Professional Development Service for Teachers

Physics

Inquiry Based Learning Suggested Solutions Autumn 2013

Investigation 1; Exploring the Volume of Melted Ice

Q1; A drinking glass is filled to the brim with water which also contains floating ice cubes. What do you think will happen to the water level in the glass when all the ice melts?

A1; I think it will overflow

Q2; What do you observe?

A2; The ice melts and the water does not overflow so my initial thought was incorrect.

Explain in your own words;
As the ice was floating it had displaced its own weight of water which was equal in volume to the displaced water i.e. the ice has the same weight as the displaced water but it has a much bigger volume.

Extension 1. There is a big stone inside in a boat which is floating in a swimming pool full of water. What will happen to the water level in the pool if the stone is taken out of the boat and placed in the water?
The water level in the pool will drop as the big stone will now displace its own volume whereas when it was in the boat it was displacing its own weight of water (which was much bigger).

Hint; Simulate with a string tied to a fishing weight/ pendulum bob / bolt in a floating plastic lid in a glass of water
Explain in your own words why this happens;
The water level in the glass will drop as the pendulum bob will now displace its own volume whereas when it was in the plastic lid it was displacing its own weight of water.

Note: Please ensure that all water investigations have a tray for a base and are done well away from the computers.

Extension 2. How would the melting of the Arctic ice affect sea levels? Would the melting of the Greenland glaciers have a different effect on sea levels?

Investigation 2; Investigating Knots in a Rope

A rope contains 2 knots, one is very loose the other is much tighter.

Q1; What do you think will happen to the knots if we pull both ends of the rope apart?

A1; The knots will tighten.

Q2; What do you observe?

A2; As the rope is pulled the looser knot will tighten until it is approximately the same size as the other knot. The two knots will then tighten at the same instant.

Explain in your own words;

There are two factors affecting the tightening of the rope namely the bending force and friction. Friction occurs where the two parts of the rope are in contact and is less in the looser knot. When pulled the looser knot tightens until friction is equal at both knots. The bending force increases when the radius of curvature decreases so a smaller knot requires a larger force to bend it.

Extension; For more details visit;
http://www.lightandmatter.com/article/knots.html

Investigation 3; Estimate Atmospheric Pressure

An empty syringe is blocked at the opening and the piston is attached to a newton balance, which is pulled.

Q1; What do you think will happen if we pull the piston of the syringe to the 5 cm mark, then the 10 cm mark and then the 15 cm mark?

A1; I think that the newton balance reading will increase as the syringe piston is extracted.

Q2; What do you observe?

A2; The newton balance reading remained constant as the piston was extracted.

Explain in your own words;

The newton balance reading remained constant as it was pulling against the atmospheric pressure which is constant.

Extension; measure the area of the piston and use it to work out the pressure of the syringe piston.

The surface area of the piston may be got by dividing the syringe volume by the length/height of the piston markings i.e. $20\ \text{cm}^3 \div 6.4\ \text{cm} = 3.12\ \text{cm}^2$

Or the piston diameter is 2.0 cm so its surface area is $\pi r^2 = \pi(1.0\times10^{-2})^2 = 3.14 \times 10^{-5}\ \text{m}^2$

The newton balance reading remained constant at 35 N

Pressure = $\frac{Force}{Area} = \frac{35}{3.13\times10^{-5}} = 1.1 \times 10^5\ \text{N m}^{-2}$

Explain;

Normal atmospheric pressure is given as $1.03 \times 10^5\ \text{N m}^{-2}$

There may be friction between the piston and the syringe which would increase the force and cause the pressure reading to be more.

Alternatively there be have been a little air in the syringe to begin with which would reduce the force and cause the pressure reading to be less.

Extension; What force is required to pull a rubber sucker from a smooth surface?

$F = PA = (1.03 \times 10^5)$(surface area of the sucker)

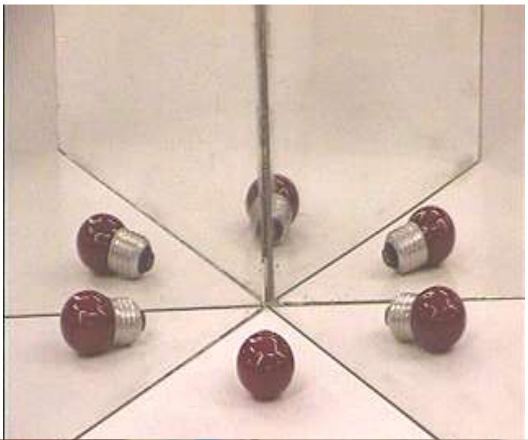
Investigation 4; Predicting and Finding Patterns for Multiple Mirror reflections

Predict the number of images formed when an object is placed between two hinged mirrors, set at the angles in the table below.

