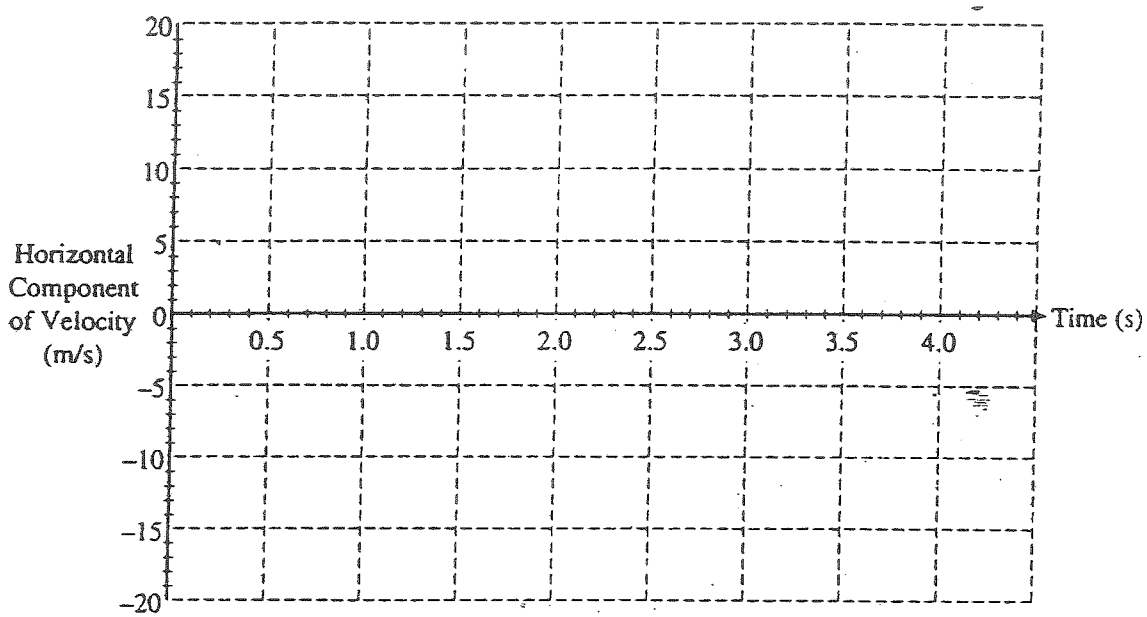
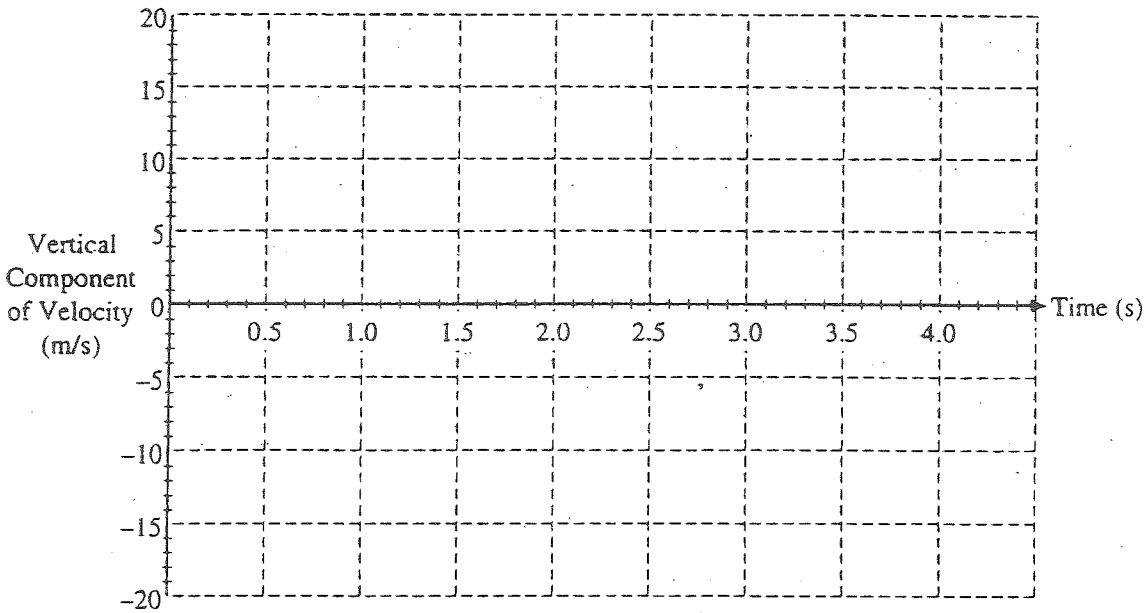
(d) On the axes below, sketch the horizontal and vertical components of the velocity of the ball as functions of time until the ball reaches the plane of the fence.





