Contrast medium experiment with a blood vessel model

Physics → Modern Physics → Production & use of X-rays

Difficulty level	Group size	Preparation time	Execution time
hard	2	45+ minutes	45+ minutes

General information

Application

Setup

Most applications of X rays are based on their ability to pass through matter. Since this ability is dependent on the density of the matter, imaging of the interior of objects and even peaple becomes possible. This has wide usage in fields such as medicine or security.

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Other information (1/2)

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Prior knowledge

The prior knowledge for this experiment is found in the Theory section.

Main principle

When a blood vessel model is irradiated with X-rays, the blood vessels themselves are not visible at first. It is only after the injection of a contrast medium that the blood vessels become visible.

Other information (2/2)

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Learning objective

The goal of this experiment is to observe the behavior of fluids inside a blood vessel.

Tasks

Inject a 50% potassium iodide solution into the blood vessel model and observe the fluorescent screen of the X-ray basic unit to follow the flow of the injected solution in the blood vessel model.

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Theory (1/4)

In radiological diagnostics, many organs and tissues can only be distinguished from each other with great difficulty. For this reason, contrast media are used in order to make the gastrointestinal tract or blood vessels, for example, visible in an X-ray image. In roentgenologic examinations of blood vessels, concentrated solutions of iodine are used for this purpose. They absorb radiation to a higher extent than the surrounding tissues, which results in high-contrast X-ray images.
If X-rays with intensity $\mathrm{I_0}$ penetrate the matter of the layer thickness d, then, in accordance with the law of absorption, the intensity I of the radiation that passes through the matter is given by (see P2541105):

$\mathrm{I} = \mathrm{I_0} e^{-\mu(\lambda,\mathrm{Z})\cdot\mathrm{d}}$ (1)

Theory (2/4)

Since the absorption is proportional to the mass of the absorber, the mass absorption coefficient μ/ρ (density $\rho[\mathrm{g/cm^3}]$ is often used instead of the linear absorption coefficient μ.

The following processes are responsible for the absorption:

1. photoelectric effect
2. scattering (Compton effect)
3. pair production

Pair production, however, requires a certain threshold energy that corresponds to twice the amount of the electron rest energy ($\mathrm{2E_0 = 2m_0c^2 = 1.02MeV}$). As a result, the absorption coefficient only comprises two components:

$$\mu = \tau_{\mathrm{photoelectriceffect}} + \sigma_{\mathrm{scattering}}$$

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Theory (3/4)

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In addition, the following applies to the available energy range of the radiation: $\tau > \sigma$

The dependence of the mass absorption coefficient on the primary radiation energy and on the atomic number Z of the absorber is described with sufficient precision by the following (empirical) relationship:

$$\frac{\tau}{\sigma} \approx \frac{\mu}{\rho} = \mathrm{k}(\lambda^3 \cdot \mathrm{Z}^3) \qquad (2)$$

In accordance with (2), the absorption increases drastically with an increasing wavelength as well as with an increasing atomic number of the absorber.
As iodine has a much higher atomic number (Z = 53) than the elements in organic tissue, it has a very high absorption power and is very well suited for use as a contrast medium.

Figures 1a and 1b show the effect of the contrast medium.

Theory (4/4)

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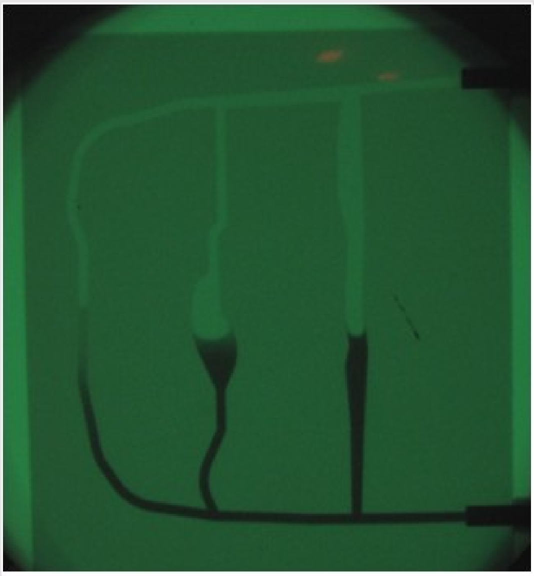

