reset to clear the settings, then Dose Mode (in cGY) or Time Mode, FD (platform distance), Filter Number.
    1. Dose Mode: Set dose for your experiment on Dosimeter, and do not set the time on the touchscreen, since the time will be calculated for the dose.
    2. Time Mode: Set on the touchscreen, you can use minutes and seconds, or decimal, using the clock icon.
    3. Filter 1 or 2 should be chosen on the Dosimeter Box
    4. FD: distance of platform to X-Ray source: follow your protocol for adjustment:
        1. Platform is adjusted using the key on the cabinet: Tape Measure on inside of cabinet
11. To adjust the sample field area on the platform, use the X-axis and Y-axis knobs above the platform.
12. ***ONLY place your sample/mice in the X-Ray Cabinet after all settings and warm up have been completed)!!!!***
13. To start dose, press the green button. The machine will start, with the lightning bolt flashing and the time will count down. The X-Ray light box on the top of the cabinet will also light up while the irradiator is running.
14. The irradiator will stop once the program is finished. If you have multiple runs, you can reset the Dosimeter box, but you do not need to change the settings. You can remove your current samples/mice, and place the next round in the cabinet.
15. When you are finished, PLEASE turn off the Irradiator.

New Irradiator Protocol B185

1. Login to binder on the bench with info
2. Turn key to "Standby"
3. Software will boot and initialize various parameters
4. Enter username and password on the touch screen
5. Once properly logged in the key can be turned to "On"
6. Choose "Recall Program"
    1. The programs that are available for your use will be determined by the Login information entered
7. Select appropriate program
    1. If you need access to a different program contact Emily Taras – tara0068@umn.edu
8. Note: the X-RAD 320 will automatically determine whether it needs to run a warm-up cycle before your selected program can be run. The duration, kV and mA will all be determined by the machine. If you are the first person to use the X-RAD 320 for the day, the warm-up cycle can take up to 20 minutes (so make sure you have signed up for enough time for both the Warm-up and your experiment if you are the first user of the day)
9. ***Your specimens should NOT be placed into the X-RAD 320 during Warm-up!!!!***
10. Insert appropriate filter for your protocol and shut the X-RAD 320 door
11. Check the platform location for the correct distance (the software does not adjust the Platform for your program, use the key to adjust platform)
12. If warm-up cycle is necessary, a message will appear on the screen
13. Select "X-Ray Start" on the touch screen to start the warm-up cycle. During this time the yellow light on the front of the interface, and the "X-Ray In-Use" light on top of the cabinet will turn on. The timer will countdown (in seconds) the remaining time to complete the warm-up.
14. Once complete, the X-Ray lights will turn off and your program will be able to be executed
15. Open the X-RAD 320 door, turn on the illuminator and center samples within the illuminated square on the platform
16. Turn the illuminator off and shut the X-RAD 320 door
17. Hit "X-Ray Start" to start program (lightning light should be on)
18. When the program has finished, the "X-Ray In-Use" lights will turn off
19. Remove your specimen
    9. If you need to run the same program, you can switch out your samples and select "X-Ray Start"
20. Exit out of the program by selecting "Exit", then, when the main screen shows the login screen, turn the key to the "Off" position to turn off the X-RAD 320
21. The cooling system for the machine will run for a while after the X-RAD 320 is turned off
22. Please email Emily if you have any problems or need help with the X-RAD 320 tara0068@umn.edu

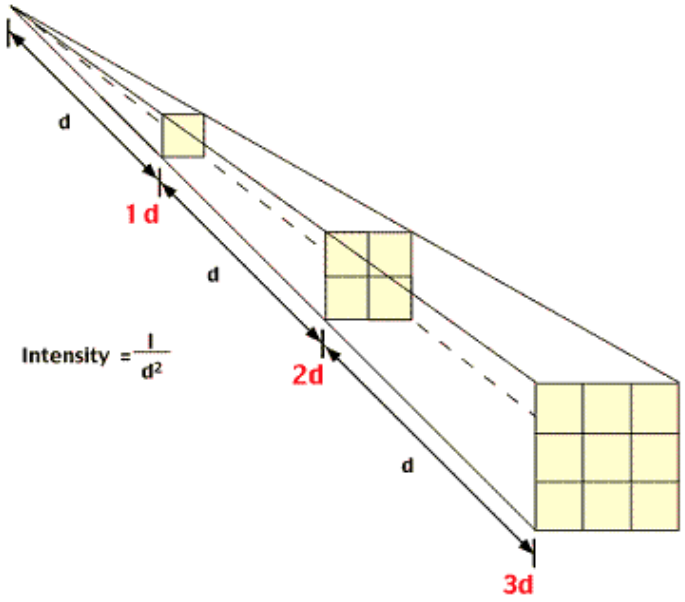
Tips and Tricks

- Warm machine up to 320 volts no matter what voltage you are using in order for the next person to successfully run the machine at whatever voltage needed for their experiment
- Turn machine on an off again if it does not work or you encounter issues
- Wait for machine to boot up in STANDBY mode before switching it to ON
- ALWAYS turn the machine off after use
- Make sure stage light is turned off before leaving.
- The most common stage height is 50 cm – however some people change it, is the stage set at 50?
- Are you gauging by dose or time?
  - Make sure the time does not run out before the dosage is complete – that might compromise your results.

Inverse Square Law

(Why the stage moves up and down to control exposure rate)

The intensity of electromagnetic ionizing radiation (gamma rays and x-rays) at any distance from a point source varies inversely as the square of that distance.



For example, if the radiation exposure is 100 R/hr at 1 inch from a point source, the exposure will be 0.01 R/hr at 100 inches. In this example, you have increased the distance by a factor of 100, so the exposure rate is decreased by a factor of 100^2 or 10,000.


Masonic Cancer Center
University of Minnesota
Comprehensive Cancer Center designated by the National Cancer Institute
Advancing Knowledge, Enhancing Care