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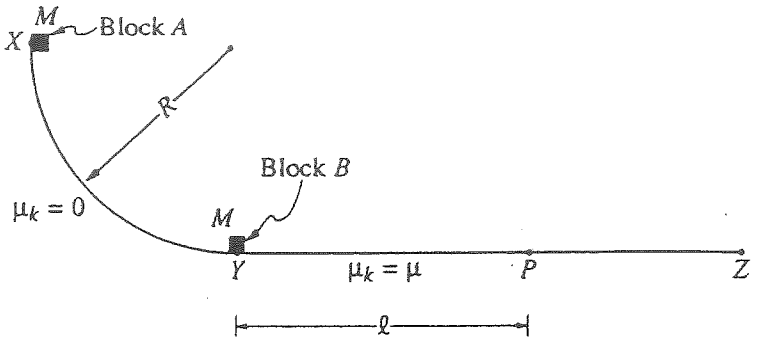


Side View

2. A track consists of a frictionless arc XY, which is a quarter-circle of radius R, and a rough horizontal section YZ. Block A of mass M is released from rest at point X, slides down the curved section of the track, and collides instantaneously and inelastically with identical block B at point Y. The two blocks move together to the right, sliding past point P, which is a distance ℓ from point Y. The coefficient of kinetic friction between the blocks and the horizontal part of the track is μ. Express your answers in terms of M, ℓ, μ, R, and g.

   (a) Determine the speed of block A just before it hits block B.

   (b) Determine the speed of the combined blocks immediately after the collision.

   (c) Determine the amount of kinetic energy lost due to the collision.

   (d) The specific heat of the material used to make the blocks is c. Determine the temperature rise that results from the collision in terms of c and the other given quantities. (Assume that no energy is transferred to the track or to the air surrounding the blocks.)

   (e) Determine the additional thermal energy that is generated as the blocks move from Y to P.

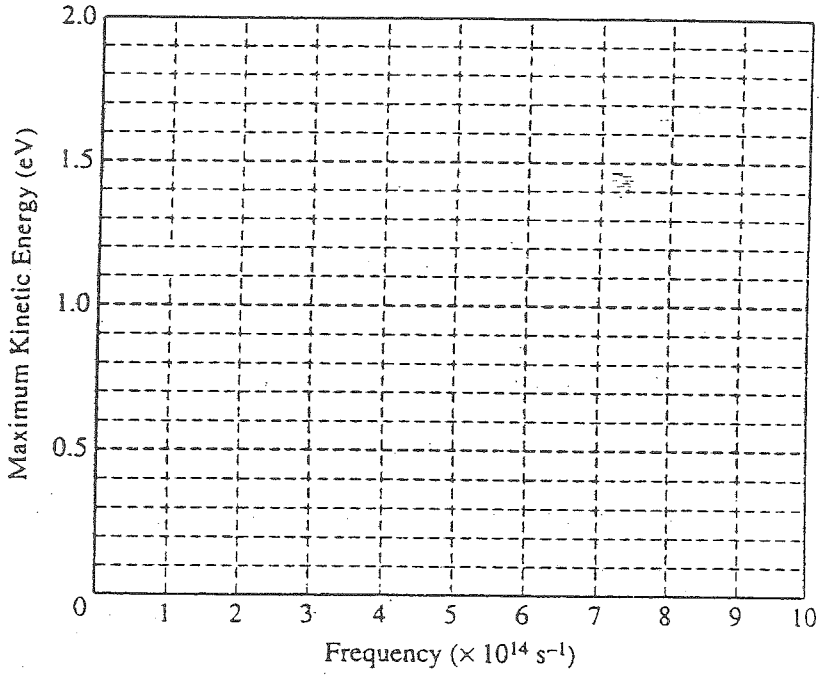
3. This question consists of two unrelated parts of approximately equal weight. Please answer both parts.