Fig. 1a: Blood vessel model with the contrast medium; half filled

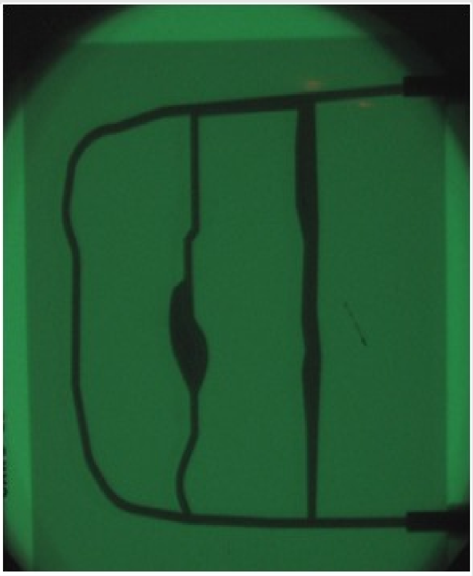

Fig. 1b: Blood vessel model with the contrast medium; completely filled

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Equipment

Position	Material	Item No.	Quantity
1	XR 4.0 expert unit, 35 kV	09057-99	1
2	XR4 X-ray Plug-in Cu tube	09057-51	1
3	XR 4.0 X-ray imaging upgrade set	09155-88	1
4	Potassium iodide 50 g	30104-05	1

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Setup and Procedure

Procedure (1/4)

- In order to prepare the contrast medium, dissolve 10 g of potassium iodide in 20 ml of water.
- Place the blood vessel model in the small safety trough that is provided. Then, position the trough directly in front of the fluorescent screen that should be located as far to the right as possible on the optical bench (Fig. 2).

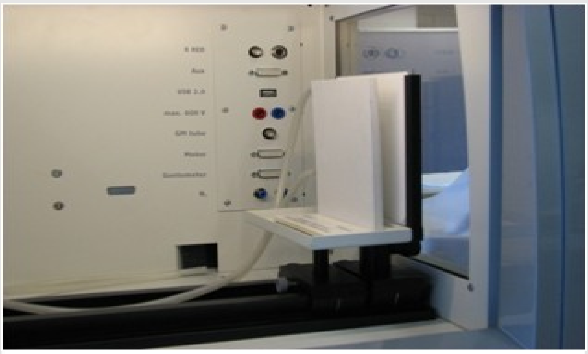

Fig. 2: set-up in the experiment chamber

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Procedure (2/4)

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- Lead the tubes through the working channel to the outside (Fig. 3).
- Fill one of the two syringes with the contrast medium.

Fig. 3: Tubes laid through the working channel

Procedure (3/4)

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- Connect the two syringes to the ends of the tubes: Ensure that the filled syringe is connected to the lower inlet of the model (Fig. 4).
- Set the X-ray tube to operate with an acceleration voltage of U_A = 35 kV and an anode current of I_A = 1 mA.
- The irradiation is performed without any diaphragm tube. Anode voltage U_A = 35 kV and anode current I_A = 1 mA.
- Darken the experiment room so that the flow of the contrast medium can be observed on the fluorescent screen. Then, inject the contrast medium in the filled syringe slowly into the blood vessel model.

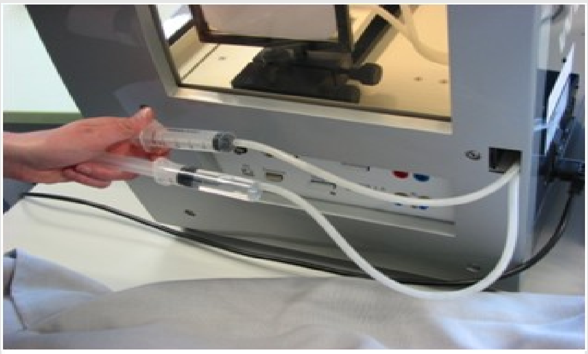

Fig. 4: Procedure

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Procedure (4/4)

Reduce the anode current and/or voltage in order to demonstrate the effect of these two parameters on the luminous intensity. For comparison, it is also interesting to fill the blood vessel model with water. If you would like to document the effect of the contrast medium in a photographic way, we recommend following the procedure described in P2542005. The contrast medium must be removed from the blood vessel model before the model is taken out of the experiment chamber:

- Remove the syringe that is connected to the lower inlet of the blood vessel model and lead the free end of the tube into the storage container.
- Press the contrast medium out with the aid of the other syringe.
- Seal the free tube ends with the plastic stoppers.

It is only then that the tubes may be pulled through the working channel and that the blood vessel model may be flushed several times with water with the aid of a syringe. Ensure to remove any residual water from the model to the maximum possible extent.

Note

Caution!

Take great care to ensure that no contrast medium can flow out into the experiment chamber. To do so, ensure that the tubes are always tightly connected and that the tube ends are always sealed with stoppers prior to removing the blood vessel model from the experiment chamber.

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