Angle between 2 plane mirrors	Predicted number of images	Counted number of images
180°		
90°		
60°		
45°		

What do you observe?

Extension; Continue to change the angle between the hinged mirrors and note your observations



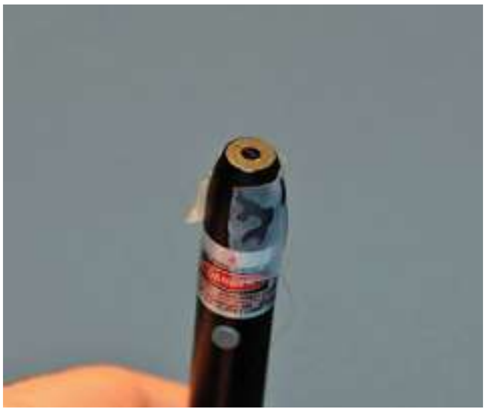
Do you see any patterns in the reflections?

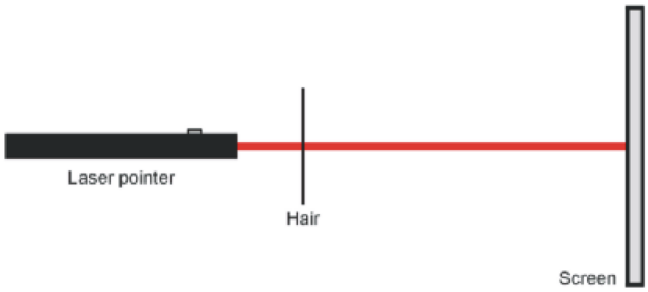
List at least three common uses for plane mirrors.

Extension; For more details visit; http://www.physicsclassroom.com/class/refln/u13l2f.cfm

Investigation 5; Diffraction and Rib of Hair

A piece of hair is attached to a laser pointer using tape. The laser is shone through the rib of hair and onto a screen.





Q1; What do you observe?

A1; A diffraction pattern from the laser light scattered from a hair is seen on the screen. [It is similar to the diffraction pattern from a single slit whose width is of the same order of magnitude as the wavelength of the light.]

Explain in your own words;

Light travels in waves. When the light encounters an obstacle it spreads around the edges of the obstacle. This is called **diffraction**.
The diffracted waves interfere to produce the diffraction pattern. Where crest meets crest constructive interference occurs and where crest meets trough destructive interference.
The intensity of the diffraction pattern is a function of angle

Extension; take measurements and calculate the diameter of the rib of hair.
By measuring the distance from the centre to one of the dark bands, the thickness of the hair can be determined. If the first dark band is considered, you can start by calculating the angle to this as seen from the hair. Measure the distance from the hair to the projection screen (*D*) and from the centre of the diffraction pattern to the first dark band (*x*).
The angle is small so $\theta \approx sin\theta \approx tan\theta \approx \frac{x}{D}$
When the angle *theta* is known, the diameter of the hair (*d*) can be found from the following equation using the wavelength *lambda* of the laser:

$$n\lambda = d\ sin\theta \quad so\ for\ n = 1 \quad and\ \sin\theta \approx \frac{x}{D}$$

$$d = \frac{D\lambda}{x}$$

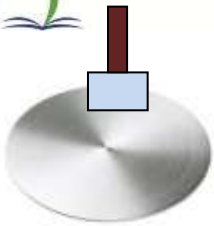
Example calculation; Find the thickness of a rib of hair which results in the first dark band being 80 cm from the centre bright band when a red laser of λ = 650 nm is shone through it and onto a screen 1 m away?

$d = \frac{D\lambda}{x} = \frac{(1)(650\times10^{-9})}{80\times10^{-2}} = 81.25\ \mu m$

For more details visit; http://www.fysikbasen.dk/English.php?page=Vis&id=87 and http://www.youtube.com/watch?v=kpsN78mQ6YY

Investigation 6; Exploring Arago's disc

Rotate a neodymium magnet close to the outer rim of the Aluminium disc



Q1; What do you observe?

A1; The Aluminium disc rotates in the same direction as the moving magnet.

Explain in your own words why this happens;

The moving magnet causes a change in the magnetic flux linking the Aluminium disc which induces an emf (Faraday's law). As the aluminium is a good conductor of electricity and as the disc is closed a current will flow.
The direction of the induced (eddy) current is such as to oppose the change in magnetic flux which caused it (Lenz's law) hence the disc rotates in the direction of the magnet to reduce this change in flux.

Give 3 examples from everyday life which use the principle of Arago's disc;

1. The wattmeter
2. The eddy current motor
3. Electromagnetic braking in power tools and trains

Note: Please ensure that all magnet investigations are done well away from the computers

For more details visit; http://www.de-monstrare.nl/pdf/Arago%27s%20disk.pdf

Investigation 7; Boiling water at << 100 °C

Place about 5 ml of warm water (50-70°C) in a syringe and seal the end or plug it with your finger.
Pull the piston back and observe.