Part 1.

A series of measurements were taken of the maximum kinetic energy of photoelectrons emitted from a metall surface when light of various frequencies is incident on the surface.

(a) The table below lists the measurements that were taken. On the axes below, plot the kinetic energy *versus* light frequency for the five data points given. Draw on the graph the line that is your estimate of the best straight-line fit to the data points.

Light Frequency (10^{14} s^{-1})	Maximum Kinetic Energy (electron volts)
5.00	0.10
6.00	0.45
7.00	0.95
8.00	1.30
9.00	1.45



(b) From this experiment, determine a value of Planck's constant h in units of electron volt-seconds. Briefly explain how you did this.

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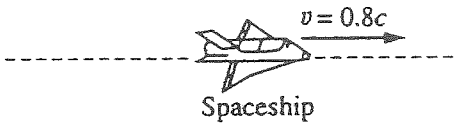
Part 2.

A spaceship travels with a constant speed of $0.8c$ as it passes by the Earth on its way to a distant star, as shown in the diagram below.



Spaceship

Earth

(a) The pilot of the spaceship measures the length of the moving ship as 20 meters. Determine its length as measured by a person on Earth.

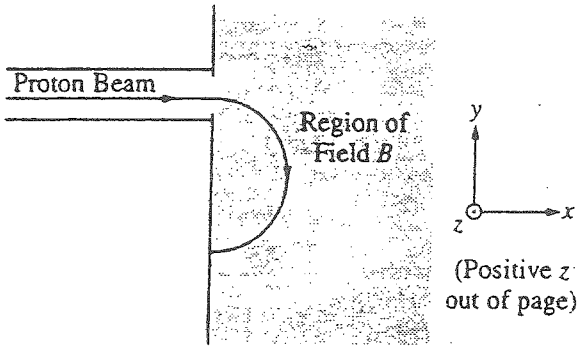
(b) The pilot of the spaceship observes that the spaceship travels for 5 years. Determine how much time has passed according to a person on Earth.

(c) Some time after passing the Earth, the pilot shoots a laser pulse backward at a speed of 3×10^8 meters per second with respect to the spaceship. Determine the speed of the laser pulse as measured by a person on Earth.

4. In a linear accelerator, protons are accelerated from rest through a potential difference to a speed of approximately 3.1×10^6 meters per second. The resulting proton beam produces a current of 2×10^{-6} ampere.

   (a) Determine the potential difference through which the protons were accelerated.

   (b) If the beam is stopped in a target, determine the amount of thermal energy that is produced in the target in one minute.



The proton beam enters a region of uniform magnetic field B, as shown above, that causes the beam to follow a semicircular path.

   (c) Determine the magnitude of the field that is required to cause an arc of radius 0.10 meter.

   (d) What is the direction of the magnetic field relative to the axes shown above on the right?

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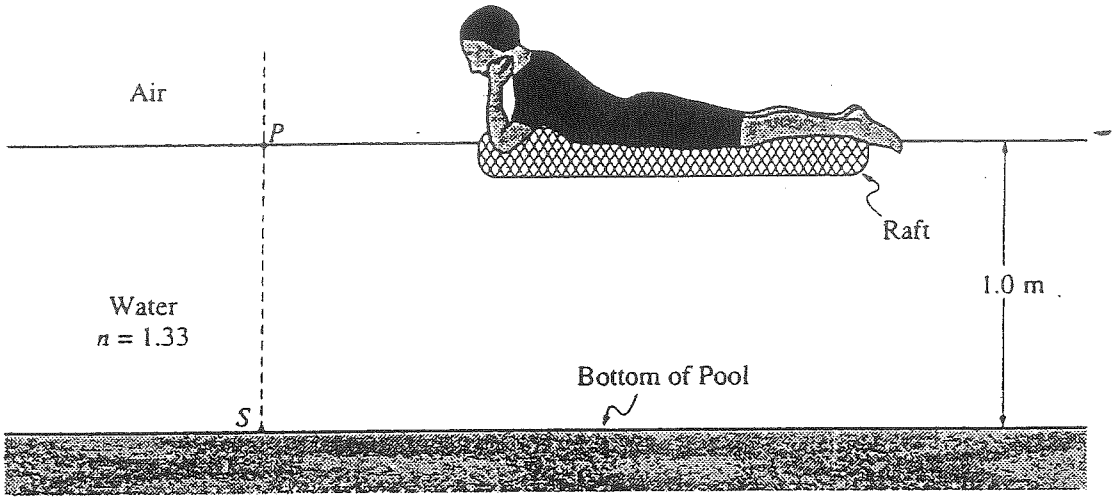
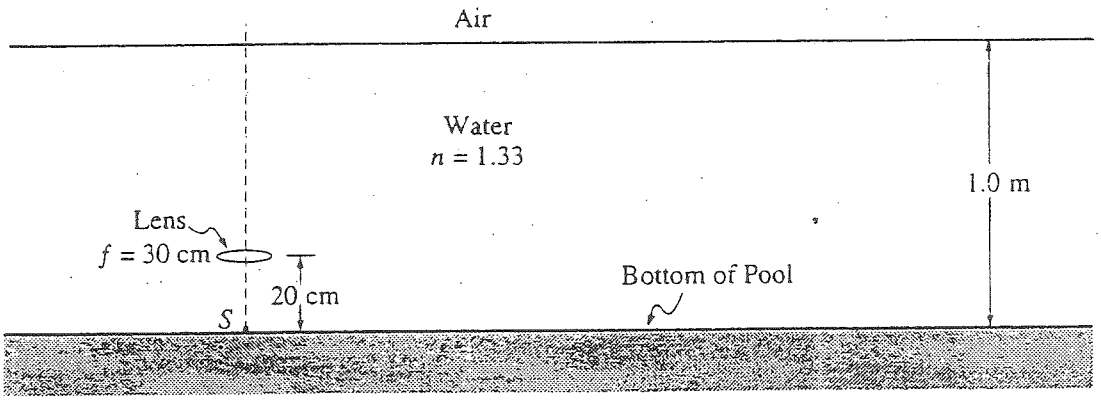


A point source S of monochromatic light is located on the bottom of a swimming pool filled with water to a depth of 1.0 meter, as shown above. The index of refraction of water is 1.33 for this light. Point P is located on the surface of the water directly above the light source. A person floats motionless on a raft so that the surface of the water is undisturbed.

(a) Determine the velocity of the source's light in water.

(b) On the diagram above, draw the approximate path of a ray of light from the source S to the eye of the person. It is <u>not</u> necessary to calculate any angles.

(c) Determine the critical angle for the air-water interface.



Suppose that a converging lens with focal length 30 centimeters in water is placed 20 centimeters above the light source, as shown in the diagram above. An image of the light source is formed by the lens.

(d) Calculate the position of the image with respect to the bottom of the pool.

(e) If, instead, the pool were filled with a material with a different index of refraction, describe the effect, if any, on the image and its position in each of the following cases.

i. The index of refraction of the material is equal to that of the lens.
ii. The index of refraction of the material is greater than that of water but less than that of the lens.