Q1; What do you observe?
A1; The water boils

Q2; Why does it not continue to boil?

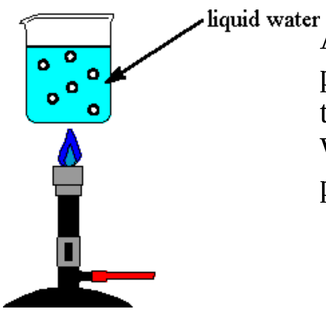
A2; When water boils it needs energy to change from a liquid to a gas (latent heat), this energy is taken from the remaining water which in turns cools.

Note; The water appears to boil very well initially as the heating also expels any dissolved air from the water.
Adding a few grains of fine sand to the water may help to make the bubbles more visible.

Explain in your own words;
The boiling point of water is dependent on the pressure. Water boils at 100°C at atmospheric pressure and at a lower temperature when the pressure is reduced. Pulling the piston causes the pressure to be reduced.

Extension; visit http://www.youtube.com/watch?v=I5mkf066p-U

Note;



A liquid boils at a temperature at which its vapour pressure is equal to the pressure of the gas above it. The lower the pressure of a gas above a liquid, the lower the temperature at which the liquid will boil.
Water boils at 100 °C at normal atmospheric pressure, at about 120 °C in a pressure cooker and about 70 °C at the top of Mount Everest.

Investigation 8; Problem Solving Maths Puzzle

Using these six standard mathematical operators (+ – × ÷ √)
and using exactly four sevens each time, generate the integers from 1 to 21.

Possible solutions:

1. $\frac{77}{77} = 1$

2. . $\frac{7}{7} + \frac{7}{7} = 2$

3. $\frac{7+7+7}{7} = 3$

4. . $\frac{77}{7} - 7 = 4$

5. . $7 - \frac{7+7}{7} = 5$

6. . $\frac{(7)(7)-7}{7} = 6$

7. . $7 + (7-7)(7) = 7$

8. .$\sqrt{(7)(7)} + \frac{7}{7} = 8$

9. . $7 + \frac{(7+7)}{7} = 9$

10. . $\frac{77-7}{7} = 10$

11. $\frac{77}{\sqrt{(7)(7)}} = 11$ or $\frac{7}{0.7} + \frac{7}{7} = 11$

12. . $\frac{77+7}{7} = 12$

13. . $(7+7) - \frac{7}{7} = 13$

14. . $(7+7+7) - 7 = 14$

15. . $(7+7) + \frac{7}{7} = 15$

16. . $\frac{7-0.7}{0.7} + 7 = 16$

17. $\frac{7}{0.7} + \sqrt{(7)(7)} = 17$

18. $\frac{77}{7} + 7 = 18$ etc.

Note: All the numbers from 1 to 21 can be got in similar ways with four 3's, four 4's, four 7's and four 9's

Investigation 9; Problem Solving Height of a Half full Conical Glass

Find the capacity of a conical glass of internal height 8 cm and diameter 10 cm.

$$V = \frac{1}{3}\pi \boldsymbol{r}^2 \boldsymbol{h} = \frac{1}{3}\pi(5)^2(8) = \frac{200\pi}{3}\text{cm}^3$$

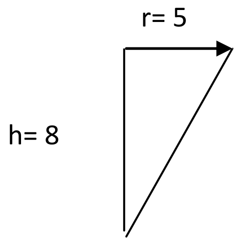
How high would the liquid be in the glass if the conical glass was filled to half its capacity?

(a) half its full height h
(b) two thirds h
(c) three quarters h
(d) four fifths h

Answer;

(d) four fifths h

Explain your answer using mathematical calculations;



The relation between the radius and height is $\frac{\boldsymbol{r}}{\boldsymbol{h}} = \frac{5}{8}$ $\;\boldsymbol{i.e.}\ \boldsymbol{r} = \frac{5\boldsymbol{h}}{8}$

If the glass contains half its capacity, it contains $\frac{100\pi}{3}\text{cm}^3$

$$V = \frac{1}{3}\pi \boldsymbol{r}_1^2 \boldsymbol{h}_1 = \frac{1}{3}\pi(\frac{5}{8}h_1)^2(\boldsymbol{h}_1) = \frac{100\pi}{3}$$

$$\Rightarrow \frac{25\boldsymbol{h}_1^3}{64} = 100 \quad \boldsymbol{i.e.}\ \boldsymbol{h}_1^3 = 256$$

$$\boldsymbol{h}_1 = 6.35$$

i.e. the half capacity height is $\frac{6.35}{8} = 0.79$ of the full height.

Extension; for more details visit http://www.parsel.uni-kiel.de/cms/fileadmin/parsel/Material/Kiel/ChampagneTeacher.pdf